Ground water monitoring and management in Underground Coal Gasification

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A further Update and Latest Trends of UCG in Southern Africa
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Project Overview

1. εUCG Technology
2. Eskom UCG Pilot Project Status
3. UCG Monitoring strategy
4. Conclusions
1. **εUCG Technology** licensed from ErgoExergy Technologies Inc. (Canada)

- Large-scale coal mining technology (applied at scale > 0.3Mt/a)
- Incorporates rock deformation and ground water influx
- Inject oxygen, air, H₂O, CO₂ etc.
- Drilling of directional, inclined, vertical and other wells
- Modern technology, based on 70+ years of Soviet work (> 20Mt of coal extracted)
- Applied in numerous international projects: the USA, Canada, Columbia, New Zealand, South Africa, Australia, China, India etc.
- εUCG uses a matrix of wells (i.e. it is not a 2-well process)
  - Average panel capacity 5 PJ/a, with life of 2-5 years
  - Average mine coal extraction rates of 95%
  - Average mine cold gas efficiency of 75-85%
  - Issues: large-scale consumption of groundwater, subsidence
1. εUCG Technology – applied to all kinds of coal

<table>
<thead>
<tr>
<th>UCG Plant</th>
<th>Rank</th>
<th>Thickness, m</th>
<th>Depth, m</th>
<th>Dip°</th>
<th>LHV,MJ/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lisichansk</td>
<td>Bituminous</td>
<td>0.44 - 2.0</td>
<td>60 - 250</td>
<td>38 - 60</td>
<td>20.1 - 23.0</td>
</tr>
<tr>
<td>Yuzhno-Abinsk</td>
<td>Bituminous</td>
<td>2.2 - 9.0</td>
<td>130 - 380</td>
<td>35 - 58</td>
<td>28.9 - 30.7</td>
</tr>
<tr>
<td>Podmoskovnaya</td>
<td>Lignite</td>
<td>2.5</td>
<td>30 - 80</td>
<td>&lt;1</td>
<td>11.8</td>
</tr>
<tr>
<td>Angren</td>
<td>Lignite</td>
<td>3.0 - 24.0</td>
<td>110 - 250</td>
<td>7</td>
<td>15.3</td>
</tr>
<tr>
<td>Shatskaya</td>
<td>Lignite</td>
<td>2.6</td>
<td>30 - 60</td>
<td>&lt;1</td>
<td>11.0</td>
</tr>
<tr>
<td>Sinelnikovo</td>
<td>Lignite</td>
<td>3.5 - 6.0</td>
<td>80</td>
<td>&lt;1</td>
<td>8.0</td>
</tr>
<tr>
<td>Chinchilla</td>
<td>Sub-bituminous</td>
<td>10.0</td>
<td>135</td>
<td>&lt;1</td>
<td>21.7</td>
</tr>
<tr>
<td>Majuba</td>
<td>Bituminous</td>
<td>3.5-4.5</td>
<td>285</td>
<td>3</td>
<td>20.3</td>
</tr>
<tr>
<td>Kingaroy</td>
<td>Sub-bituminous</td>
<td>17.0</td>
<td>200</td>
<td>5</td>
<td>23.5</td>
</tr>
<tr>
<td>Huntly West</td>
<td>Bituminous</td>
<td>4.0-22.0</td>
<td>220-540</td>
<td>0-75</td>
<td>24.5</td>
</tr>
<tr>
<td>CC Alberta</td>
<td>Sub-bituminous</td>
<td>7.0</td>
<td>150-260</td>
<td>6</td>
<td>20.5-23.0</td>
</tr>
<tr>
<td>Alaska SHR</td>
<td>Lignite/Sub-bituminous</td>
<td>1.0-12.0</td>
<td>50-650</td>
<td>0-75</td>
<td>11.0-16.5</td>
</tr>
</tbody>
</table>
1. εUCG Technology – proactive strategy for groundwater protection

- The εUCG cavity is maintained at a pressure such that there is a negative hydraulic gradient into the cavity.
- This enables the containment of the process and its products within the cavity.
2. Eskom Majuba UCG Pilot Project Status

Eskom has licensed UCG technology from Ergo Exergy Technologies Inc. (Canada)
2. Eskom Majuba UCG Pilot Project Status

<table>
<thead>
<tr>
<th>Research Achievements</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent, long-term fuel source</td>
<td>✔</td>
</tr>
<tr>
<td>Total Environmental footprint (including C)</td>
<td>In progress</td>
</tr>
<tr>
<td>Low cost energy source</td>
<td>In progress</td>
</tr>
<tr>
<td>Mining efficiency</td>
<td>✔</td>
</tr>
<tr>
<td>Security of supply – baseload or mid-merit option</td>
<td>In progress</td>
</tr>
<tr>
<td>Technology transfer</td>
<td>In progress</td>
</tr>
<tr>
<td>Mining safety</td>
<td>✔</td>
</tr>
<tr>
<td>Broader geographic distribution for new generating capacity</td>
<td>✔</td>
</tr>
<tr>
<td>Job creation in rural locations</td>
<td>✔</td>
</tr>
<tr>
<td>Valuable by-products</td>
<td>✔</td>
</tr>
<tr>
<td>Ash left underground</td>
<td>✔</td>
</tr>
</tbody>
</table>
2. Eskom Majuba UCG Pilot Project Status

- Eskom’s UCG project is in the research phase, and Eskom does not yet regard UCG technology as commercially mature.
- Eskom’s present UCG focus is restricted to research only, and commercial UCG development is beyond Eskom’s mandated scope of activity.
- Eskom has found that a developmental technology cannot fully comply with South African environmental laws intended for commercial projects, as the regulators ideally require the research answers before permitting the research. The solution is phasing the development, and working with the regulators.
- Eskom welcomes questions and suggestions now, whilst the technology is still in the research phase.
3. UCG monitoring strategy – gasifier as a source

- Coal is ignited in an underground cavity created in the coal seam
- Gasification produces syngas, water vapour and other volatiles, which are removed as products and burned to produce electricity
- Remaining within the gasification cavity are the residual ash and slag from the coal, and residual salts from the groundwater
- So the gasifier is our principal geo-environmental source – the “mine”
3. UCG monitoring strategy – gasifier as a source

Syngas, water vapour, volatiles → production wells
Residual ash & salts remain in the gasifier → source
3. UCG monitoring strategy – gasifier as a source

- Residual ash (from burnt coal) and salts (from groundwater)
- Inorganic components:
  - Around 250 kg incombustible solids (ash) per cubic metre of coal
  - Mostly Si, Al, Ca
  - Some trace elements are indicators of UCG even if present in low / acceptable levels, e.g. B, Se, Sr, Te
  - Mineralogy of residue controls solubility in the inflowing groundwater
    - Some material slag or other insoluble phases
    - Some material soluble, e.g. Na, K salts
    - **Under investigation**
- Organic components:
  - Phenols, BTEX, PAHs, tars
3. UCG monitoring strategy - receptors

4 aquifers at Majuba but coal seam aquifer is the *source*

- Deep coal seam aquifer: not currently used and pre-UCG baseline water quality unsuitable for domestic or agricultural use
  - Brackish: 600 – 3,500 mg/l TDS
  - Phenols, Benzene, Methylbenzene, Xylenes, PAH - all present as residue from the coalification process
- Lower intermediate aquifer

**B4 dolerite layer – natural confining layer**
3. UCG monitoring strategy - receptors

B4 dolerite layer – natural confining layer

*Receptors above dolerite – should be unaffected by normal operations:*

- Upper intermediate aquifer
- Shallow aquifer: used for agricultural purposes – although not at the Majuba site, may already be impacted by pre-mining activities
  - Fuel spills from agriculture and industry
  - Herbicides and pesticides
3. UCG monitoring strategy – pathways & receptors
3. UCG monitoring strategy – source controls

- Pro-active strategy,
  - Gasifier operating pressure below *hydrostatic pressure* at all times.
  - Pressure gradient towards the cavity: controlled ingress of groundwater used in gasification, and preventing egress of potential contaminants

- Re-active monitoring strategy,
  - Check no vertical migration of contaminants to shallow / upper intermediate aquifers,
    - separated from the coal seam and lower intermediate aquifers by dolerite sill
  - *Cone of depression* caused by gasification should be creating a pressure barrier against contaminant flow away from the gasifier – monitoring to check for migration of contaminants away from cone of depression, and respond
3. UCG monitoring strategy – conceptual basis

- **Aim**: observe whether the intrinsic source controls operate
- **Vertical**: check for vertical migration of contaminants by monitoring the shallow and upper intermediate aquifers separate from the coal seam and lower intermediate aquifers
- **Horizontal**: check that all contaminants remain within the cone of depression, and therefore are not migrating away from the gasifier

*Therefore*

- **Water quality compliance is expected at edge of cone of depression:**
  - 1,500 m from production well collars in coal seam and intermediate lower
  - 450 m from production well collars in shallow and intermediate upper
### 3. UCG monitoring strategy – groundwater zones

<table>
<thead>
<tr>
<th>UCG Zone during operations</th>
<th>Conventional mine equivalent</th>
<th>Conceptual basis</th>
<th>Monitoring purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>Underground mine workings or open pit - “process water”</td>
<td>Operational area</td>
<td>Observe levels “process water” against operations summary</td>
</tr>
<tr>
<td>Process Control</td>
<td>Safety zone around mine workings or open pit</td>
<td>Buffer zone for early warning of any problems</td>
<td>Monitor for significant changes in early warning indicators</td>
</tr>
<tr>
<td>Compliance</td>
<td>External environment</td>
<td>Area expected to be unaffected by UCG operations</td>
<td>Compliance required against agreed WUL quality standards</td>
</tr>
</tbody>
</table>
3. UCG monitoring strategy – application of standards

- Process control zone – monitor all but some parameters as early warning indicators that could suggest onset of contamination
  - Phenols, pH variation, sulphate, TDS, benzene, Ca and Sr
  - Water level – indicative of pressure

- Compliance zone – apply the water use guidelines except where exceeded by pre-UCG baseline / undisturbed control:

<table>
<thead>
<tr>
<th>Aquifer</th>
<th>Guideline applied</th>
<th>Baseline or control applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow aquifer</td>
<td>DWAF agricultural water use limit except where exceeded by baseline</td>
<td>Use baseline for Manganese, Sodium, upper limit of pH</td>
</tr>
<tr>
<td>Coal seam aquifer</td>
<td>DWAF agricultural water use limit e.g. calcium, sulphate, nitrate - except where exceeded by baseline</td>
<td>Use baseline for TDS, manganese, sodium and fluoride</td>
</tr>
</tbody>
</table>
3. UCG monitoring strategy – after gasification

• Monitoring will continue to be required during the post-operations recovery phase.
  o Water table will be recovering (rebounding)
  o Water quality in the Production zone will be recovering due to dilution - Production zone becomes part of Process Control zone
  o Compliance zone is retained without alteration.

• Closure phase - monitoring depends on the closure plan
4. Conclusions

- UCG has got a significant role to play in South Africa’s energy future.
- UCG is able to extract the presently unminable coal resources in a safe and environmentally friendly manner.
- Eskom has partnered with Ergo Exergy Technology, to benefit from their significant body of UCG knowledge derived over 70+ years.
- Eskom has contracted Golder as an external, expert hydrogeological partner
- The UCG process and its products are contained within the cavity by design, to minimise contamination of underground aquifers.
- Eskom’s UCG project is in the research phase, and welcomes questions and suggestions now so as to optimise the research value.
4. Conclusions

• Eskom has found that a developmental technology requires phased development for regulatory purposes.

• The monitoring strategy is derived from the intrinsic source controls in UCG:
  - *Not only* checks “if anything is coming out”, *but also*
  - Checks the performance of the source controls themselves.

• Opportunity for collaboration between Eskom and the DWA, allowing the DWA to monitor and determine the efficiency of its preferred licensing approach for UCG, before UCG moves into being a commercial application in South Africa.