A Study of the Relative Impact of Particle Size Distribution on Gold Recovery

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Abstract

With the continuous decline in high-grade gold ores in Ghana and globally, there is an increasing reliance on low-grade ores. Hence, over the past few decades, the processing of low-grade gold ores has gained significant attention in the mining industry and is associated with high plant throughput to meet production targets stipulated by stakeholders. Leaching is a major unit operation associated with gold ore processing, which is significantly affected by particle size distribution. This paper assesses the impact of changes in particle size distribution on gold recovery from a low-grade ore using sodium cyanide as a lixiviant. A gold oxide ore from a Ghanaian mining operation was used in this investigation. The ore was milled and prepared into feed sizes ranging from 50–90% passing 106 µm and leached over 24 hours using conventional bottle roll test. The differing ore size fractions were leached individually in a well-mixed pulp (55 wt.%) at pH 10.5–11. In the bottle roll tests, the sodium cyanide concentration was maintained at 250 ppm at a room temperature. An Atomic Absorption Spectrometer (AAS) was used to characterize the leachate and residue samples obtained from the leaching tests. The present paper highlights that the changes in leach feed particle size has significant effect on gold recovery, suggesting that increasing plant throughput to compensate head grade decline requires subsequent review of leach feed particle size to meet operational targets.

Keywords: Gold, Low-grade ores, Leaching, Particle size distribution, Sodium cyanide

1 Introduction

It is well documented in literature that mining plays a significant role in the socioeconomic development of Ghana and other African countries (Garvin *et al*., 2009). Akabzaa (2007) indicated that mining presents a massive potential of providing substantial revenue and employment, which could boost the livelihood of Ghanaians. A review of literature has suggested that, Ghana plays a key role in the global minerals industry, being well endowed with gold, diamond, manganese and bauxite (Adadey, 1997; Akabzaa, 2007; Garvin *et al*., 2009; Hilson, 2002; Hilson and Potter, 2005). According to Aryee (2001), gold is a significant contributor to Ghana's economy, accounting for about 38% of the country's total merchandise and over 90% of the overall mineral exports. Elsewhere, Akabzaa (2007) and Adadey (1997) acknowledged that gold accounts for more than 80% of all mineral revenue.

A typical gold mining operation in Ghana, over the past decade observed significant changes in the characteristics of the feed (mainly particle size distribution) to its leaching circuit, with its associated challenges including fluctuating gold dissolution rates and sodium cyanide consumption, respectively. It has been identified that the processing plant is operating at a higher throughput than it was designed, with leaching conducted on feed of P_{70} of 106 µm (instead of P_{80} = 106 µm) at a pulp density of 55%, as opposed to the desired conventional pulp density of 40–45 %. This could potentially result in a build-up of silt in the leach tanks as suggested by Osei *et al*. (2016). Osei *et al*. (2016) explained that poor grinding due to increased plant throughput and subsequent carry-over effect of flocculants used in thickening leach feed can lead to repeated settling of ore particles in leach tanks, with its associated gold losses as reported by Konadu *et al*. (2014) and Ofori-Sarpong *et al*. (2019).

Gold leaching is a diffusion–controlled phenomenon; hence the effect of particle size cannot be underestimated. During leaching, the lixiviant percolates through the ore and dissolves the mineral of interest. Gold dissolves on reaction with dilute aerated sodium cyanide solution (Gönen, 2003), however the leaching efficiency may be affected by the particle size of the ore/feed among other factors. In a system dominated by fine particles, it is expected that the rate of lixiviant percolation will be faster, resulting in higher leaching rate (Beyuo *et al*., 2016). On the other hand, where the particles are too fine, slimes are produced, and solid-liquid separation problems may be encountered.

The objective of the present work is to examine the dynamics of gold leaching from a low-grade ore obtained from a Ghanaian mining operation with differing particle sizes in the presence of sodium cyanide lixiviant system. The recovery of gold and cyanide consumption as a function of leach feed particle sizes were studied by varying the leaching duration over 24 hours.

2 Materials and Methods Used

2.1 Materials

Leach feed samples (0.72 ± 0.15 g/t Au) obtained from an oxide gold ore processing plant in Ghana was used in this investigation. Sodium cyanide (NaCN 95% purity) and lime (Carmeuse Ghana Ltd., Takoradi) were used as lixiviant and pH-modifier, respectively. Tap water with a total dissolved solids (TDS) of less than 50 ppm was used in preparing the pulp.

2.2 Method Used

Leaching tests were conducted using the conventional bottle roll test, where an opening on the lid of the bottle was used for the reagents (sodium cyanide, lime, and air) addition and sampling. Leaching experiments were conducted at room temperature (25–30 °C), with 1000 g of sample mixed with tap water to prepare a pulp of 55 wt.% density. For each test, the pulp was initially dosed with lime to increase its pH to 10.5–11, after the addition of 250 ppm NaCN. The pH probe used was calibrated before the commencement of each test. The experiments were conducted over 24 hours (h), where samples were collected at 1, 2, 4, 9, and 24 h. The samples obtained after 1–9 h leaching were filtered through a 0.2 µm filter paper, and the solution retained for subsequent chemical analysis using the AAS. At the end of the leach test (24 h), the pulp was then filtered, to obtained leachate and “residue” samples, respectively. The solution sample was then submitted for gold analysis (using the AAS) and cyanide titration. The cyanide concentration in the solution samples was determined via titration with standard silver nitrate solution. The titration endpoint was the change in the orange colour of rhodamine indicator to yellow. The residue sample was also submitted for gold analysis via fire assay.

3 Results and Discussion

3.1 Influence of Particle size distribution on gold recovery

A typical bulk leach feed plant sample was initially obtained and leached over 24 h using the bottle roll test. Particle size analysis conducted on the plant leach feed indicated that the sample was 78% passing 106 µm, with about 15% of the particles retained on the 150 µm test sieve. This was done to provide the baseline gold recovery using the plant feed. A gold recovery of 88 ± 2% was obtained after 24 h leach test.

In order to investigate the relative influence of changes in particle size of the leach feed on gold recovery, the leach test was conducted based on pH ≥ 10.5 and 250 ppm NaCN as initial values for 50 – 90 % passing 106 µm grain sizes. Gold recovery obtained after 24 h leach for each size fraction has been presented in Figure 1.

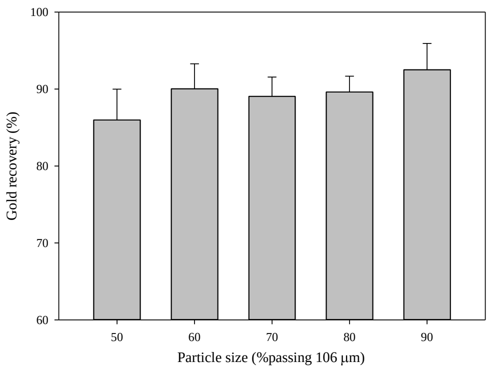

Figure 1 Effect of Particle Size on Gold Recovery

It can be seen from Figure 1 that gold recovery increased with finer leach feed, which is consistent with that reported in the literature. The highest leaching extent was obtained for the test conducted on the finest feed (90% < 106 µm), where a gold recovery of 93% was attained. Gold recoveries attained for leach feed samples with 60–80% < 106 µm can be described as statistically identical, which suggests that there is no much difference in the gold recovered when the particle size is reduced from 60% to 80% passing 106 µm. The extent of leaching obtained for leach feed sizes 60–80% < 106 µm could be describe as identical to that obtained with the typical plant leach sample (78% < 106 µm). The results thus suggest that should the milling performance be enhanced to achieve a leach feed of size 90% < 106 µm, the gold recovery could be increased by about 3 – 5%.

3.2 Effect of Leaching Time on Gold Recovery

During the leaching tests, samples were obtained at 1, 2, 3, 4, 9 and 24 h to assess the changes in gold recovery as a function of time. The results have been summarised in Figure 2. As expected, gold leaching increased with time as presented elsewhere by Baghalha (2012) and Birich *et al*. (2019). The results suggest a fast gold dissolution reaction rate at the beginning for all the leach feed size fractions. The slowing down of the dissolved/recovered gold per unit hour after the first 1 h of testing may be attributed to the decreasing free cyanide-ions in solution.

The highest gold recovery at each leaching time during the first 9 h was obtained for tests conducted on the 80% <106 µm feed, although the highest overall recovery at the end of the 24 h period of 93% was achieved with 90% <106 µm feed. This may be due to the exposed gangue minerals as a result of the relatively 'finer' grinding to achieve 90% <106 µm, which may have interacted with the cyanide ions, which potentially slowed down gold dissolution.

Also, a slower rate of gold recovery is seen for tests conducted on the 50% to 70% < 106 µm feed. This may be as a result of the slower rate of percolation of NaCN through the coarse-grained feed particles during the leaching process.

The upward trends seen in Figure 2 also indicate the possibility of more gold dissolution occurring should the leach extend beyond the 24 h which in effect will have a positive tune on the residual grades reported from the test. This reiterates the fact that residence time plays a significant role during gold dissolution.

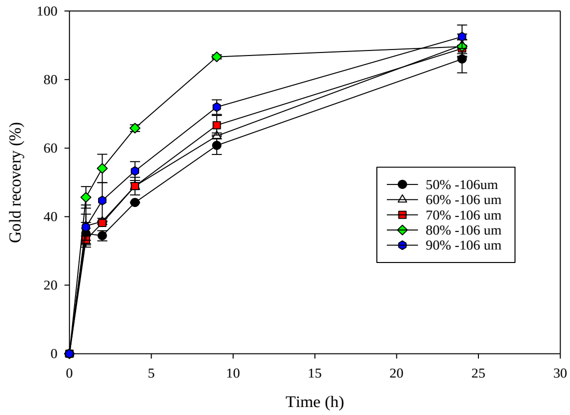

Figure 2 Gold recovery as a function of leaching time

3.3 Cyanide Consumption

At the end of each leaching test (24 h), a subsample of the filtrate was obtained and submitted for titrimetric analysis to determine the residual NaCN concentration. The difference in the initial and final NaCN concentrations for each test was determined as NaCN consumed. The residual NaCN concentration and gold recovery for each leach feed size fraction have been summarised in Figure 3.

As observed earlier, the recoveries obtained for leach feed with grain sizes 60–80% < 106 µm are identical, however the amount NaCN consumed varied significantly. For example, 70 ppm NaCN was consumed during leaching of 60% <106 µm to attain a maximum recovery of 90%, whereas 87 ppm and 82 ppm NaCN were used during the tests conducted on 70% and 80% < 106 µm ore particles, respectively. This may be as a result of the slower rate of percolation when leaching coarse-grained particles, consequently resulting in lower levels of NaCN consumption per unit time, hence higher residual CN^- in the leachate.

On the other hand, finer feed samples have larger surface area exposed for reaction, with shorter length of path of travel of the NaCN, resulting in higher consumption and consequently enhanced gold leaching.

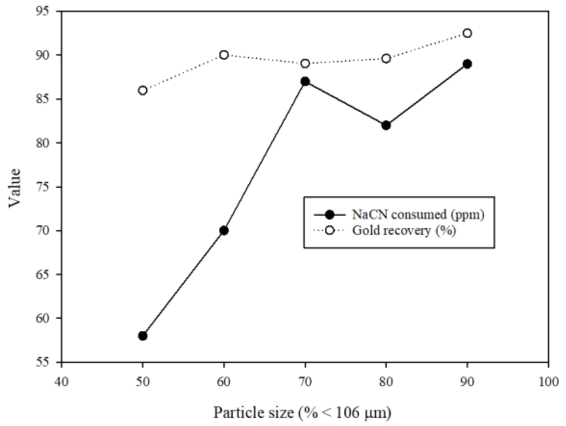

Figure 3 Cyanide consumption and gold recovery as a function of leach feed particle size

3.4 Implications of the Study

The main objective of milling is to reduce the ore particle size to librate the gold particles for enhanced leaching/recovery to attain the highest financial return. When the plant throughput is increased, there should be a corresponding change in other metallurgical parameters to maintain or enhance gold recovery.

Typically, where plant throughput is increased with little or no changes in the milling operations and parameters, coarser grained particles are produced which may potentially lead to decrease in gold recovery, high residual CN^- ions reporting to the tailings and silt build-up in the leaching tanks.

Furthermore, where the plant throughput has been increased beyond the designed capacity, the residence time for gold leaching in most cases reduces, with its associated challenges. It is thus expected that the overall gold recovery may potentially decrease, with the ongoing increased plant throughput. Extra tanks may be built to increase the residence time, to reduce gold loss to the tailings.

Overall, the grinding and leaching circuits need to be optimised to enhance gold recovery in the plant. This should include the economic implications of changes in the milling and leaching circuits to help in making informed decisions on improving the gold recovery in realtion to increased plant throughput.

4 Conclusions and Recommendations

To replicate the industrial leaching process, a gold ore sample (78% passing 106 µm) was leached over 24 h using 250 ppm NaCN at pH ≥ 10.5, where an overall gold recovery of 88 ± 2% was obtained.

The evaluation of the effect of changes in leach feed grain sizes revealed that gold recovery from the ore is grind–sensitive. The highest gold recovery of 93% was attained when a feed of grind size 90% passing 106 µm was used, where about 36% of the total NaCN was consumed over 24 h leaching process.

At an ore grain size of 90% passing 106 µm, the recovery curve was predicted to trend upwards after 24 h, which suggests that the leaching duration may be extended to further increase gold recovery. However, this decision may need further economic evaluation to be implemented.

Future studies involving further grinding to produce finer leach feed (< 75 µm) to compensate for the extension of leaching duration may also be investigated.

Overall, changes in plant throughput to recompense head grade decline should be carried out with a corresponding review of leach feed particle size and other leaching parameters (e.g. residence time, pulp density) to meet operational targets.

References

Adadey, E. (1997),"The role of the mining industry in the economy of Ghana", *Proceedings of the national symposium on the mining industry and the environment*, University of Science and Technology/International Development Research Centre Environmental Research Group, Accra, pp. 10-17.

Akabzaa, T. (2007), "African mining codes, a race to the bottom", *African Agenda*, Vol. 7, pp. 62-63.

Aryee, B.N. (2001), "Ghana's mining sector: its contribution to the national economy", *Resources Policy*, Vol. 27, pp. 61-75.

Baghalha, M. (2012), "The leaching kinetics of an oxide gold ore with iodide/iodine solutions", *Hydrometallurgy*, Vol. 113, pp. 42-50.

Beyuo, M., Abaka-Wood, G.B., Asamoah, R.K., A., K., Amankwah, R.K. (2016), "A Comparative Study of Sodium Cyanide and Jinchan™ Gold Leaching Reagents: A Case Study at Goldfields

Ghana Limited", *4th UMaT Biennial International Mining and Mineral Conference*, Tarkwa, Ghana, pp. MR 195-199.

Birich, A., Stopic, S., Friedrich, B. (2019), "Kinetic Investigation and Dissolution Behavior of Cyanide Alternative Gold Leaching Reagents", *Scientific reports*, Vol. 9, pp. 1-10.

Garvin, T., McGee, T.K., Smoyer-Tomic, K.E., Aubynn, E.A. (2009), "Community–company relations in gold mining in Ghana", *Journal of Environmental Management*, Vol. 90, pp. 571-586.

Gönen, N. (2003), "Leaching of finely disseminated gold ore with cyanide and thiourea solutions", *Hydrometallurgy*, Vol. 69, pp. 169-176.

Hilson, G. (2002), "Harvesting mineral riches: 1000 years of gold mining in Ghana", *Resources Policy*, Vol. 28, pp. 13-26.

Hilson, G., Potter, C. (2005), "Structural adjustment and subsistence industry: artisanal gold mining in Ghana", *Development and change*, Vol. 36, pp. 103-131.

Konadu, K.T., Abaka-Wood, G.B., Ofori- Sarpong, G. (2014), Gold Loses due to Silt Formation in Leaching Tanks, *3rd UMaT Biennial International Mining and Mineral Conference*, Tarkwa, Ghana, pp. 289-293.

Ofori-Sarpong, G., Okwaisie, T., Amankwah, R. (2019), "Geometallurgical Studies on Gold Ore for Enhanced Comminution and Leaching", *Ghana Mining Journal*, Vol. 19, pp. 59-65.

Osei, R., Abaka-Wood, G., Ofori-Sarpong, G., Amankwah, R. (2016), "Siltation of Ore Particles in Leaching Tanks: Causative Factors and Mitigation Measures", *Ghana Mining Journal*, Vol. 16, pp. 51-57.

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