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Effect of Particle Size and pH on Recovery of Gold with Bottle Roll Test Method at PT Citra Palu Minerals

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Abstract

Bottle Roll Test (BRT) is a leaching testing method on a laboratory scale used in this test. The sample tested was low grade gold ore (< 1 ppm Au) from Poboya, Palu, Central Sulawesi at PT Citra Palu Minerals. Leaching was carried out for 24 hours with samples taken at 2, 4, 6, 12, and 24 hours. The parameters tested were particle size (-125 +100 µm, -100 +75 µm, and -75 µm), and pH (10-11, 11-12, and 12-13). The parameters set are 48% solid percent, 300 ppm cyanide concentration, dissolved oxygen using free air, 50 RPM agitation speed, and 24 hours leaching residence time. The research results showed that the highest gold recovery was obtained in samples with particle size of -75 µm and a pH of 10-11. The highest gold recovery is 91,5%.

Keywords: Leaching, Bottle Roll Test, Gold, Particle Size, pH

Introduction

Gold cyanidation is a method commonly used to dissolve gold. With the presence of complex substances such as cyanide, gold and silver are dissolved to form stable complex ions $Au(CN)_2$ and $Ag(CN)_2$ (Franco et al., 2007). Oxygen will undergo a reduction process and H_2O_2 will be formed as an intermediate product in the first reaction stage and become an oxidizing agent in the second stage (Elorza-Rodríguez et al., 2006) (Li et al., 2023).

Particle size is a smaller particle size can increase the rate of gold dissolution. This is because the smaller particle size provides a larger contact surface area between the solid and liquid, thus increasing the extraction rate (MU et al., 2018). pH lime is commonly used to regulate pH in the gold leaching process (Franco et al., 2004). Gold dissolution is expected to decrease with increasing pH because OH- ions are adsorbed on the gold surface and prevent cyanide from entering the gold surface (Chen et al., 2020). This is also caused by an increase in other competing reactions such as sulfide dissolution and dissolution of other reactive species (Fomchenko et al., 2016) (Aylmore, 2016).

Cyanide Concentration in the gold extraction rate increases with increasing free cyanide concentration (Aghazadeh et al., 2021). Excessive cyanide causes the formation

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of cyanide complexes with impurities in the system (Chandra & Gerson, 2010). If the ore contains sulfide compounds, more cyanide is needed (Gui et al., 2023). However, suboptimal cyanide consumption can have a negative impact on the gold recovery process (Anderson, 2016) (X. Zhang et al., 2024).

The solid percentage is the ratio between the weight of solids and the total weight of the slurry (Anipsitakis & Dionysiou, 2003). The greater of solid percentage, the greater the solid fraction, so the opportunity for reaction between gold and the solution will be smaller. This is related to the limited movement of atoms or ions. A high solid percentage also results in a decrease in the dissolved oxygen (DO) value so that the reaction rate decreases. Therefore, the solid percentage is maintained in the range of 40%-50%. Dissolved Oxygen is essential in the gold ore cyanidation process, because the reaction rate is influenced by the concentration of this compound. The need for dissolved oxygen depends on the type of mineral, in general the higher dissolved oxygen, so the reaction getting faster (Zeng et al., 2024) (L. Zhang et al., 2022).

Agitation speed is one of the important factors in the gold dissolution process (Ma et al., 2024). However, this depends on the thickness of the diffusion layer and the mixing characteristics so that particle diffusion can be optimal with agitation. Increasing the stirring speed can increase the gold dissolution rate because it can reduce the thickness of the diffusion layer (Zhou et al., 2024). Therefore, the mass transfer rate of cyanide and oxygen is increased and the accessibility to dissolved oxygen is higher. Therefore, this study was conducted to determine the effect of particle size and pH on gold recovery using low-grade gold ore samples (S. Zhang & Nicol, 2005).

Research Methods

The experiment was conducted nine times with different grain sizes and pH. The cyanide concentration was set at 300 ppm, dissolved oxygen using free air, solid percentage was set at 48%, bottle roll agitation speed was 50 RPM, and residence time was 24 hours (Manning & Kappes, 2016). The research parameters are described in Table 1.

Tabel 1. Fixed Variable of Research

Factors	Value	Unit
Cyanide Concentration	300	ppm
Solid Percentage	48	%
Dissolved Oxygen	5-6	ppm
Agitation Speed	50	RPM
Residence Time	24	hour

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The independent variables tested were grain size with variations of -125 +100 µm, -100 +75 µm, and -75 µm and pH with variations of 10-11, 11-12, and 12-13. The research using Bottle Roll Test method which usually used on a laboratory scale to measure how effectively gold can be extracted using cyanide solution. The bottle roll can be seen in Figure 1.

Figure 1. Bottle Roll

This research began in February 2024 to April 2024 which was conducted in the laboratory of PT Citra Palu Minerals facilities. The gold ore samples taken from the River Reef Zone (RRZ) Poboya mining area, Palu, Central Sulawesi. The research using Bottle Roll Test method. The stages carried out in this BRT are:

1) Prepare samples with grain sizes (-125 +100 µm, -100 +75 µm, and, -75 µm) then each sample is put into a bottle as much as 1200 grams.
2) Put 1300 ml of water into the bottle to achieve a solids percentage of 48%. Then mixing is carried out for 5 minutes so that the solid and water samples are mixed homogeneously.
3) Check the pH and DO on the slurry. Then the pH is adjusted with pH variations (10-11, 11-12, 12-13). The pH was adjusted by adding lime.
4) Add cyanide until the concentration on 300 ppm.
5) The leaching process was started by turning on the bottle roll machine with an agitation speed of 50 RPM. Then a slurry sample of 300 ml was taken at 2, 4, 6, 12 and 24 hours.
6) The slurry from the sampling was separated between solid and solution using filter paper to obtain 55 ml of solution.
7) The solution was used for reading Au levels and titration tests.
8) After 24 hours, the slurry was filtered using a vacuum to separate the solid residue and the rich solution.
9) The residue was dried in an oven and 25 grams were taken to be digested using aqua regia solution to dissolve Au in the residue so that it could be read on AAS.

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Results of Research and Discussion

This research using bottle roll test method with a residence time of 24 hours to determine the percent recovery of Au. The cyanide concentration was set at 300 ppm. The gold ore samples tested were the result of mining in the River Reef Zone (RRZ) Poboya area, Palu, Central Sulawesi. The low grade sample has a gold content of <1 ppm. The head grade test data for low grade gold ore can be seen in Table 2.

Table 2. Head Grade Data

Particle Size (µm)	Au (ppm)	Ag (ppm)	Cu (ppm)
-125 +100	0,625	2,8	8
-100 +75	0,701	3,5	9
-75	0,831	4,1	10

The test was conducted with particle size variations of -125 +100 µm, -100 +75 µm, and -75 µm aimed to determine the effect of grain size on gold leaching. While the pH conditions were varied in the range of 10-11, 11-12, and 12-13. The pH variation was determined in alkaline conditions to avoid the risk of HCN gas formation if the pH was varied in acidic conditions. From these variations, the optimal pH for gold leaching can be determined. The experiment was conducted nine times with different grain sizes and pH. The cyanide concentration was set at 300 ppm, dissolved oxygen used free air, the solid percentage was set at 48%, the bottle roll agitation speed was 50 RPM, and the residence time was 24 hours. The experiment resulted in gold recovery as seen in Table 3.

Table 3. Leaching BRT Data

No	Particle Size (µm)	pH	Gold Recovery (%)
1.	-125 +100	10-11	84,5
2.	-125 +100	11-12	83,9
3.	-125 +100	12-13	83,3
4.	-100 +75	10-11	88,6
5.	-100 +75	11-12	86,3
6.	-100 +75	12-13	85,9
7.	-75	10-11	91,5

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8.	-75	11-12	90,9
9.	-75	12-13	90,2

The kinetic graph presented in Figure 2 is the result of bottle roll test on the sample that produced the highest gold recovery. The highest gold recovery was obtained in the sample -75 µm particle size and the pH was set in the range of 10-11. This kinetics was obtained from the results of solution sampling carried out at 2, 4, 6, 12, and 24 hours. From the graph it can be seen that gold recovery increases with longer residence time.

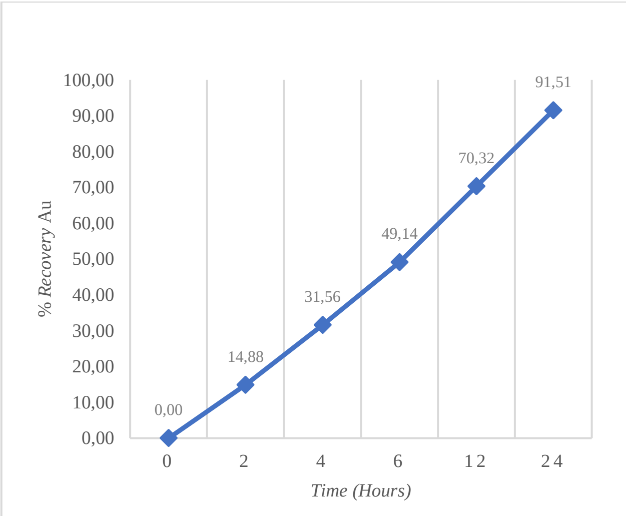

Figure 2. Gold Recovery Kinetics Graph

Conclusion

1. Effect of Particle Size

Based on the results of data processing, the smallest grain size of -75 µm produces the highest gold recovery, 91.5%. Smaller particle sizes can increase the rate of gold dissolution. This is because smaller particle sizes provide a larger contact surface area between solid and liquid, thus increasing the extraction rate. Gold that has been perfectly liberated will be easier to obtain with cyanide forming a complex compound aurocyanide or $Au(CN)^{2-}$.

2. Effect of pH

Variations in pH 10-11 produce the highest gold recovery compared to other pH conditions, 91.5%. High pH conditions (>10) can minimize the formation of hydrogen cyanide which causes the loss of cyanide as HCN gas. From these data, operating pH conditions that are too high can have detrimental effects. The decrease in leaching effectiveness with a decrease in gold and silver recovery at pH 12-13 proves that pH conditions that are too high are not optimal when applied to gold leaching. In addition, the need for lime will also increase with the increasing pH condition settings. High pH

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conditions cause cyanate formation because free cyanide will be oxidized by oxygen to [CNO] ions. Cyanate is undesirable in gold leaching because it can reduce the concentration of free cyanide and cannot dissolve gold.

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