3.0 RESULTS AND DISCUSSIONS

This project work considered the use of different blend ratios of PicaGold and ChemQuest activated carbon within specific pulp densities in order to optimise gold recovery at Gold Fields Ghana Limited (GFGL). The results for the various analyses made are presented and discussed in this section.

3.1 Gold Adsorption Kinetics of the Carbons

To know the adsorption kinetics of the carbons to be analysed, an activity test was performed. Figure 3.1 represents the gold left in solution after one hour of adsorption by the various carbons. It is evident in figure 3.1 that as time elasped the gold in solution decreased gradually. It can be said that after 15 minutes, more gold was adsorbed by the PicaGold as compared to ChemQuest. However, after 30-45 minutes of adsorption, it was realized that more gold was adsorbed by ChemQuest than PicaGold. Finally, it was observed that after one hour, more gold was adsorbed by PicaGold than ChemQuest.

![Gold Adsorption Kinetics Graph](image)

Fig. 3.1 Activity of PicaGold and ChemQuest Activated Carbon

A standard measure of the kinetic index is the Anglo-American Research Laboratories method
CA68 that nominates an R value after 1-hour contact time. The R value is the measure of the rate of gold adsorbed by the carbon. It indicates that if \( R > 60\% \) then the carbon is recommended for use in gold adsorption. PicaGold had an R value of 69.69\% while that of ChemQuest was 60.63\% after the one hour contact time. It can also be said that, these carbons could be advanced relatively faster when in the CIL tanks since it adsorbs a high percentage of gold in a short period. The gold left in solution after a period of one hour when PicaGold was used indicates that it is more active than ChemQuest to some extent. However, it is likely that at prolonged residence time and differences in media this trend may change. The results of gold left in solution and derivation of the R value for the various carbons are shown in table 3.1 and equation 3.1 respectively.

**Table 3.1: Results for Gold left in Solution after One Hour Contact Time**

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Gold in Solution (ppm)</th>
<th>ChemQuest</th>
<th>PicaGold</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10.11</td>
<td>10.26</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>8.89</td>
<td>8.43</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>5.8</td>
<td>6.71</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>5.06</td>
<td>5.37</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>3.98</td>
<td>3.11</td>
<td></td>
</tr>
</tbody>
</table>

**3.1.1 Calculating the R Value for PicaGold and ChemQuest Activated Carbon**

\[
R = \frac{\text{Initial gold in solution} - \text{gold left in solution}}{\text{Initial gold in solution}} \times 100\%
\]

Therefore for ChemQuest, the R value was obtained as follows;

\[
= \frac{10.11 - 3.98}{10.11} \times 100\%
\]

\[
= 60.63\% \quad (1)
\]

For PicaGold, we have;
\[ \frac{10.26 - 3.11}{10.26} \times 100\% = 69.69\% \] 

(2)

3.2 Gold Leached into Solution at the various Pulp Densities

Figure 3.2 gives the gold leached into solution against the various pulp densities prepared. Leaching of the dried feed sample resulted in the following amount of gold in solution.

The amount of dissolved gold available for adsorption decreased with increasing pulp density with the highest gold in solution resulting from 52% solids. This was as a result of mass transport which is maximized at lower pulp densities. It can therefore be said that the highest gold leached into solution available for adsorption by the activated carbons is at 52% solids, this decrease as the pulp density increased.

Fig. 3.2 Effect of Pulp Densities on Leaching of Gold
3.3  **Gold Recovered by the carbon Blends at the various Pulp Densities**

3.3.1  Gold Recovered by the various carbon Blends at 52% Solids

Figure 3.3 represents the amount of gold adsorbed by the carbons out of the gold leached into solution at 52% solids. It is observed that, the highest gold was recovered by the carbons with the blend ratio 50:50, followed by 25:75. Comparing their recoveries to that obtained by the individual carbons (that is 100% PicaGold and 100% ChemQuest), it can be said that there is a synergy when the carbons are blended to some extent.

![Gold Recovered by Carbon at 52% Solids](image)

**Blend Ratios (P:C) of Activated Carbons**

**Fig. 3.3 Gold Recovered by carbon at 52% Solids**

Also, as the mass of PicaGold increases from 25%-50% the gold adsorbed also increased. Although, the discussion on the carbon activity suggested that PicaGold is more active than ChemQuest, it is realized from Fig. 3.3 that at a pulp of 52% solids 100% ChemQuest gave a higher recovery than 100% PicaGold. This buttresses the fact that the behaviour of a carbon can differ with
respect to the medium for adsorption.

3.3.2 Gold Recovered by the various carbon Blends at 54% Solids

The gold adsorbed by the various carbon ratios at 54% solids is presented in Fig. 3.4. In this figure, again, the highest recovery was made by the blend ratio of 50:50, followed directly by 25:75. Also the gold adsorbed on the carbon blend increased with increasing content of PicaGold up to 50% where the highest percentage of gold adsorbed was 96.77%.

However, beyond 50:50 blend further increase in PicaGold activated carbon resulted in a decrease in the percentage of gold adsorbed, that is, comparing 25:75 and 50:50 to 75:25. It can be said that since equal masses of the various carbons was presented at 50:50 blend, there was an equal share of the strength and weakness of PicaGold and ChemQuest and hence the weakness of one was
supplemented by the strength of the other. This resulted in the highest recovery of 96.77%. It is again realized here that 100% PicaGold adsorbed more gold than 100% ChemQuest. This suggests that PicaGold could work better to some extent in relatively higher pulp densities than ChemQuest due to the former’s relatively high specific gravity.

3.3.3 Gold Recovered by the Carbon at 56% Solids

The last pulp analysed to see its effect on adsorption by the different carbon blends was 56%, and the result is depicted in Fig. 3.5. This figure presents a different trend compared to Figs. 3.3 and 3.4. The highest gold was recovered by 75:25 carbon blend with a percentage of 97.07.

With the introduction of PicaGold (considering from 100% ChemQuest) it was realized that the recovery dropped from 96.7% to 96.06% and increased slightly to 96.62% that is, for 50:50 blend. However, it was observed that as the quantity of PicaGold became more than ChemQuest, that is 75% PicaGold, the highest amount of gold was recovered. It can therefore be said that for recovery to be high at 56% solids, the amount of PicaGold in the blend should be more than ChemQuest. Also in figure 3.5, it was expected that since literature reviewed that these carbon have almost the
same gold loading capacities but differences in specific gravity (s.g) (PicaGold’s s.g -1.41 and that of ChemQuest is 1.35), the former was supposed to work better in relatively high pulps than the latter. However, this was not what was realized. This implies that apart from the high pulp density and high specific gravity, other properties also influenced this result.

3.3.4 Comparing the Percent Solids Analysed

Comparing the figures for gold recovered by the various carbon blend at their respective percent solids (52%, 54% and 56% solids) in figure 3.6, it was realized that the gold adsorbed at 100% PicaGold increased as the pulp density increased. This indicates that PicaGold does better at high densities to some extent. For 100% ChemQuest, no definite trend can be described; it is realized that its recovery fluctuates, that is, from 52% through 54% to 56%.
Pulp Densities Analysed

Fig. 3.6 Comparing Gold Recovered at the various Percent Solids

Again, it is seen that the highest gold was recovered at 52% when the blend was 50:50. The lowest gold was recovered by two carbon blends at different pulps; that is, 100:0 at 52% and 0:100 at 54% with a recovery of 94.22%.

3.4 Particle Size Distribution

It was observed from the particle size analysis conducted that 99.93% of the particles of PicaGold reported as +1.18 mm, and that of ChemQuest was 99.89%. According to Staunton et al, (2010), the active size distribution range of carbons are 1.00-2.36 mm hence it can be inferred from the results obtained that, 96.93% of the particles of PicaGold and 97.50% of ChemQuest fall in the active range. It was also reviewed that the maximum allowable fraction outside the active range shall not be more than 3% by mass of the carbon when selection. The values representing the size distribution of PicaGold and ChemQuest activated carbons are shown in table 3.2.

Table 3.2 Particle Size Distribution of the Carbon Types
<table>
<thead>
<tr>
<th>Sieve Size (mm)</th>
<th>Percentage Retained (%)</th>
<th>PicaGold</th>
<th>ChemQuest</th>
</tr>
</thead>
<tbody>
<tr>
<td>+3.35</td>
<td>3.00</td>
<td>2.39</td>
<td></td>
</tr>
<tr>
<td>+2.36</td>
<td>70.36</td>
<td>69.20</td>
<td></td>
</tr>
<tr>
<td>+2.00</td>
<td>21.35</td>
<td>21.82</td>
<td></td>
</tr>
<tr>
<td>+1.70</td>
<td>4.51</td>
<td>5.40</td>
<td></td>
</tr>
<tr>
<td>+1.18</td>
<td>0.71</td>
<td>1.08</td>
<td></td>
</tr>
<tr>
<td>+0.85</td>
<td>0.06</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>-0.85</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

### 3.5 Cost Analysis

From the above deduction, it can be inferred that it is technically feasible to employ a blend of PicaGold and ChemQuest activated carbons at each of the pulp densities analysed. However, a firm judgment will depend on the economic efficiency considerations. Table 3.3 gives a detailed cost analysis to ascertain the economic viability regarding the blend ratios and the various pulp densities. The calculations were based on the average grade of ore at GFGL-Tarkwa which is 1.5 g/t and the gold recovered by the carbon with respect to the amount leached into solution. Also, at GFGL-Tarkwa, 12 g of carbon is used to recover gold from 1 L slurry. Hence the amount of solid mass in this 1 L was calculated in order to find the cost of gold with respect to the dried mass.

Table 3.3 Cost Analysis for Price of Gold per Carbon Blend
| Pulp Density (P:C) | Blend Ratio | Au Leached (%) | Au Adsorbed (%) | Mass of Au Leached\((10^{-3})\)(g) | Mass of Au Adsorbed\((10^{-3})\)(g) | Price of Gold Recovered ($| Price of Gold per Carbon
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>52</td>
<td>0:100</td>
<td>93.63</td>
<td>96.65</td>
<td>1.0616</td>
<td>1.0259</td>
<td>0.0568</td>
<td>1.3589</td>
</tr>
<tr>
<td></td>
<td>25:75</td>
<td>97.01</td>
<td>97.34</td>
<td>1.0998</td>
<td>1.0705</td>
<td>0.0593</td>
<td>1.4354</td>
</tr>
<tr>
<td></td>
<td>50:50</td>
<td>97.23</td>
<td>97.76</td>
<td>1.1023</td>
<td>1.0776</td>
<td>0.0597</td>
<td>1.4668</td>
</tr>
<tr>
<td></td>
<td>75:25</td>
<td>93.68</td>
<td>96.42</td>
<td>1.0614</td>
<td>1.0234</td>
<td>0.0567</td>
<td>1.4104</td>
</tr>
<tr>
<td></td>
<td>100:0</td>
<td>97.59</td>
<td>94.22</td>
<td>1.1064</td>
<td>1.0425</td>
<td>0.0578</td>
<td>1.4596</td>
</tr>
<tr>
<td>54</td>
<td>0:100</td>
<td>95.30</td>
<td>94.22</td>
<td>1.1419</td>
<td>1.0759</td>
<td>0.0596</td>
<td>1.4258</td>
</tr>
<tr>
<td></td>
<td>25:75</td>
<td>94.98</td>
<td>96.21</td>
<td>1.1381</td>
<td>1.0949</td>
<td>0.0607</td>
<td>1.4693</td>
</tr>
<tr>
<td></td>
<td>50:50</td>
<td>95.18</td>
<td>96.77</td>
<td>1.1404</td>
<td>1.1036</td>
<td>0.0612</td>
<td>1.5037</td>
</tr>
<tr>
<td></td>
<td>75:25</td>
<td>92.90</td>
<td>94.95</td>
<td>1.1131</td>
<td>1.0569</td>
<td>0.0586</td>
<td>1.4577</td>
</tr>
<tr>
<td></td>
<td>100:0</td>
<td>97.61</td>
<td>95.35</td>
<td>1.1696</td>
<td>1.1152</td>
<td>0.0618</td>
<td>1.5606</td>
</tr>
<tr>
<td>56</td>
<td>0:100</td>
<td>94.17</td>
<td>96.70</td>
<td>1.1913</td>
<td>1.1520</td>
<td>0.0638</td>
<td>1.5263</td>
</tr>
<tr>
<td></td>
<td>25:75</td>
<td>89.74</td>
<td>96.06</td>
<td>1.1353</td>
<td>1.0906</td>
<td>0.0604</td>
<td>1.4620</td>
</tr>
<tr>
<td></td>
<td>50:50</td>
<td>96.27</td>
<td>96.62</td>
<td>1.2179</td>
<td>1.1767</td>
<td>0.0652</td>
<td>1.6020</td>
</tr>
<tr>
<td></td>
<td>75:25</td>
<td>92.93</td>
<td>97.07</td>
<td>1.1757</td>
<td>1.1413</td>
<td>0.0632</td>
<td>1.5721</td>
</tr>
<tr>
<td></td>
<td>100:0</td>
<td>92.06</td>
<td>96.58</td>
<td>1.1647</td>
<td>1.1413</td>
<td>0.0554</td>
<td>1.4000</td>
</tr>
</tbody>
</table>
Although the cost of PicaGold is less than ChemQuest, the price of gold per carbon was dependent on the amount of gold adsorbed by the respective carbons. It can also be said that for most of the pulp densities analysed, the highest gold price per carbon was obtained when the blend was 50:50. It was only at 54% solids where the highest gold price per carbon was attained at 100% PicaGold. For the 50:50, it was realized that as the pulp density increased the price of gold per carbon also increased. The calculations below give a detailed analysis of how the entries in Table 3.3 were obtained.

### 3.6 Calculation of Entries in Table 3.3

#### 3.6.1 Calculations for Head Grade

The calculated head grades for the various analyses made were obtained as follows;

$$\text{mass of carbon} \times (\text{Au on carbon}) \times \text{mass of solution} \times (\text{Au left in solution}) \times \text{mass of solids} \times (\text{Au in tailings})$$

$$\text{mass of solids}$$

For instance, at 52% a solid when carbon blends was 0:100, the head grade was obtained as follows;

$$\frac{8 \times 96.5 + 461.54 \times 0.058 + 500 \times 0.1085}{500} = \frac{853.02}{500} = 1.7060 \text{ g/t}$$

This calculation was done for all the other pulp densities and blends.

#### 3.6.2 Calculation for Gold Leached into Solution

$$\frac{\text{mass of carbon} \times (\text{Au on carbon}) \times \text{mass of solution} \times (\text{Au left in solution}) \times \text{mass of solids} \times (\text{Au in tailings})}{\text{mass of solids} \times \text{head grade}} \times 100$$

Therefore, at 52% using the blend 0:100, the gold leached into solution was obtained as follows;

$$\frac{8 \times 96.5 + 461.54 \times 0.058}{500 \times 1.7060} \times 100 = 93.63\%$$
3.6.3 Calculations for Gold Recovered by the Carbon

\[
\frac{\text{mass of carbon} \times (\text{Au on carbon})}{\text{mass of carbon} \times (\text{Au on carbon}) \times \text{mass of solution} \times (\text{Au left in solution})} \times 100
\]

Using the blend 0:100 at a pulp of 52% the gold recovered by the carbon was obtained as follows;

\[
\frac{8 \times 96.5}{8 \times 96.5 + 461.54 \times 0.058} \times 100
\]

\[
= \frac{772}{798.77} \times 100
\]

\[
= 96.65\% 
\]

(5)

This calculation was done for all the entries for gold recovered.

3.6.4 Calculations for Cost Analysis

If 12 g of carbon is used to recover gold from 1000 ml of slurry then at 52% solids, if 500 g of solid mass is used to obtain a pulp of 661.54 ml then

\[
661.54 \text{ ml} \approx 1000 \text{ ml}
\]

\[
500 \text{ g} \approx S
\]

Therefore S (solid mass in 1000 ml) will be;

\[
\frac{1000}{661.54} \times 500 = 755.81 \text{ g} 
\]

(6)

If the average head grade of gold at GFGL is 1.5 g/t then the mass of gold in the above solid mass is;

\[
755.81 \text{ g} \times 10^{-6} \text{t} \times 1.5 \text{ g/t} = 1.1337 \times 10^{-3} \text{ g/t}
\]

(7)

Using the gold leached into solution at 52% when carbon blend was 0:100 we will have

\[
\frac{93.64}{100} \times 1.1337 \times 10^{-3}
\]

\[
= 1.0616 \times 10^{-3} \text{ g}
\]

(8)
that is, mass of gold leached into solution.

Gold recovered by the carbon is given as;

\[
\frac{96.64 \times 1.0616 \times 10^{-3}}{100} = 1.0259 \times 10^{-3} \text{ g} \quad (9)
\]

To obtain this value in ounce we have;

1 ounce \approx 28.3495 g

? \approx 1.0259 \times 10^{-3}

therefore;

\[
\frac{1.0259 \times 10^{-3}}{28.3495} = 3.6189 \times 10^{-5} \text{ ounce} \quad (10)
\]

Also, if 1 ounce of gold = $1570.89

then 3.6189 \times 10^{-5} \text{ ounce} will be;

\[
3.6189 \times 10^{-5} \times 1570.89 = $0.0568 \quad (11)
\]

Price of ChemQuest; early 2013 = $ 3487/t

Price of PicaGold; early 2013 = $ 3304/t

From the above, 0:100 indicates 100% ChemQuest, therefore the price of carbon which was used for the above recovery is calculated as follows;

\[
12 \times 10^{-6} \times 3304 = $0.0418
\]

To obtain the gold price per carbon, we have;

\[
0.0568 \div 0.0418
\]
The same steps were taken to obtain all the entries in Table 3.3.