Enhancement of coal seam gas by N2 injection - a laboratory study

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Recommended Citation
Aziz, Naj; Florentin, Raul; Zhang, Lei; Ren, Ting; and Black, Dennis, "Enhancement of coal seam gas by N2 injection - a laboratory study" (2014). Faculty of Engineering and Information Sciences - Papers: Part A. 3762.  
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Enhancement of coal seam gas by N2 injection - a laboratory study

Disciplines
Engineering | Science and Technology Studies

Publication Details

This conference paper is available at Research Online: https://ro.uow.edu.au/eispapers/3762
Enhancement of Coal Seam Gas by N$_2$ Injection - A laboratory study

Naj Aziz

Raul Florentin, Lei Zhang, Ting Ren and Dennis Black

School of Civil, Mining and Environmental Engineering
University of Wollongong Australia
Recoverable economic **demonstrated** resources of black coal: **73.2 bt**
Recoverable **inferred** resources: **125.160 bt.**

**Brown Coal:** > **68 bt** mainly in Vic. and small quantity in SA
Australia is 4th largest producer of black coal, after China, USA & India.

5th largest producer of brown coal, after Germany, Russia, Turkey and USA.

Brown Coal Output: 68 Mt in 2010 (Vic and S/A)
Almost 98% of black coal is sourced from Queensland & NSW. Australia produces and exports both metallurgical (COKING) and thermal (STEAMING) coal in almost equal proportions. **Queensland** produces the majority of Australia's metallurgical (coking) coal, **New South Wales** produces predominantly thermal (steaming) coal.

<table>
<thead>
<tr>
<th>State</th>
<th>No of Mines</th>
<th>Production (Mt)</th>
<th>Methods of Mining (Mt)</th>
<th>Employment</th>
<th>Productivity Saleable Tonnes /man year</th>
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<td>UG</td>
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<td>Sale</td>
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<td></td>
<td>(119)</td>
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</table>
AUSTRALIAN RAW COAL PRODUCTION
BY METHOD OF MINING

- No of Longwall: 30-31
- Production 2010: 100 Mt
- Total Underground: >100 Mt
Currently there are around 30 longwall operations in Australia. 45% of the longwall mines require regular gas drainage to manage coal seam gas emissions within the mine.

Coal seam gas represents potentially a significant risk to the safety and productivity of underground mines.

**Queensland Mines**
- Grasstree,
- North Goonyella,
- Moranbah North,
- Oaky No.1,
- Oaky North
- Newlands
- Carborough Downs

**New South Wales Mines**
- Appin,
- Integra
- Mandalong,
- Metropolitan,
- Beltana,
- Tahmoor,
- West Cliff,
- Whitehaven.
**Intensive Underground Gas Drainage Drilling**

- **Typical Bulli Seam Colliery Gas Drainage**
  - Total Drilling ~145,000 metres per year
  - Total budget ~A$6-7M per year
  - Drilling cost ~A$50-100 per metre
  - Drilling rate ~60-65 metres per rig shift
  - Borehole diameter = 96mm
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<th>Colliery</th>
<th>Date</th>
<th>Seam</th>
<th>Basin</th>
<th>Depth (m)</th>
<th>No of O/B</th>
<th>No. Killed</th>
<th>Gas</th>
<th>Ejected coal size (t)</th>
<th>Work Place</th>
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<td>Sydney</td>
<td>425</td>
<td>154</td>
<td>-</td>
<td>CO₂, Mainly with CH₄</td>
<td>200</td>
<td>Pick</td>
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<td></td>
<td>pres.</td>
<td></td>
<td></td>
<td></td>
<td>(tot)</td>
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</table>

* Total Number of outbursts > 730

No of O/B since 1895 > 730
Some sections of some coal seams are difficult to drain of gas. Bulli seam, Illawarra Coal Measure formation, Sydney Basin.
<table>
<thead>
<tr>
<th>Coal Property</th>
<th>Minimum</th>
<th>Maximum</th>
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<tbody>
<tr>
<td>CH$_4$/(CH$_4$+CO$_2$) (%)</td>
<td>6.5</td>
<td>97.8</td>
</tr>
<tr>
<td>Gas Content (m$^3$/t)</td>
<td>5.2</td>
<td>15.7</td>
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<tr>
<td>Permeability (mD)</td>
<td>0.05</td>
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<tr>
<td>Seam Thickness (m)</td>
<td>2.3</td>
<td>3.2</td>
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<tr>
<td>Ash Content (%)</td>
<td>9.4</td>
<td>14.8</td>
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<tr>
<td>Moisture Content (%)</td>
<td>0.7</td>
<td>1.3</td>
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<tr>
<td>Vitrinite Reflectance ($R_{V_{\text{max}}}$)</td>
<td>1.23</td>
<td>1.36</td>
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<tr>
<td>Vitrinite (%)</td>
<td>28.9</td>
<td>54.5</td>
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<tr>
<td>Inertinite (%)</td>
<td>45.5</td>
<td>71.1</td>
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<tr>
<td>Mineral Matter (%)</td>
<td>1.8</td>
<td>5.8</td>
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<tr>
<td>Volatile Matter (%)</td>
<td>19.7</td>
<td>25.3</td>
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</table>
Gas content contours relative to mine workings

- 90% CO2
- 60% CO2
- 90% CH4

Difficult to Drain zone

Easy to drain
Permeability contours (mD) relative to mine workings

90% CO2                  60% CO2                                        90% CH4
CO\textsubscript{2} rich area

90%

Intermediate area

60% CO\textsubscript{2}

Perm: 3.3 mD

Panel length: 3 - 3.5 km

High Permeability

Low Permeability

CH\textsubscript{4} rich area

94%

519 31B

519 21B

520 3B
$N_2$ injection and recovery of the inherent gases;

Seam Gas:
- $CO_2$ or
- $CH_4$ or
- $CH_4 / CO_2$

- Laboratory study
MFORR
Laboratory Experimental study - N2 Injection

Nitrogen Injection methods

Axial N2 Charge (Reverse/Direct)  Lateral N2 Charge (Indirect)
Triaxial permeability apparatus and MFORRR

Axial Load

Pressure Chamber

Core Sample

10 t Load Cell

Gas Outlet

Flowmeters

N₂, CO₂, CH₄

Data Logger

Lateral Injection

0-180mL/min - 0-2 L/min - 0-15 L/min

Hole Dia: 2.0 mm

539 - 2122

University of Wollongong

10th IMVC-SA
Test 4 - Gas flow through core sample saturated at 3000 kPa
Mine A - Sample 519-2122 (Size 54 mm diameter)
Carbon dioxide vs Nitrogen

1 day = 1440 min

Flow: 0.4 L/S = 3.3 m3/d
Per: 3.3 mD

CO2 increase: 50%
N2 drop: 50%

Initial CO2 Sat Time: 10.8 days
15550 min

N2 Charge time: 110 min
20 min

Flow: 0.4 L/S = 3.3 m3/d
Per: 3.3 mD

Initial CO2 Sat Time: 10.8 days
15550 min

N2 Charge time: 110 min
20 min

Time (min)

Confining pressure (kPa)

Gas composition (%)

CO2 AirFree (%) N2 AirFree (%) Pressure
Panel length: 3 - 3.5 km

CO₂ rich area
90%

Intermediate area

60% CO₂

Perm: 3.3 mD

CH₄ rich area
94%

519 31B

519 21B

520 3B
**CO2:** Saturation Time = 10.8 days
- 0-50%: 20 min.
- Hence 50% composition point occur at 15,730 min (10.9 days)
- @ 3200 kPa the Maximum CO2 flowing through the sample = 0.04 l/sec (3.3 m3/d)
- with Cleat permeability of 0.5-1.5 mD

**CH4:** Full saturation = 5760 min (4d)
- Flow @ 3200 kPa = 0.04 l/sec (3.3 m3/d)
- with cleat permeability of 2.5 mD
- CH4 drainage improvement = 20% after 90 min

**CO2/CH4:** Initial Saturation Time = 7630 min (5.3 days)
- Time for full N2 Charge at zero reduction of CO2/CH4 = 30 min

---

**CH4 and CO2 Recovery by N2 Injection**

**Test 4 - Gas flow through core sample saturated at 3000 kPa**
- Mine A - Sample 519-2122 (Size 54 mm diameter)
- Carbon dioxide vs Nitrogen

**Test 5 - Gas flow through core sample saturated at 3000 kPa**
- Mine A - Sample 519-2122 (Size 54 mm diameter)
- Methane vs Nitrogen

**Test 3 - Gas flow through core sample saturated at 3000 kPa**
- Mine A - Sample 519-2122 (Size 54 mm diameter)
- Carbon dioxide/Methane (52% / 48%) vs Nitrogen
Permeability contours (mD) relative to mine workings and measurement locations.

- **CO2**
- **CO2/CH4**
- **CH4**

Panels:
- 519 Panel
- 518 Panel
- 517 Panel
- 516 Panel
- 521 Panel
- 520 Panel

Flow direction indicated by arrows.
Axial /Reverse /Direct Injection Method

1. Seal gas chamber and evacuate to near zero pressure
2. Load the coal sample axially to 750 kg Force (3 MPa pressure)
3. Charge the cell with CO₂ and monitor. Maintain gas sorption equilibrium at 2 MPa.
4. Charge N₂
5. Release permeated gas out of the gas chamber at every 6 min to pass through flowmeters and to GC for gas composition analysis.
During the N₂ flushing process, CO₂ composition of the chamber gradually decreased as N₂ composition increased. The whole flushing test took more than 13 hrs (800 min).

- Press. Gradient for gas collection = 50 kPa
- Time for 1.0 L gas collection: 10 sec.
- N₂ consumed during flushing: 101 L
- CO₂ liberated: 33 L.

**Ratio:** 3:1
In the **desorption process**, CO$_2$ composition starts to increase from 3.4% to 9.4%, while N$_2$ composition decreases from 96.6% to 90.6% over a period of around 3 hrs (200 min) time.

The collected gas volume of CO$_2$ and N$_2$ in the desorption process was 37.7 L of N$_2$ and 2.3 L of CO$_2$, a ratio **16.3 : 1**
The microstructures of the hard-to-drain coal samples appear to be less generated or fractured as compared with the easy-to-drain samples. This may explain another reason for the difficulty of draining gas from coal sections of Bulli seam in hard-to-drain area, where the coal structure is less fractured.
CONCLUSIONS

- $N_2$ Injection is a viable method of gas recovery from coal particularly from hard to drain sections of coal seams

- Higher quantities of $N_2$ gas is required to remove $CO_2$ gas during both forced and reversed method of $N_2$ injection

- Coal structure and permeability are important factors in the drainability of gas from coal.
Now Online:

http://ro.uow.edu.au/coal

[All papers since 1998]

UOW Coal Mining websites:

http://research.uow.edu.au/coal

Next Conference (Coal 2015), February 11-13, 2015:

http://www.coalconference.com.au
http://research.uow.edu.au/coal

http://www.uow.edu.au/eng/longwall
http://www.uow.edu.au/eng/outburst
http://www.uow.edu.au/eng/pillar
The next Coal Operators’ Conference ‘Coal 2015’ is scheduled for February 11 and 13th, 2015, at the University of Wollongong. The Conference will address issues related to various aspects of modern coal mining operations both surface and underground. Accordingly, papers are invited from the following topics:

- Surface mining.
- Geology.
- Heading development.
- Mining methods; longwall, bord and pillar, top coal caving and hydraulic mining.
- Equipment and machinery performance or innovations.
- Ground control and strata management.
- Longwall and roof fall recovery.
- Instrumentation and monitoring.
- Rock bolting, cable bolting or other roof support techniques.
- Mine subsidence.
- Mine ventilation, mine gas drainage and outburst control.
- Mine fires and explosions.
- Mine flooding.
- Risk management.
- Mine management and mine contract.

We strongly encourage receiving papers from coal mine operations, as well as fundamental and applied coal mining research.

<table>
<thead>
<tr>
<th>Abstract submission</th>
<th>August 28th, 2014</th>
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<tr>
<td>Acceptance of the paper based on abstract</td>
<td>September 15th, 2014</td>
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<tr>
<td>Date of full paper submission</td>
<td>November 27th, 2014</td>
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<td>Conference day</td>
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Tel: 0424 193 520
Email: petervrahas@eventico.com.au
www.eventico.com.au

http://www.coalconference.com.au
Soma Mine Accident, June 2014