Geological sequestration of CO2 in NW Taiwan: Potential and Perspectives

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**Legend**
- **Produced oil or gas**
- **Injected CO₂**
- **Stored CO₂**

**Diagram**
- Illustration of geological storage options with various depths and locations indicated by labeled points (e.g., 2 km, 1 km).
Highest CO$_2$ emitting plants in western Taiwan (Units: Mt/yr)

- Datang Power plant: 7.16 Mt/yr
- Taichung: 36.33 Mt/yr
- Mailiao: 25.3 Mt/yr
- Hsinta: 18.24 Mt/yr

Resources: http://www.carma.org/

A: CPC gas fields in Miaoli-Hsinchu
B: Kuanyin district in Taoyuan
CO2 reserve in onshore structures estimated by CPC is about 2.9 billion tons.
Geological Model

Yunghoshan (YHS) depleted gas field
Cap rock
(Chinshui Sh)

Reservoir
(Kuehchulin Fm.)

(Talu Fm).

Cap rock
Reservoir

depleted gas production fm.
Geological Framework in the Taoyuan Tableland

Kuanyin Site

[Map showing geological formations and sites]
Basin Stratigraphy and Hydrocarbon-bearing Zones in Northern Taiwan

Three CO₂ Geosequestration Systems

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<td>Sandstones</td>
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- Seal rocks
- Reservoir rocks
- Chinshui Shale
- Kueichulin & Nanchuang Formations
- Talu Shale
- Peiliao Formation
- Piling Shale
- Mushan & Wuchishan Formations
A seismic section across the Taoyuan Tableland
A seismic section offshore Taoyuan Tableland
Depth map of reservoir top (Kueichulin Fm)

Kuanyin Site
Targets of Geophysical Monitor

• Assessment of seismic hazard in CO$_2$ storage field
  – Siting and setting of seismometer sites
  – Researching locations and patterns of seismogenic structures around storage field
  – Assessing impact of seismogenic structure activity on storage field
  – Monitoring induced earthquake by CO$_2$ injection

  – Research of local stress field
  – Investigating and analyzing local stress field
  – Building local 3-D stress field
  – Analyzing safety of storage field failure
Seismicity of 1900-2014 in NW Taiwan

- Seismicity of 1900/01/01-2014/05/29
- GPS stations
- New broadband seismometers
- Square on Star has 6 seismometers around #6well
- Scope of Yunghoshan anticline
- Active faults
- Pre-existing faults
10 broad band seismometers in Yunghoshan

Dual band continuous GPS stations

Large magnitude earthquakes and slip rate deficit
Risk Assessment

- Geological model of YHS
- Assessment of fault reactivation stability and max. injection pressure

In situ stress in the subsurface

YHSE-1
(800~2600m)
147°±5°

YHS-11
(3200~5200m)
157°±5°

Talu sand

YTP Sandstone
Fault reactivation potentiality assessment

Fault reactivation potentiality at specific depth
Risk assessment of seal leakage

- Shale continuity and kriging method,

Talu Sh (cap rock) of YHS

Normalized and discretized litho-column, indicating 7:3 for sh/non-sh ratio

Curve fitting of semi-variation along vertical direction

Semi-variation indicating 150 m of shale continuity
Objectives of Geochemical Experiments

*To investigate the extent that the trace elements in sandstone and shale either dissolve into formation water or absorb from formation water during the interaction of rock-water-supercritical CO\textsubscript{2} fluid.

*To investigate whether or not the changes in crystalline phases and microstructures of sandstone and shale during the interaction of rock-water-supercritical CO\textsubscript{2} fluid.
Rock-water-CO$_2$ interaction experiments for dissolution of trace elements using a high pressure clave simulation facility

Rok-water-CO2 interaction was conducted for 35 days using a high pressure clave simulation facility under the conditions of high pressure (250 bars) and high temperature (100°C) in which the injected CO$_2$ became supercritical fluid.
Experimental Results - Dissolution of trace elements

Interaction of rock-water-CO$_2$ at 100°C and 250 bars for sandstone (trace elements concentration in ppb)

V, Cr, Mn, Fe, Co, Cu, Zn and As tended to be desorbed from sandstone to formation water.
Interaction of rock-water-CO$_2$ at 100 °C and 250 bars for shale (trace elements concentration in ppb)

Mn, Fe, Co, Cu, Zn, and As tended to be desorbed from shale to formation water.
Interaction of rock-water in the presence and absence of CO$_2$ fluid at 100 °C and 250 bars for sandstone (dissolution of trace elements from sandstone)

The decrease of Sr concentration in formation water is higher than the increase of Sr content in sandstone in the presence of CO$_2$, indicating that more Sr from formation water was lost and adsorbed on sandstone. However, Sr concentrations in formation water and sandstone in the absence of CO$_2$ are nearly equivalent.
Interaction of rock-water in the presence and absence of CO$_2$ fluid at 100 °C and 250 bars for shale (dissolution of trace elements from shale)

Similar to sandstone, the decrease of Sr concentration in formation water is higher than the increase of Sr content in shale in the presence of CO$_2$, indicating that more Sr from formation water was lost and adsorbed on shale. However, Sr concentration in formation water is lower than that in shale in the absence of CO$_2$, indicating that less Sr from formation water was lost and adsorbed on shale.
Potential-reserve estimation

- YHS

Top of Talu SS (depleted gas prod. fm.)

Reservoir of Talu SS.

Reserve of CO2 in Talu SS.

Gas prod.

CO2 injection

OGIP = 1.22*10^9 SCM

Gp = 0.92*10^9 SCM

effective res. = 1.23*10^9 SCM (2.3 Mt)

theoretical res. = 1.35*10^9 SCM (2.5 Mt)
Assessment of CO2 Column Height

YTP Sandstone
Structural relief \( = 250 \) m
Critical pressure perturbation: 3.3 Mpa (from Monte Carlo analysis)
Equivalent to \( h_{\text{co2}} = 481 \) m (assuming \( \rho_{\text{co2}} = 0.7 \text{ g/cm}^3 \))

Talu Sand
Structural relief \( h = 800 \) m
Critical pressure perturbation: 12.0 MPa
Equivalent to \( h_{\text{co2}} = 1749 \) m

The pore pressure of 12 Mpa will not be reached because the structural closure of the Talu sand is only 800 m. Thus the CO\(_2\)-injection into the Talu sand will not compromise stability of the Tengping fault.
- Taoyuan district
- Geological model
- Estimation of CO2 reserve
- Reservoir model

Estimated reserve = 4.6 billion tons
Perspectives - Simulation

Kuehchulin Fm. in YHS

Three injection wells (Y3, Y4, Y6)
Injection rate = 3.6 Mton/year
Injection time = 20 years

Critical pore pressure differential = 3.04 MPa
Perspectives -Simulation

Kuehchulin Fm. in YHS

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Perspectives
-Simulation

Kuehchulin Fm. in YHS

Three injection wells (Y3, Y4, Y6)
Injection rate = 3.6 Mton/year
Injection time = 20 years

Critical pore pressure differential = 3.04 MPa
Talu SS in YHS

Fault (Low permeability)

Critical pore pres. dif. = 12.06 MPa
Nanchuang Fm in Taoyuan

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
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<tr>
<td>CO₂ injection rate</td>
<td>87,600 ton/year</td>
</tr>
<tr>
<td>Injection time</td>
<td>20 years</td>
</tr>
<tr>
<td>Simulation time</td>
<td>100 years</td>
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</tbody>
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<tr>
<th>Stratum</th>
<th>k (mD)</th>
<th>Φ (-)</th>
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</thead>
<tbody>
<tr>
<td>Cap rock</td>
<td>2.3</td>
<td>0.142</td>
</tr>
<tr>
<td>Reservoir</td>
<td>1000</td>
<td>0.345</td>
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(Lee and Ni, 2014)
Conclusions

• In offshore and onshore NW Taiwan, geological conditions for CO2 sequestration are the structural and stratigraphic traps and contain two seal-reservoir systems.

• Risks of intriguing seismicity, fault reactivation, seal leakage and geochemical reaction have been assessed.

• After consideration of geological models and risk assessments, potential reserve of CO2 injection has been estimated and drifting behavior of CO2 in the subsurface has been simulated.
Thanks for your attention!