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Effect of Application Rate on Gold Ore Extraction Process with Column Test Method at PT J Resources Bolaang Mongondow, North Sulawesi

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Abstract

PT J Resouces Bolaang Mongondow is engaged in gold processing with the heap leach process using the dynamic cell method. However, currently there will be a change to the static cell method so that it will affect the operational strategy including the application rate. Therefore, in this research, testwork was carried out to determine the best application rate to be used in the static cell process, studying the effect of application rate on leaching kinetics, percent gold extraction value, and cyanide consumption. The research stages include preparation and testing of head assay samples, leaching, and preparation and testing of tailings samples using the column test method. The application rate variations used were 20 $L/m^2/h$, a combination of 20 & 10 $L/m^2/h$, and 10 $L/m^2/h$. Pregnant leach solution obtained per day is checked for pH, free cyanide, and metal content analysis for the calculation of the percent extraction by back calculated. The results showed that the application rate of 20 $L/m^2/h$ and the combination of 20 & 10 $L/m^2/h$ had faster primary leaching kinetics than the application rate of 10 $L/m^2/h$. Analysis of the percent extraction of application rate 10 $L/m^2/h$ has the highest percent extraction of 89% (0.2081 mg/L gold). Application rate also has an impact on cyanide consumption, where the application rate of 20 $L/m^2/h$ has the highest cyanide consumption of 0.13 g/t. Meanwhile, the application rate combination of 20 & 10 $L/m^2/h$ and 10 $L/m^2/h$ had cyanide consumption of 0.081 g/t and 0.067 g/t, respectively. From the results, it is concluded that the best application rate is the combination of 20 & 10 $L/m^2/h$, judging from the leaching kinetics factor and the percent extraction obtained. On the other hand, the volume of solution produced is also less so that it can minimize the occurrence of landslides on the leach pad.

Keywords: Application Rate, Gold Extraction, Column test, Extractive Metallurgy, Heap leaching

Introduction

Gold is a soft yellow metal, with the highest ductility and malleability of any metal. Gold crystallizes in a cubic system, and has a high high thermal and electrical

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conductivity (Yannopoulos, 1991). Gold is a very economical mineral and has a high selling price, where in its own processing the most economical process is cyanidation (Widara et al., 2017). Gold processing can generally be done by two processing methods, namely: amalgamation and cyanidation. The gold (Au) and silver (Ag) leaching method that has a high recovery value is the cyanidation method. However, cyanide has high toxicity to the environment and slow reaction kinetics (Yustanti et al., 2018) (Tanriverdi et al., 2005). The cyanidation method is one of the methods in the hydrometallurgical process, hydrometallurgy itself is a separation technique that uses chemical solutions or reagents to capture or dissolve the metal. This technique can be applied to separate gold metal from low grade gold ores (Wahyuningsih & Pamungkas, 2022). Cyanide solution waste, which is toxic, can harm the life of aquatic biota and surrounding plants and plants in the vicinity and can ultimately endanger human life. To avoid environmental problems caused by cyanide waste, it is necessary to create a waste treatment system before the waste is disposed of it is necessary to make a waste treatment system before the waste is disposed of. In addition to its shortcomings in terms of toxicity, the following are some of the advantages of using cyanide solution in the gold processing process, namely high percent extraction, ease of control, low investment and easy installation and the process has been proven effective (Asamoah, 2020). There are alternative solvents that can be used such as thiourea, halogen, thiocyanate (Mufakhir et al., 2019), thiosulfate (Riastuti et al., 2022), chlorination, alkaline glycine, and ammonium polysulfide (Rapele et al., 2022), thiourea ($CS(NH_2)_2$) leaching method was developed as an alternative that is considered much safer than cyanidation and amalgamation methods due to its more environmentally friendly output (Nursiah et al., 2019). However, cyanide replacement solvents have not been widely applied on an industrial scale, due to insufficient effectiveness and economics (Arham et al., 2020).

In the mining process, ore is excavated along with surrounding rocks and minerals. To get gold, several processing processes need to be carried out. One of the methods used is heap leach. Heap leach is done by piling the ore in a pile. Processing begins with crushing the ore, then agglomeration is carried out to bind very small materials. The agglomerated material is then transported to the heap leach pad and irrigated with sodium cyanide solution to separate gold from other materials (Suci et al., 2022). Chemical solution used for irrigation comes out through pipes under the ore and gravel piles and will enter the launder box. If the grade of chemical solution from leaching is high, the chemical solution will be flowed to the pregnant leach solution pond (PLS) to be processed in ADR into bullions (Nabella et al., 2024). If the gold ore contains sulfide minerals, Pb salts can be added which serve to help oxidize the metals and can increase the degree of liberation. In addition, Pb^{2+} ions can precipitate sulphide ions from mineral impurities (Kusdarini et al., 2018). When added during leaching, $Pb(NO_3)_2$ has been shown to increase Au recovery (Sarempa & Isjudarto, 2014).

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PT J Resources Bolaang Mongondow conducts gold processing with the heap leach process using the dynamic cell method, but there will be changes towards static cells so that there will be changes in operational strategies, especially in the application rate used. In the heap leach process, the application rate is one of the things that needs to be considered because it has an impact on the heap leach process. Application rate is generally the amount of solution given to a place with a certain area per hour. In selecting the optimum application rate for the irrigation process, it is necessary to know about the permeability and moisture retention of the ore pile. Low permeability zones (usually in the surface layer) will affect the optimum application rate used, which when using excessive application rates will result in ponding, short-circuiting, and channelling of solution, resulting in unleached areas of the pile (Ghorbani et al., 2016).

At PT J Resources Bolaang Mongondow in checking permeability using mini column test (MCT) testwork, where the ore requirements are said to be included in good permeability which is> 150 ml / min for silica alteration type ore, when it is below this then the permeability of the ore is said to be low / not good (PT J Resources Bolaang Mongondow, 2024). Variations in the application rate of the leaching solution can sometimes be beneficial, for example in the gold leaching process where a decrease in the application rate can balance the decline in metal that tends to occur over time. In addition, changes in application rate are necessary due to the evolution of heap permeability. If the solution flow rate is too low, then the leaching time may become too long resulting in decreased economics (Watling, 2006). In irrigating the application rate used, it is done with a wobbler tool, where each wobbler with a different nozzle size has a different amount of solution that can be flowed and the range of flow. The wobbler can be seen in Figure 1 below.

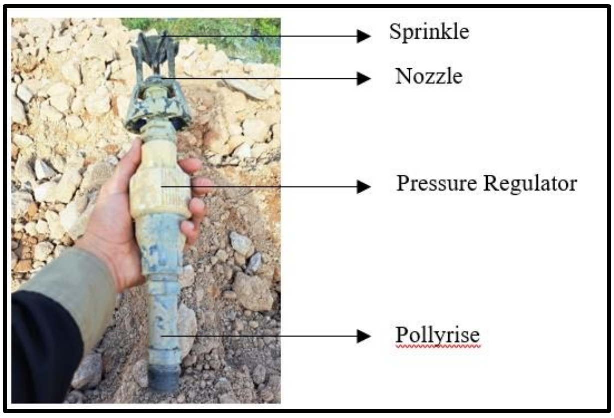

Figure 1 Wobbler
Source: Obtained from Personal Documentation (2023)

Research Methods

This research was conducted using the column test method, using ore with a grade of 0.3 g/t - 0.5 g/t which is included in low grade ore. The variations that want to be studied in this study are the application rate variations used, which are divided into three

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variations including 20 L/m^2/h, 10 L/m^2/h, and a combination of 20 & 10 L/m^2/h. in the application rate combination of 20 & 10 L/m^2/h, primary leaching will use an application rate of 20 L/m^2/h and an application rate of 10 L/m^2/h will be used in secondary leaching.

As for the ore used is oxide type gold ore where the use of cyanide for the extraction of oxide type gold ore tends to be more effective than sulfide ore, due to the presence of gold minerals trapped in sulfide minerals, causing these minerals to be difficult to dissolve, thus affecting the percentage of gold extraction (Marsden & House, 2006).

From the results of the research, there are several things that will be discussed including the effect of application rate on leaching kinetics, the effect of application rate on the percentage of gold extraction, the effect of application rate on reagent (cyanide) consumption, and from these three things will be drawn conclusions to find out the best application rate that can be used. The experimental procedures in this study are:

a. Sample Preparation

- The gold ore preperation stage is carried out by separating the size using a vibrating screen and manual screen. The ore size is separated into 4 size fractions namely +25 mm, -25mm +12 mm, -12 mm +6 mm, and -6 mm (Kirana, 2023).
- After each size fraction of the ore is separated, it is then homogenized manually using a shovel.
- Each size fraction is separated by cone and quatering method which is adjusted to the needs of three column tests. Furthermore, each sample will be weighed and put into sacks.
- Head assay sampling is carried out on each size fraction, where each size fraction requires a sample of 5 sample bags in each column test with the weight of each colico of 1000 grams except for the size fraction -25mm +12 mm of 500 grams, so that each size fraction requires a total of 20 samples in each column test, where each size fraction will be taken as many as 5 samples.
- Head samples will then be put into the oven for 6-8 hours, then weighed again to obtain the % moisture value of the sample.
- Bringing the head samples to the laboratory for analysis of AuFA, AuCN, and other bound metals.

b. Leaching

- Each ore size fraction is weighed with the weight of each size fraction as follows; 12 kg for the +25 mm size fraction, 17 kg for the -25 mm +12 mm size fraction, 17 kg for the -12 mm +6 mm size fraction, and 14 kg for the -6 mm size fraction. Determination of the number of samples in each size fraction is done by forecasting or forecasting methods which are adjusted to the number of samples. At the size of +25 mm, 12 kg is obtained because it is 20% of the total ore, which is 60 kg, while for the remaining 80% it is divided into three, but with the condition that the size of -6 mm has a smaller amount of ore in order to avoid the

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occurrence of a solution that cannot pass through the ore in the column test. So that from this consideration, each ore weight is obtained in each size fraction as listed above.

- Mixing the weighed samples and adding lime as much as 186.82 grams, the number of added lime was obtained from the lime test experiment that had been carried out previously. Mixing is done so that the ore and lime can be homogenized evenly, so that the lime can contact all samples.
- Inserting or loading the sample that has been mixed into the column, then installing the geotech above the sample and placing the marbles on the geotech.
- The on flow solution that has been prepared before will be calibrated with a flowrate of 5.9 ml/min for an application rate of 20 L/m^2/h and 2.9 ml/min for an application rate of 10 L/m^2/h, while for the combined application rate on the first 5 days of leaching will use a flowrate of 5.9 ml/min and for day 6 until the leaching process ends using a flowrate of 2.9 ml/min. The irrigation process is carried out for 24 hours.
- Weighing the volume of PLS and taking PLS samples as many as two bottles after 24 hours. The first bottle will be checked for pH, CN titration and AAS analysis to determine the content of gold and other metals. The second bottle will be archived.
- Repeating steps 4 and 5, until the net gold value is <0,02 ppm.
- Perform rinsing by flowing fresh water into the column.

c. Tailing Sampel Preparation

- Samples that have finished rinsing (spent ore), will then be removed from the column and will be dried for 6-8 hours using an oven.
- Samples that have been removed from the oven will be sized using a vibrating screen and manual screen to separate the +25 mm, -25 mm +12 mm, -12 mm +6 mm, and -6 mm size fractions.
- Samples with sizes +25 mm, -25 +12 mm, and -12 mm +6 mm will be crushed until the size becomes -6 mm in each size fraction.
- Each size fraction is taken as much as 500 grams in each colico, where each size fraction is taken as many as 5 sample bags. So that the total sample is 60 sample bags.
- Submitting spent ore samples to the laboratory for analysis of AuFA, AuCN, and other metals.

Result and Discussion

Results of Research

From the results of the experiments that have been carried out, an analysis of the metal content in the ore before the leaching process and after the leaching process (spent

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ore) is obtained. In addition, the results of the percent extraction of each application rate variation can be seen below.

a. Head Assay and Tailing Analysis Results

Head assay analysis is an analysis performed on ore before entering the process, to determine the metal content contained in the ore. The results of the head assay analysis can be seen in Table 1. From the results obtained, it is known that the Au grade contained in the ore is in accordance with the Au grade to be processed, namely in the low grade category (0.3 g/t - 0.5 g/t).

Apart from the head assay analysis, an analysis is also carried out on tailings or spent ore, to determine the remaining grade in the ore which will be used to obtain the back calculated grade value and used in the calculation of the percent extraction. The following tailings analysis results can be seen in Table 2.

Table 1. Head Assay Analysis Results

Variasi *Application Rate*	AuFA	AuCN	QLT	Ag	Cu	Fe	Pb	Zn
	g/t	g/t	%	g/t	g/t	%	g/t	g/t
10 $L/m^2/h$	0,49	0,42	88%	0,40	58,15	4,22	31,35	1,88
20 $L/m^2/h$	0,44	0,42	94%	0,23	57,35	4,56	30,60	2,45
20 & 10 $L/m^2/h$	0,48	0,43	89%	0,29	60,89	4,10	30,50	2,09

Source: obtained from primary data, (2024)

Table 2. Tailing Analysis Results

Variasi *Application Rate*	AuFA	AuCN	QLT	Ag	Cu	Fe	Pb	Zn
	g/t	g/t	%	g/t	g/t	%	g/t	g/t
10 $L/m^2/h$	0,12	0,05	44%	0,00	59,37	4,26	34,16	2,35
20 $L/m^2/h$	0,13	0,07	55%	0,17	63,31	4,86	37,78	2,70
20 & 10 $L/m^2/h$	0,12	0,06	51%	0,78	60,77	4,59	36,04	2,56

Source: obtained from primary data, (2024)

b. Percent Extraction of Gold and Other Metals

The calculation of percent extraction is based on two calculation formulas, namely head calculated and back calculated. Head calculated requires PLS volume data and PLS metal content and ore head assay data that has been submitted at the beginning to analyze the metal content contained therein. Meanwhile, if it is back calculated, it requires data on the volume and metal content in the BLS and the residual metal content contained in the tail.

Of the two calculations above, back calculated calculations are preferred, because they provide calculation results that are closer to the results in the field compared to head calculated calculations. For example, in the results of the Au calculation with

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head calculated where the percent extraction value is more than 100%, this is because the extracted Au is more than the results of the Au head assay test on the ore, so the calculation with head calculated is not representative. The results of the percent extraction by head calculated and back calculated can be seen in Table 3 and Table 4.

Tabel 3. Percent Extraction by head Calculated

Variation	%Ekstraksi Head Calculated						
Application Rate	AuFA	AuCN	Ag	Cu	Fe	Pb	Zn
10 *L//m²/h*	93%	107%	46%	3%	0%	0%	4%
20 *L/m²/h*	109%	116%	165%	8%	0%	0%	5%
20 & 10 *L/m²/h*	93%	106%	79%	3%	0%	0%	4%

Source: obtained from primary data, (2024)

Tabel 4. Percent Extraction by Back Calculated

Variation	%Ekstraksi Back Calculated						
Application Rate	AuFA	AuCN	Ag	Cu	Fe	Pb	Zn
10 *L//m²/h*	78%	89%	46%	3%	1%	-1%	0%
20 *L/m²/h*	79%	87%	8%	7%	2%	0%	3%
20 & 10 *L/m²/h*	79%	88%	8%	3%	1%	0%	2%

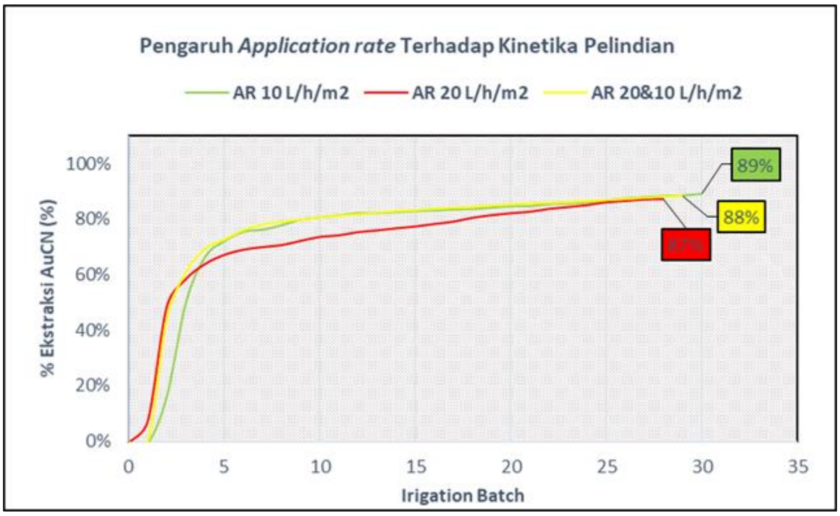
Source: obtained from primary data, (2024)

Discussion

From the results of the research that has been carried out, there are several things that will be discussed in this study including:

a. Effect of Application Rate on Leaching Kinetics

In this study, three application rate variations were carried out, namely 20 L/m2/h, 10 L/m2/h, and a combination of 20 & 10 L/m^2/h. Leaching kinetics talk about the rate of reaction that occurs in the process, where in Figure 2 below can be



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seen leaching kinetics in each application rate variation.

Figure 2. Graph of the Effect of Application Rate on Gold Leaching Kinetics
Source: obtained from primary data, (2024)

From Figure 2 it is known that in primary leaching, application rate 20 L/m^2/h and application rate combination of 20 & 10 L/m^2/h have faster leaching kinetics than application rate 10 L/m^2/h. This is because the application rate of 20 L/m^2/h and the combined application rate of 20 & 10 L/m2/h in primary leaching have more volume so that the opportunity to react between reagents and gold ore is greater, which causes an increase in the leaching rate. However, in the 4th and 5th irrigation batches of application rate 20 L/m^2/h there is an acceptable anomaly, where there is a decrease in leaching kinetics compared to the combined application rate of 20 & 10 L/m^2/h and application rate of 10 L/m^2/h. From the analysis that has been carried out, it is concluded that there are several causes of this decrease, namely solution on flow at an application rate of 20 L/m^2/h which is not in contact with the ore because the solution flows through the inside of the test column or the edge of the ore pile, but it can also be caused by channeling solution.

In theory for batch irrigation, a high application rate will be faster in getting the desired net gold limit value, because the volume of solution used is also increasing. So the batch irrigation time will be faster for higher application rates. From the results obtained, it is known that the application rate of 20 L/m^2/h has an irrigation batch of 28 batches, for the application rate combination of 20 & 10 L/m^2/h has an irrigation batch of 29 batches, and the application rate of 10 L/m^2/h has an irrigation batch of 30 batches. Although the results obtained are in accordance with the existing theory, the irrigation batch values cannot be approximated to the leach pad to obtain the leaching time in the field, because the cross-sectional area of the test column is far different from the leach pad area and the amount of ore/sample used is very different. However, to make an outline or rough approach, it can be done where when the leaching kinetics are faster and the irrigation batch is faster, the outline in the field will be faster too.

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b. Effect of Application Rate on Percent Gold Extraction

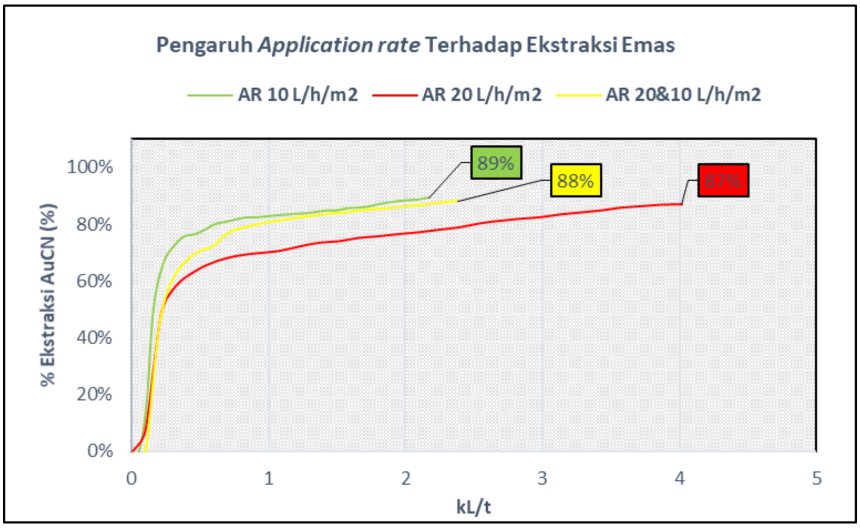

Figure 3. Graph of the Effect of Application Rate on Percent Gold Extraction
Source: obtained from primary data, (2024)

From Figure 3, it is known that the highest percent extraction of gold (AuCN) occurs at an application rate of 10 L/m^2/h of 89% or about 0.2081 mg/L of gold can be obtained in the leach solution, which is because the application rate of 10 L/m^2/h has a longer contact time than the application rate of 20 application rate 10 L/m^2/h and the application rate combination of 20 & 10 L/m^2/h. Thus, the contact between reagents and gold becomes more and longer. This is also validated by looking at the remaining gold in the tailings which can be seen in Table 2, where the application rate of 10 L/m^2/h has the least gold in the tailings. At a combination application rate of 20 & 10 L/m^2/h has a percent gold extraction (AuCN) of 88% or can be obtained around 0.1889 mg/L of gold in the leach solution, where although the primary leaching uses an application rate of 20 L/m^2/h, but in secondary leaching it uses an application rate of 10 L/m^2/h. So that the percent extraction value is not too much different from the application rate of 10 L/m^2/h, but even though the percent extraction is smaller than the application rate of 10 L/m^2/h, the batch irrigation time is faster, so it can increase the process rate on the leach pad.

While the application rate of 20 L/m^2/h obtained an extraction value of 87% or can be obtained around 0.1204 mg/L gold, which is the smallest percent extraction value of the three application rate variations, this is because the application rate of 20 L/m^2/h has a large volume of solution so that the reagent contact with the ore runs faster or only briefly, validated by the Au in the tailings in the application rate variation of 20 L/m^2/h which is more at 0.07 ppm.

In terms of irrigation batch application rate 20 L/m^2/h is the fastest with a total irrigation batch of 28 bacth. The results obtained are in accordance with the existing theory. There is an anomaly in the level of Au on flow used, where the level of Au on

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flow is fairly high (which is 0.180 ppm). However, this does not really affect the results that have been obtained, because it is still in accordance with existing theory. Even if there is an influence, it will affect the direction of batch irrigation, because an increase in the level of Au on flow will cause an increase in net gold, so that batch irrigation should be completed faster. In addition, it can cause bias in the results of gold extraction values.

c. Effect of Application Rate on Cyanide Consumption

From the data that has been processed, it is obtained that the highest cyanide consumption is at an application rate of 20 L/m^2/h of 0.13 kg/t, then a combination application rate of 20 & 10 L/m^2/h with a cyanide consumption of 0.081 kg/t, and finally an application rate of 10 L/m^2/h with a cyanide consumption of 0.065 kg/t.

From the acquisition of cyanide consumption, it is in accordance with the existing theory, where the greater the application rate used, the higher the cyanide consumption and vice versa. This is because the volume is increasing in the higher application rate variation, so the cyanide consumption is increasing. The cyanide consumption graph can be seen in Figure 4 below.

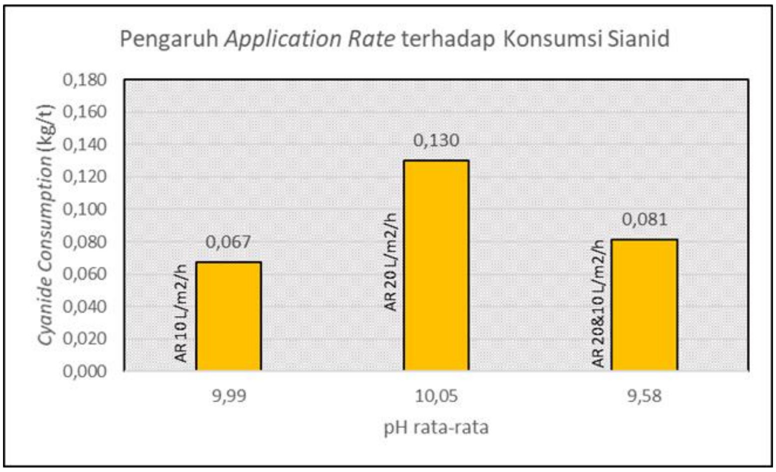

Figure 4. Graph of the Effect of Application Rate on Cyanide Consumption
Source: Obtained from Primary Data (2024)

d. The Best Application Rate That Can Be Used

In terms of leaching kinetics, cyanide consumption, and percent extraction, it can be concluded that the most optimal application rate variation to be used in static heap leach is a combination application rate variation of 20 & 10 L/m^2/h because with a percent extraction value that is not much different from the application rate of 10 L/m^2/h which is only 1% different, a faster leaching process can be carried out so that production can be increased. In addition to the three things above, using a combination application rate of 20 & 10 L/m^2/h, can reduce the solution used compared to the

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application rate of 20 L/m^2/h so as to minimize the decrease in the mechanical strength of the material in holding the pile which can cause landslides to occur in the cell. In terms of batch irrigation, the combined application rate of 20 & 10 L/m^2/h is also faster than the application rate of 10 L/m^2/h, so that the leaching time is faster.

Conclusion

Based on the data, results and discussion that have been obtained, the conclusions of this study are as follows:

1. Application rate of 20 L/m^2/h and application rate combination of 20 & 10 L/m^2/h have faster primary leaching kinetics compared to application rate of 10 L/m^2/h. For irrigation batch application rate 20 L/m^2/h has the fastest irrigation batch for 28 batches, then application rate 20 & 10 L/m^2/h combination for 29 batches, and application rate 10 L/m^2/h for 30 batches.
2. Application rate of 10 L/m^2/h has the highest percent gold extraction of 89% or 0.2081 mg/L gold. Meanwhile, the application rate combination of 20 & 10 L/m^2/h has a percent extraction value of 88% or 0.1889 mg/L gold. And for application rate 20 L/m^2/h has a percent extraction value of 87% or 0.1204 mg/L gold.
3. Application rate 20 has the highest cyanide consumption compared to other application rates of 0.13 kg/t. Meanwhile, the application rate combination of 20&10 L/m^2/h has a cyanide consumption of 0.081 kg/ton, and the lowest at application rate 10 L/m^2/h of 0.065 kg/t.
4. It can be concluded that the best application rate is the application rate combination of 20 & 10 L/m^2/h.

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