Evaluation of the Cyanidation Leaching of Gold in a Waste Rock Ore

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ABSTRACT: *Samples of the waste rock obtained from Marofengin South Africa ground 60, 70 and 80% passing 75μm were leached with cyanide in bottle roll tests. The results obtained showed that the percentage gold dissolution depends more on the ore size consists than on the cyanide concentration with the highest average dissolution rates of 88.75, 94.34 and 95.90% found at 600, 500 and 500 ppm, for 60, 70 and 80% passing sizes, respectively. It was also noted that the lowest average percents cyanide consumption of 62.91, 61.73 and 58.56 at 60, 70 and 80% passing 75 μm were obtained at the 500 ppm cyanide concentrations. It was further observed that a clear pattern of increasing residual lime content was only observed at the 70% grind size, with the least lime content of 150.37 ppm at 500 ppm cyanide concentration being higher than the least lime contents for the 60 and 80% grind sizes. The results obtained thus suggest the 70% grind passing 75 μm ore with the gold dissolution percentage very close to the conventional 80% passing size at the lowest cyanide consumption of 500 ppm, much lower daily power consumption of about 925 kWh and high residual lime content that indicated the minimization of cyanide loss as hydrogen cyanide,a good choice for the leaching of the waste rock.*

KEY WORDS: *Waste rock, Ground, Dissolution, Cyanide, Lime, pH, Power consumption.*

INTRODUCTION

Gold mostly occurs in nature in its native state but usually with some quantity of silver. The average concentration of gold in the world at about 0.005 g/t is much lower than those of the other metals. As a result of its weak affinity for oxygen and sulphur and high affinity for some metals, gold tends to concentrate in residual hydrothermal fluids and subsequent metallic or sulphidic phases, rather than in silicates. Rocks that are high in clays and low in carbonates are the best sources of gold as re-precipitation occurs when the hydrothermal solutions come in contact with a reducing environment, such as a region of high carbonate [1].Gold ore thickened pulps are treated with cyanide leaching reagents with the addition of an oxidant such as air or oxygen. Leaching takes place in a series of agitated leach reactors with the pH of the pulp adjusted to a value of about 9.5 to 11 using lime to

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ensure minimum loss of cyanide as hydrogen cyanide (*Stange*, 1999). The addition of lime to a cyanide pulp is also done to prevent gold hydrolysis and to neutralize any acidic constituents present in the ore [1]. The use of optimal quantity of cyanide for leaching will minimize environmental effects, maximize the safety of workers and reduce costs [2]. The usual excess cyanide consumption is partly due cyanide oxidation to cyanate, loss through volatilization as hydrogen cyanide gas, complexation with copper, iron, zinc or through reaction with sulphur species to form thiocyanate [3].

The extraction rate of gold is influenced by the particle size of the ore because the smaller the size of the particles, the greater the interfacial surface area between the solid and the leaching liquid and therefore the higher the leaching rate. In general, leaching rate increases with increased concentration of reagent, but only up to a certain maximum level [4]. The leaching mechanism may also change as a result of changes in the concentration of the leachant. The leaching mechanism may for instance change from chemically controlled to diffusion controlled when the concentration of reagent is changed from high to low. Other factors such as the contact time between the leachant and the ore, the agitation rate of the slurry and the slurry density also influence the extraction rate of gold [5]. A cyanide bottle roll test is a standard first step in assessing the gold recovery possible by cyanide leaching. During a bottle roll test, the prepared ore is gently agitated in a cyanide lixiviant. The test results provide information on expected recovery rates, reagent consumption and accurately predict the results obtainable from pilot and industrial plants. The recovery results are considered maximums because attrition grinding creates fines and liberates recoverable values that would not be liberated from the material during a static leach. Bottle roll tests are conducted on ores as coarse as 50 mm [6, 7].

In this study, the effects of process variables such as the degree of ore fineness and concentration of cyanide on the leaching extraction of gold from a waste rock dump were investigated.

EXPERIMENTAL SECTION

Materials

Sample collection

Three bags of samples each weighing 6 kg were collected from number 12 rock waste dumpsite near Merafong in Carletonville area of South Africa. The grab method was used to obtain a representative sample. The sample was crushed using a primary crusher to a size suitable for pulverization and then wet screened in order to obtain different particle sizes, that is, +212 μm, +105 μm, +75 μm and -75 μm. The cyanide and lime used were obtained from SASOL. The waste rocks were found to assay about 0.9 g/t gold.

Sample preparation

The sample was crushed, pulverized and wet screened to 60, 70 and 80% passing the 75 μm apertures.

Methods

About 500 g of the waste rock sample ground 60% passing 75 μm was weighed into the 5-litres rolling bottle and 500 mL of water was added. The slurry in the bottle was rolled for 30 minutes, the pH of the solution was taken and adjusted to about 11 with lime. Cyanide at 500 ppm concentration was added and the slurry mixed with cyanide was rolled for the retention time of 24 hours. The final pH was taken, the pulp was filtered and the gold pregnant solution was obtained. The solution was then analyzed for gold, lime and cyanide according to standard [7, 8, 9]. The solid residue was washed thrice to remove any adhering gold, dried and analyzed for residual gold. The procedure described was done in triplicates. The procedure was repeated but with cyanide concentrations of 600 and 700 ppm. The whole procedure described was again carried out but with waste rock samples ground to 70 and 80% passing 75 μm.

RESULTS AND DISCUSSION

Results

Fig. 1 shows the percentage gold dissolution as a function of the degree of fineness of the ore and the concentration of cyanide in the leachant. It was observed that the percentage gold dissolution generally increased with the percentage of the ore passing 75 μm with the highest average of 88.8, 94.3 and 95.9% obtained at 60, 70 and 80% passing sizes, respectively. It was also noted that the percentage gold dissolution did not increase directly with increasing concentration of cyanide in the leachant with the highest average dissolution rates of 88.8, 94.3 and 95.9% found at 600, 500 and 500 ppm, for 60, 70 and 80% passing sizes, respectively. It was noted that the percentage gold dissolution for ore

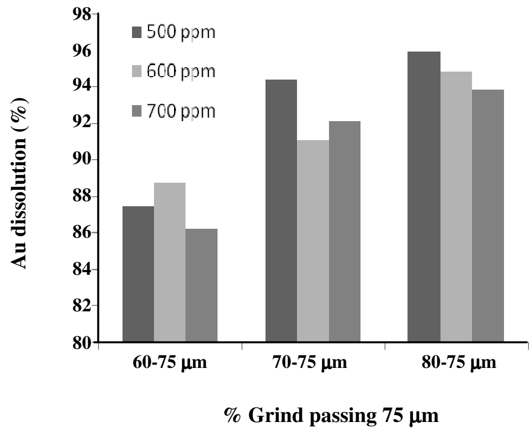

Fig. 1: Gold dissolution rate in slurry of different size fractions passing 75 µm at various cyanide concentrations.

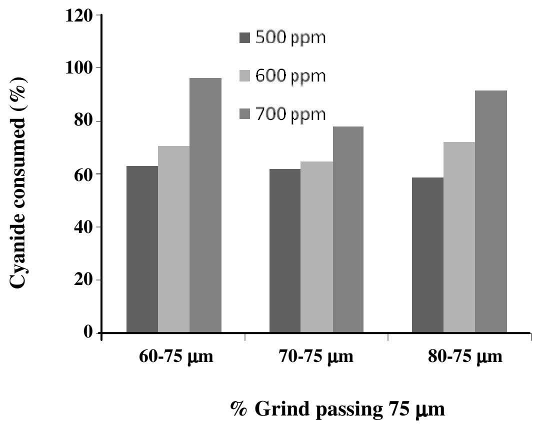

Fig. 2: Cyanide consumed in slurry of different size fractions passing 75 µm at different cyanide concentrations.

particles passing 80% is only about 1.6% higher than for 70% passing size consist. The results obtained thus strongly suggest that the gold ore particle size is a more significant factor than cyanide concentration in determining the percentage dissolution of gold particles and that beyond a certain limit, an increase in cyanide concentration may not produce a corresponding rate in gold dissolution and may even retard it [10]. It has also been observed that elevated cyanide and metal-cyanide concentrations in the solution can significantly increase the complexity and cost of recovering gold and silver [11].

The increase in the percentage dissolution of gold with decreased particle size of the ore might have been due to the increased surface area produced for the leaching reaction at the lower particle sizes [5]. It was reported by *Habashi* [10] that the decrease in the percentage dissolution of gold at increased cyanide concentration was due to the increase in the pH of the solution with increased cyanide addition due to the hydrolysis of cyanide to produce hydrogen cyanide and hydroxide. But in the modern approach to cyanidation, high pH is maintained by the addition of lime to avoid the hydrolysis reaction. The decrease in percentage gold dissolution with increasing cyanide concentration might then be due to an alteration in the leaching mechanism in the slurry as the cyanide concentration increased or an increased in the dissolution of the associated metals like silver and copper at the expense of gold or the reduction in pH value. The formation of some insoluble complexes with the gold solute might also be responsible. The results obtained strongly suggest the 70% passing 75 µm grind size at 500 ppm cyanide concentration as the best leaching combination to obtain gold dissolution closest to that obtained at the highest grind size of 80% passing 75 µm which has been the conventional choice [4].It should however be noted that the recovery results are to be considered maximums because attrition grinding creates fines and liberates recoverable values that would not be liberated from the material during a static leach [7].

Fig. 2 presents the percentage cyanide consumption as a function of the ore degree of fineness. It was observed that the percent cyanide consumption generally increased with cyanide concentration at each grind size with the highest average percents of 96, 77.8 and 91.3 obtained at 60, 70 and 80% passing 75 µm, respectively at the highest cyanide concentration of 700 ppm. The results obtained thus indicated that high cyanide consumption occurred with increasing cyanide concentration at all grind sizes with the highest found at the coarsest grind of 60% and the lowest at the intermediate size of 70% passing 75 µm. Thus, at the 700 ppm cyanide concentration, cyanide consumption gave an exceptional behavior with the 70% grind size consumption being lower than the finer 80% passing 75 µm. It was also noted that the lowest average percents cyanide consumption of 62.9, 61.7 and 58.6 at 60, 70 and 80% passing 75 µm were obtained at the 500 ppm cyanide concentrations. These results suggest that at the 500 ppm cyanide concentration, cyanide consumption decreased with increasing ore fineness. It was however noted that only a marginal difference of about 3.2% occurred

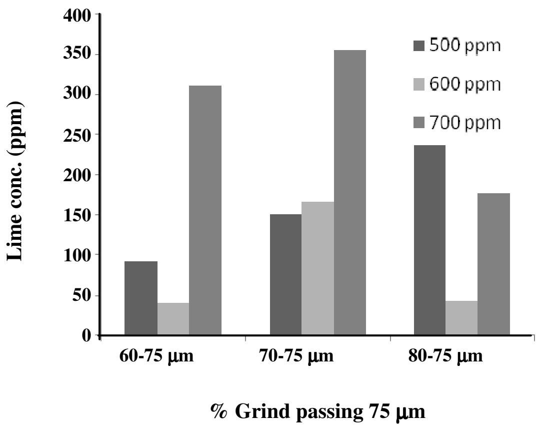

Fig. 3: Lime concentration in leach solution at 60, 70 and 80% passing 75 µm.

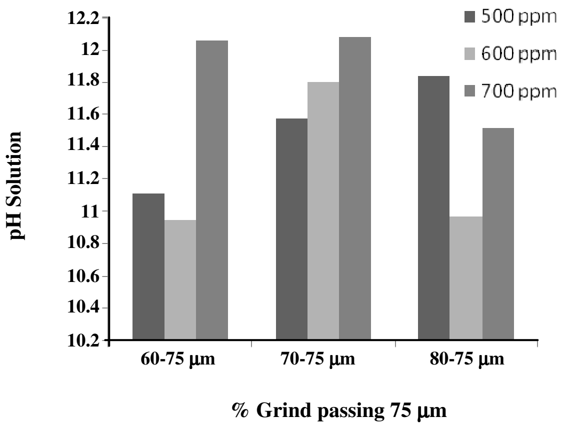

Fig. 4: pH of leach solutions at 60, 70 and 80 % passing 75 µm.

between the 70 and 80% passing grinds and thus the 70% passing ore grind at 500 ppm may be an appropriate choice to minimize cyanide consumption without excessive grinding of the ore.

The lime concentrations in the final leached solutions at varying particle fineness and cyanide concentration are presented in Fig. 3. The results obtained showed that no clear pattern of dependence of lime concentration with ore grind fineness and cyanide concentration was observed. The highest lime contents of 309.4, 354.8 and 236.4 ppm, were obtained at the pairs of 60% grind, 700 ppm cyanide; 70% grind, 700 ppm cyanide; 80% grind, 500 ppm cyanide, respectively. It was further observed that a clear pattern of increasing lime content with increasing cyanide concentration was only observed at the 70% grind size, with the least residual lime content of 150.4 ppm at 500 ppm cyanide concentration higher than the least lime contents for the 60 and 80% grind sizes. The results obtained thus suggest the 70% grind passing 75 µm ore with the least lime consumption as a good choice for the leaching reaction as it implies the sustenance of the much needed alkaline medium for the gold dissolution reaction.

Fig. 4 shows the variation of pH with ore grind fineness and cyanide concentration. It was observed that no consistent pattern of variation of pH with ore grind fineness and cyanide concentration occurred. It was found that the highest pH of 12.05, 12.08 and 11.83 were obtained at the pairs of 60% grind, 700 ppm; 70% grind, 700 ppm; 80% grind, 500 ppm. It was further noted that the lowest pH values of 11.53 obtained for the 70% passing grind at 500 ppm is much higher than the 10.94 and 10.97 obtained at 60 and 80% passing grinds. The results thus showed that the pH values at the 70% grind for all the cyanide concentrations provided the required alkaline medium for optimal and safe leaching. It was observed that contrary to expectation, the pH values at the highest cyanide concentration of 700 ppm gave the highest pH values at 60 and 70% grind sizes. The high alkalinity of the final solution in the 60% and 70% grind at 700 ppm may be because of its highest cyanide consumption of about 96% in comparison with about 93% for the 80% grind making the residual solution richer in lime.

The power consumption for ore grinding at different grind sizes passing 75 µm are shown Fig. 5. It was observed that power consumption increased with increased ore fineness, with power consumption at the conventional 80% passing size about 925 kWh higher than at 70% passing size, daily. The results indicate that ore grind fineness should only be done to a level that will maximize gold dissolution at the lowest possible power consumption. It has been reported that grinding circuits are the largest power consumers and most costly to operate accounting for about 50% of the power supplied to the US mills annually [12].

CONCLUSIONS

The Marofeng waste rock samples were successfully upgraded by cyanide bottle roll leaching with over 92% gold value recovery into the pregnant solution. The results showed that ore particle size is a more significant factor than cyanide concentration in determining the

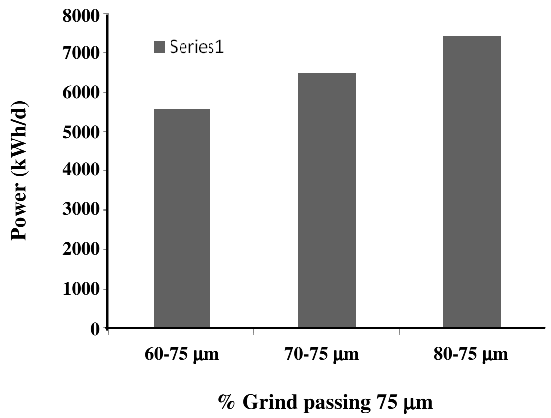

Fig. 5: Power consumption at 60, 70 and 80 % passing 75 µm.

percentage dissolution of gold particles and that beyond a certain limit, an increase in cyanide concentration retard gold dissolution and increase the complexity and cost of recovering gold and silver. It was also noted that only a marginal difference of 3.17% occurred between the 70 and 80% passing grinds and thus the 70% passing ore grind at 500 ppm may be an appropriate choice to minimize cyanide consumption without excessive grinding of the ore. The results obtained further showed that the 70% grind passing 75 µm ore gave the least lime consumption and thus the required alkaline medium for optimal leaching at all concentrations. In addition, the power consumption at the 70% passing grind size was about 925 kWh/day lower than for the conventional 80% passing 75 µm size.

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