Coal Seam Gas Development and Environmental Implications - examples from Australia, USA, and NZ

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Contents

• What is Coal Seam Gas (CSG)?
• CSG Basins:
  • United States
  • Australia
  • New Zealand
• CSG Water Quantity: how much water is being co-produced?
• CSG Water Quality:
  • Geochemical evolution
  • Water chemistry characteristics throughout different basins
• Legislation and Potential environmental aspects
  • Environmental Legislation in QLD
  • Aquifer depressurisation
  » Impacts associated with surface disposal:
    » Plants: toxicity and salinity problems
    » Soil dispersion
  » Management options
Coal Seam Gas

“A form of natural gas (mainly methane) sorbed in underground coal beds”
## CSG in the USA

![Map of the USA showing CSG basins](image)

<table>
<thead>
<tr>
<th>Basin</th>
<th>State</th>
<th>No. Wells</th>
<th>Average Water Production (m³/day/well)</th>
<th>Gas (TCM/day/well)</th>
<th>Water Content (m³/TCM)</th>
<th>Water Type</th>
<th>pH</th>
<th>TDS (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Warrior</td>
<td>AL</td>
<td>3423</td>
<td>7.5</td>
<td>2.6</td>
<td>2.86</td>
<td>Na-Cl-HCO₃</td>
<td>5.4-9.9</td>
<td>160-31,000</td>
</tr>
<tr>
<td>Powder River</td>
<td>MT</td>
<td>13,880</td>
<td>32.9</td>
<td>1.9</td>
<td>17.33</td>
<td>Na-HCO₃</td>
<td>8-8.0</td>
<td>270-3,010</td>
</tr>
<tr>
<td>Raton</td>
<td>WY</td>
<td>694</td>
<td>42.3</td>
<td>8.5</td>
<td>4.98</td>
<td>Na-HCO₃</td>
<td>7-7.9</td>
<td>86-2,582</td>
</tr>
<tr>
<td>San Juan</td>
<td>CO, NM</td>
<td>3,089</td>
<td>4.0</td>
<td>22.7</td>
<td>0.18</td>
<td>Na-HCO₃-Cl</td>
<td>7-9.7</td>
<td>130-171,000</td>
</tr>
<tr>
<td>Uinta</td>
<td>UT</td>
<td>558</td>
<td>34.2</td>
<td>17.7</td>
<td>1.93</td>
<td>Na-HCO₃-Cl</td>
<td>7.0-8.2</td>
<td>35-42,700</td>
</tr>
</tbody>
</table>
CSG in Australia

CSG exploration and field development in Australian coal basins

Major Coal Basins in Australia

- Arckaringa Basin
- Bowen Basin
- Canning Basin
- Clarence Moreton Basin
- Fingal Basin
- Galilee Basin

CSG fields

- *Basin area includes coal measures and other hydrogeological units

QUT - a university for the real world®
Surat Basin (QLD)
CSG in New Zealand

CSG exploration in New Zealand coal basins

New Zealand Coal Basins
- Buller
- Greywacke
- Matarua
- Waitakere
- Kawerau
- Omaha
- Ohauru-Tangareakau
- Wharekauhau
- Mangapahi
- Hinemoa

Wellington
Auckland
Christchurch
Dunedin
Hokitika
Greymouth
Maramarua
Huntly North
Ohau
Maramarua (North Island)
Water Quantity (production)

Average Water Production

(m³/day per well)

San Juan  Black Warrior  Powder River  Uinta  Raton

Water Quantity (production)
Water Quality. Geochemical evolution

1. Methyl-group fermentation
2. CO2 Reduction

\[ \text{SO}_4^{2-} + 2\text{CH}_3\text{O} + 2\text{H}^+ \Leftrightarrow \text{H}_2\text{S} + 2\text{H}_2\text{O} + 2\text{CO}_2 \quad \text{pH} < 7.0 \]

\[ \text{SO}_4^{2-} + 2\text{CH}_3\text{O} + \text{H}^+ \Leftrightarrow \text{HS}^- + 2\text{H}_2\text{O} + 2\text{CO}_2 \quad \text{pH} > 7.0 \]

\[ 2\text{CH}_3\text{O} + \text{H}_2\text{O} \Leftrightarrow \text{CH}_4 + \text{HCO}_3^- + \text{H}^+ \]
Water Quality. Geochemical evolution

$$
\begin{align*}
\text{SO}_4^{2-} + 2\text{CH}_3\text{O} + 2\text{H}^+ & \rightleftharpoons \text{H}_2\text{S} + 2\text{H}_2\text{O} + 2\text{CO}_2 \quad \text{pH} < 7.0 \\
\text{SO}_4^{2-} + 2\text{CH}_3\text{O} + \text{H}^+ & \rightleftharpoons \text{HS}^- + 2\text{H}_2\text{O} + 2\text{CO}_2 \quad \text{pH} > 7.0 \\
2\text{CH}_3\text{O} + \text{H}_2\text{O} & \rightleftharpoons \text{CH}_4 + \text{HCO}_3^- + \text{H}^+
\end{align*}
$$
Water Quality. Geochemical evolution

\[
\begin{align*}
\text{Dissolution of Sodium Feldspars} \\
\text{Na}^+ \text{ concentration increases due to the dissolution of minerals such as sodium feldspar; dissolution of marine associated waters (where present) can also increase Na}^+ \text{ and Cl concentrations} \\
\text{Na}^+ \text{ concentration along the path of flow} \\
\text{Ion Exchange} \\
\text{Ca}^{2+} \text{ and Mg}^{2+} \text{ hold more tightly than Na}^+ \text{ in clays} \\
\text{Ca}^{2+} \text{ and Mg}^{2+} \text{ concentrations along the path of flow} \\
\text{Na}^+ \text{ concentration along the path of flow} \\
\end{align*}
\]

\[
\begin{align*}
\text{Na}_2X + \text{Ca}^{2+} & \rightleftharpoons \text{CaX} + 2 \text{Na}^+ \\
\text{Na}_2X + \text{Mg}^{2+} & \rightleftharpoons \text{MgX} + 2 \text{Na}^+
\end{align*}
\]

where
\[
\begin{align*}
\text{Na}^+ & = \text{sodium ion} \\
\text{Ca}^{2+} & = \text{calcium ion} \\
\text{Mg}^{2+} & = \text{magnesium ion} \\
X & = \text{clay or shale}
\end{align*}
\]
Typical Water Quality

$\uparrow$ Na$^+$
$\uparrow$ HCO$_3^-$
$\uparrow$ Cl (marine association)
TDS <30000 mg/l (brackish)

$\downarrow$ Ca$^{2+}$
$\downarrow$ Mg$^{2+}$
$\downarrow$ SO$_4^{2-}$ \rightarrow 0
Ph $\sim$ 7
CSG Water samples from selected Australian, NZ, and US basins

- pH: neutral
- TDS: 200 – 12000 mg/l
CSG Water samples from selected Australian, NZ, and US basins

Water type:
Na-HCO$_3$-Cl
Water Quality: CSG Water Sparging
Water Quality: controlled by carbonate chemistry

- Bicarbonate
- Carbonate
- Carbon dioxide

Initial conditions (pH = 7.4)

Final conditions (pH = 8.6)

Max Bicarbonate conditions (pH = 8.3)

40% Ca Precipitation
Potential Environmental Aspects

- Environmental Legislation
- Aquifer depressurisation
- Impacts associated with surface disposal:
  » Plants: toxicity and salinity problems
  » Soil dispersion
- Other impacts and management options
## Relevant Legislation

<table>
<thead>
<tr>
<th>Commonwealth (DEWHA)</th>
<th>CSG Related</th>
<th>QLD Government (DNRW)</th>
</tr>
</thead>
</table>
  - Environmental Programs  
  - Assessments & Reports  
  - Controls on CSG operations  
  - Due to poor recharge and over demand DNRW imposed a moratorium on the granting on GW licences in areas considered at risk |
  - Enabled CSG operators to extract as much water as required  
  - Requires producers to fully identify GW impacts through specific studies and to carry out monitoring programs  
  - Does not specify a max drawdown value on neighbouring wells but states the producers must comply with a “trigger threshold”  
| • Ministerial Councils (i.e. 2000 ANZECC guideline) | | • QLD CSG Water Management Policy (Nov 2008)  
  - To ensure environmental outcomes and facilitate beneficial applications |
Aquifer Depressurisation. Example: Surat Basin
Impacts associated with surface disposal: salinity and specific ion toxicity

Salinity problems:

- Toxicity issues:
  1) Sodium and Chloride: Leaf burn, scorch, and dying of leaf tissue, which may reduce crop yield.
  2) Trace elements: Zinc can accumulate in soils and can be taken up into plant tissue causing growth reduction. Boron (toxicity) may be present.

Source: http://waterquality.montana.edu/

PRB (WY): Impounded CSG water discharge in an ephemeral channel. Die-off of plants occurred within 1 week of exposure to CSG Water discharge.
Source: MSU
Impacts associated with land disposal: Soil impairment

CSG Water

$\uparrow Na^+$
$\downarrow Ca^{2+}$
$\downarrow Mg^{2+}$
$\uparrow SAR$
TDS $< 30,000$ mg/l

Soil dispersion, loss of permeability and infiltration problems

$SAR = \frac{[Na]}{\sqrt{\frac{[Ca] + [Mg]}{2}}}$

About 25% Increase due to CaCO$_3$ precipitation
Example: Powder River Basin, Montana (US)

Dispersed soils following CSG product water application. This is a typical response of high-clay soils to high-sodium water.

Source: http://waterquality.montana.edu/
Example: Selected water samples assessed using ANZECC guidelines

- Moranbah
- Tipton
- Maramarua
- Greymouth

- 🌞 Stable soil structure
- 🌡️ Depends on soil properties & rainfall
- 😞 Soil structural problems are likely
Management Options

Treatment Options

- Evaporation / settlement ponds
- Ion exchange
- Artificial wetlands
- Reverse Osmosis
- Distillation
- Other

Disposal Options

- Well injection
- Land application
- Surface water disposal
- Beneficial Use
Treatment option: Ion Exchange

Na absorption
10-16 meq/l

SAR reduction
from 30 down to 7
Questions