Investigation of the potential for mineral carbonation of South African PGM tailings

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Background

- Rising CO$_2$ levels increase rate of global warming
- SA generates 93% electricity coal combustion
- 420 million t CO$_2$ & volumes of industrial wastes

(Cloete, 2009)

Adapted from Koonin (2008)
Natural Carbonation and CCS Strategies

• Mimicking natural weathering:

$\text{(Ca,Mg)}\text{SiO}_3 \text{ (s)} + \text{CO}_2 \text{ (g)} \rightarrow \text{(Ca,Mg)}\text{CO}_3 \text{ (s)} + \text{SiO}_2 \text{ (s)}$

• Not easily reversible & products are benign in nature

(Lackner, 1995)
Objectives of Study

• Characterisation of Merensky tailings from four PGM operations along the western limb of the BIC

• Develop a ranking scheme of theoretical carbonation potential

• Estimate maximum theoretical sequestration capacity of the PGM industry in SA per annum

• Validate the ranking scheme through kinetic testing
<table>
<thead>
<tr>
<th>Mining Operation</th>
<th>Northam</th>
<th>BRPM</th>
<th>Impala</th>
<th>Lonmin</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mineralogy</strong></td>
<td>Harzburgitic</td>
<td>Pyroxenetic</td>
<td>Pyroxenetic</td>
<td>Pyroxenetic</td>
</tr>
<tr>
<td><em>$R_{CO2}$</em></td>
<td>2.6</td>
<td>3.9</td>
<td>3.9</td>
<td>3.7</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tonnage of Merensky Tailings pa</td>
<td>1002 kt</td>
<td>1049 kt</td>
<td>5385 kt</td>
<td>2636 kt</td>
</tr>
<tr>
<td>Carbonation Capacity kt CO$_2$ pa</td>
<td>388</td>
<td>270</td>
<td>1372</td>
<td>716</td>
</tr>
<tr>
<td><strong>Distance from CO$_2$ Source</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance from Secunda</td>
<td>300 km</td>
<td>280 km</td>
<td>250 km</td>
<td>215 km</td>
</tr>
</tbody>
</table>

**Rank**

*$R_{CO2}$ = Tonnage of tailings required to sequester 1 ton of CO$_2$ (g)*

![Inkaba yeAfrica]
Kinetic Analysis

• Indirect two step “pH swing”

• Leach carried out on 10g PGM tailings in 500mL 2M HCl at T=70ºC for 8 hours

• Filtered, pH increased to 9 by addition 5M NaOH

• Carbonated at pH 9, CO$_2$ gas flow rate of 1L/min, T=20ºC
Acid Leach: Mg

- Olivine & serpentine are most reactive
- Talc & chlorite are least reactive
- Increased Mg deportment in olivine & serpentine phases results in a greater $X_{\text{Mg}}$ %
• Plagioclase is the most reactive
• BRPM and Impala behave similarly as do Northam & Lonmin
• Increased deportment of Ca in plagioclase results in a greater $X_{Ca}$ %
Carbonation

Acid test for carbonates

Diffractogram of the carbonated precipitate

Leach:

\[
\begin{aligned}
HCl + \frac{1}{6}Mg_3Si_2O_5(OH)_4 &\rightarrow \frac{1}{2}Mg^{2+} + Cl^- \\
&+ \frac{1}{3}SiO_2 + \frac{5}{6}H_2O
\end{aligned}
\]

Carbonation:

\[
\begin{aligned}
5MgCl_2(aq) + 10NaOH(aq) &\rightarrow 4CO_2(g) + 10NaCl(aq) \\
&+ Mg_5(OH)_2(CO_3)_4 \cdot 4H_2O(s)
\end{aligned}
\]
Conclusion

• Merensky PGM tailings have been carbonated via an indirect two-stage “pH swing” method

• Mild leach conditions - reacted mineral capacity is lower than stoichiometric capacity

• The difference in extraction % can be linked to mineralogy - Mg leach

• Leaching efficiencies (Mg) for BRPM & Lonmin may be improved with longer reaction times; Northam & Impala may be improved by “harsher” leach conditions
Acknowledgements

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www.nrf.ac.za

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www.mineralstometals.uct.ac.za

Inkaba yeAfrica
www.inkaba.org
Theoretical Carbonation Capacity of PGM Industry

Theoretical Carbonation Capacities Per Annum

- Total CO₂ capacity **13.9 Mtpa** accounts for **43%** of **32 Mtpa** of CO₂ produced by synthetic fuels industry SA