Study of The Effect of Temperature On The Desorption Efficiency of Precious Metals In The Elution Process Using Anglo American Research Laboratories (AARL) Method

Frideni Yushandiana Putri[a*], Mei Iftita Mawarda'[a], Sulaeman[b], Riria Zendy Mirahati[a], Shofa Rijalul Haq[c]

[a]*Program Studi Teknik Metalurgi, Fakultas Teknologi Mineral, UPN Veteran Yogyakarta, Yogyakarta, Indonesia 55283*
[b]*PT Indo Muro Kencana, Camp-Muro Site, Dirung, Dirung Lingkin, Tanah Siang Sel., Kabupaten Murung Raya, Kalimantan Tengah, Indonesia 73971*
[c]*Mining Engineering Division, Universitas Pembangunan Nasional Veteran Yogyakarta, Yogyakarta, Indonesia 55283*

[*]Corresponding author: frideni_gf@yahoo.com

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ABSTRACT. The elution process, known as the desorption of gold from carbon into solution, uses high temperature and pressure. Activated carbon is used as an adsorbent in the precious metal adsorption process. PT Indo Muro Kencana uses the Anglo American Research Laboratories (AARL) method to desorb valuable metals from the activated carbon of the Carbon In Pulp (CIP) process. The elution process of this research involves 9 stages: Pre-heat, Pre-soak 1, Pre-soak Circulation, Lean 1, Presoak 2, Lean 2, Water Elution 1, Water Elution 2, and Cooling. This study found that copper (Cu) metal desorbed from carbon first, followed by silver (Ag) metal, with the desorption of gold (Au) metal occurring last due to the influence of the stability value of metal cyanide complexes. High cyanide concentrations (~ 10% CN^-) were given in Pre-soak 1, Pre-soak Circulation, and Pre-soak 2. The elution process is significantly affected by high process temperatures, particularly 123°C in the Lean 2 stage, which effectively desorbs gold (Au) at its optimal point. The solution product that only contains copper from the initial 60 minutes of the Pre-heat and Pre-soak 1 processes was transferred to the tailings tank to improve the efficiency of the refining process. The total recoveries for gold (Au), silver (Ag), and copper (Cu) were 93.1%, 95%, and 94.7%, respectively.

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1. INTRODUCTION

In gold processing, elution is the process of releasing precious metals from carbon particles. Water with low ion strength is pumped into the elution column at high temperature and pressure[1]. This causes the precious metals in the activated carbon to desorb into a solution with a smaller volume and higher concentration of valuable metals.[2]. The solution containing valuable metals is then processed using electrowinning and smelting to produce dore bullion.

Activated carbon, as the adsorbent in the precious metal adsorption process, holds immense potential. Its high adsorption capacity for gases and chemical compounds, driven by the numerous pores on its surface, is a promising feature [3]. The relationship between the surface area of carbon and its pore structure, with smaller pores leading to a larger surface area and increased adsorption rates for valuable metals, further underscores its potential [4].

Activated carbon is commonly available in granular and powdered forms. The fine powder particles measure 5-10 µm, while the granules range from 0.8-1.2 mm in size. Activated carbon is further classified by pore size, including micropores (<2 nm), mesopores (2 nm – 50 nm), and macropores (>50 nm). Additionally, there are supermicropores (0.7-2 nm) and ultramicropores (<0.7 nm) [4].

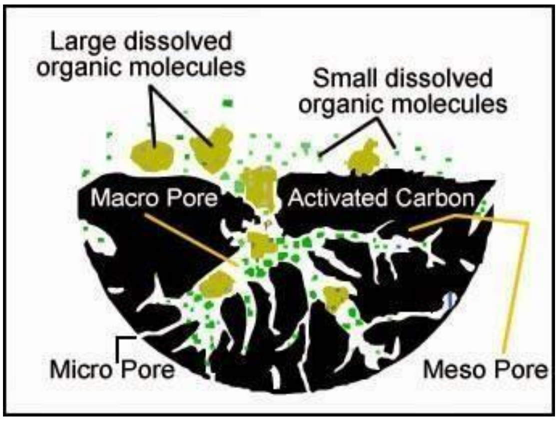

Figure 1. Activated Carbon Pore Structure Scheme [4]

The carbon-containing precious metals from the leaching circuit is eluted using a caustic cyanide solution in an elution column at a temperature higher than 90°C. [5]. According to Adams and Nicol (1986), the current elution process has three methods: the Zadra method, the Anglo American Research Laboratories (AARL) method, and the organic solvent method, which combines both. The Zadra method involves circulating the cyanide solution into the elution column and the electrowinning cells simultaneously. In contrast, the Anglo American Research Laboratories (AARL) method includes a pre-treatment step with hot cyanide solution and elution using hot deionized water. In the AARL method, 2-3 elution cycles can be performed per day in one column. The organic solvent method, a versatile approach that combines the Zadra and AARL methods, uses many organic solvents such as methanol, ethanol, acetone, or acetonitrile, opening up a wide range of potential applications. [5]. The elution rate for the AARL method is significantly faster than the Zadra method, requiring only 6 to 7 hours for the elution process [6]. At PT Indo Muro Kencana (IMK), the elution process uses the Anglo-American Research Laboratories (AARL) system. In this system, the pregnant solution is first collected in a tank before being processed in the electrowinning stage. The desorption of gold from carbon in the elution process can be expressed with equilibrium equations (1) and (2).

$$Ca[C\text{-}(Au(CN)_2]_{2(s)} \rightarrow 2Au(CN)_2^- + Ca^+_{(s)} + 2C_{(s)} \tag{1}$$

$$Ca[C\text{-}(Ag(CN)_2]_{2(s)} \rightarrow 2Ag(CN)_2^- + Ca^+_{(s)} + 2C_{(s)} \tag{2}$$

Temperature is a critical factor in the elution process. The loading capacity of precious metals on carbon decreases as the temperature increases [1]. High temperatures (between 90°C and 130°C) and high pressures (between 200 and 300 kPa) are necessary for effectively eluting precious metals using a cyanide solution [7]. At 180°C and atmospheric pressure, the elution rate is eight times faster than at 90°C [8]. The solubility of Au(CN)2- is 14 times higher in hot water than in cold water for the elution process [9].

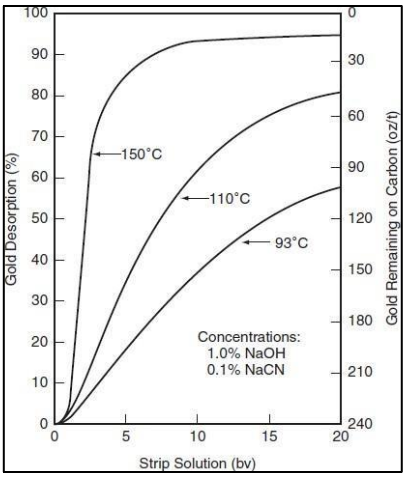

Figure 2. Effect of Temperature on Gold Desorption [8]

The picture above shows that using a 1% NaOH concentration and 0.1% NaCN, the amount of gold on the carbon decreases as the temperature increases. This is because increasing temperature can optimize the elution process, which removes a substance from an adsorbent by washing it with a solvent [6]. Furthermore, temperature also influences the adsorption of gold onto carbon, as the reaction is exothermic, leading to desorption as the temperature rises. Consequently, the loading capacity decreases as the temperature increases [9]. Thus, the graph shows that gold desorption increases at higher temperatures. In addition, the contact time between the solution and carbon is crucial because a longer contact time between carbon and the solution enhances the desorption of valuable metals on the carbon.

In the elution process, it's also essential to maintain the cyanide concentration. Enhancing the cyanide concentration intensifies the competition between cyanide ions and Au(CN)2-, leading to a shift of the aurocyanide complex from carbon to a higher concentration [8]. This displacement allows free cyanide to take the place of $Au(CN)_{2-}$ on the carbon. Moreover, pH influences the stability of the complex bound to the adsorbent during elution. An increase in H_3O^+ ions causes the equilibrium to shift to the right, forming more HCN [10]. Furthermore, the flow rate of the solution used in elution, expressed in terms of the volume of the carbon layer per hour (bv/hr), impacts the amount of gold charged on the carbon, decreasing with an increase in flow rate [8].

2. MATERIAL AND METHODS

The described process entails the use of activated carbon derived specifically from coconut shells to desorb valuable metals, such as gold, from the carbon matrix. The research involves the acquisition of samples from various sources, including solid materials, the solution phase, and the activated carbon itself. These samples are subjected to thorough analysis using an Atomic Absorption Spectrophotometer (AAS) to precisely determine the concentrations of metal elements present, with a particular focus on gold, silver, and copper. This detailed approach allows for a comprehensive understanding of the chemical composition and metal content within the samples.

The research equipment includes an elution column, reagent tank, heat exchanger, pH meter, burette, glass beaker, and sample bottles. The materials used in this research include activated carbon-containing valuable metals from the adsorption process, water, NaOH (sodium hydroxide), and NaCN (sodium cyanide).

The process of desorbing valuable metals begins by loading the carbon into the elution column. The loaded carbon is washed with water to remove any remaining impurities in the leaching circuit. Before entering the elution column, the water is heated using a heat exchanger. Once the water reaches 100°C, it is pumped into the elution column for a 30-minute pre-heating phase. During this phase, samples are taken from the upper valve of the elution column, with 4 sample bottles collected at 10-minute intervals. The output from this process is discarded as tailings.

Then, prepare a solution by mixing 25% NaOH, 5% NaCN, and the rest with water in the pre-soak tank until it reaches 60% capacity (volume). Then, pump 30% of the solution into the heat exchanger to heat it to 103°C before feeding it into the elution column. Next, introduce the heated solution into the elution column for a 30-minute pre-soak process. During this stage, collect 3 sample bottles from the upper valve of the elution column at 10-minute intervals. Finally, discard the output from this stage as tailings.

The remaining pre-soak solution in the pre-soak tank is pumped into the heat exchanger, heated to around 106°C, and then circulated into the elution column. This is done to evenly distribute the pre-soak solution with carbon, weakening the bond between gold and carbon so that gold can be recovered as a solution. This stage, known as pre-soak circulation, lasts for 20 minutes. Samples are taken simultaneously at the inlet and outlet of the heat exchanger, totalling 4 sample bottles (2 from the inlet and 2 from the outlet) at 10-minute intervals. The output from this stage is directed to the pregnant tank for further electrowinning processes.

The next stage is Lean 1, where the solution used comes from water elution two and cooling in the previous batch. This solution is collected in the lean tank, pumped into the heat exchanger, heated to 107°C, and then introduced into the elution column for 30 minutes. Sample collection at this stage is done simultaneously at the inlet and outlet of the heat exchanger, with a total of 6 sample bottles (3 from the inlet and 3 from the outlet) collected at 10-minute intervals. The output from this stage is directed to the pregnant tank.

After that is the pre-soak 2 stage, the solution from the pre-soak tank is pumped into the heat exchanger where it is heated to 108° C, and then introduced into the elution column. This stage lasts for 15 minutes, and sample collection is carried out simultaneously at the inlet and outlet of the heat exchanger. Four sample bottles (2 from the inlet and 2 from the outlet) are collected at 10-minute intervals. The output from this stage is directed to the pregnant tank.

Following the pre-soak 2 stage is Lean 2. In this stage, the solution from water elution 2 and cooling in the previous batch is reused. The lean solution is pumped into the heat exchanger, heated to 115°C, and then introduced into the elution column for 90 minutes. During this stage, samples are collected simultaneously at the inlet and outlet of the heat exchanger. A total of 18 sample bottles (9 from the inlet and 9 from the outlet) are collected at 10-minute intervals. The output from this stage is directed to the pregnant tank.

The next step is water elution 1. In this stage, water is pumped into the heat exchanger and heated to 115°C. It is then introduced into the elution column for 25 minutes. Sample collection takes place at the outlet of the heat exchanger, with 3 sample bottles collected at 10-minute intervals. The output from this stage is directed to the pregnant tank. After that, water elution 2 is carried out, similar to water elution 1. Water is pumped into the heat exchanger, heated to 117°C, and then introduced into the elution column for 65 minutes. Sample collection is done at the outlet of the heat exchanger, with 7 sample bottles collected at 10-minute intervals. The output from this stage is directed to the lean tank for the next batch process.

The final stage of the elution process involves cooling, where room-temperature water is pumped into the elution column for 40 minutes. Sample collection is done at the outlet of the heat exchanger, with 4 sample bottles collected at 10-minute intervals. The output from this stage is directed to the lean tank for the next batch process. Samples collected at each stage are checked for pH and then titrated using a rhodanine indicator.

3. RESULT AND DISCUSSION

The desorption process of valuable metals from carbon is carried out in 9 stages: Pre-heat, Pre-soak 1, Pre-soak Circulation, Lean 1, Pre-soak 2, Lean 2, Water Elution 1, Water Elution 2, and Cooling. This experiment takes 6 hours, and samples were taken at intervals of 5 to 10 minutes for each stage. Concentrations of metal elements, specifically gold, silver, and copper, were measured using an Atomic Absorption Spectrophotometer (AAS) and can be found in Table 1.

Table 1. Metal Concentrations Analyzed By AAS

No	Sequence	Step Duration (mins)	Au Soln ppm	Ag Soln ppm	Cu Soln ppm
1	Preheat	30	0.00	0.00	0.00
	Preheat		0.01	0.25	0.01
	Preheat		0.01	0.19	0.01
	Preheat		0.03	1.94	2.94
2	Presoak 1	30	0.03	5.06	11.76
	Presoak 1		0.06	9.67	14.05
	Presoak 1		0.06	12.09	15.47
3	Presoak circulation	20	0.11	14.63	16.14
	Presoak circulation		0.13	22.01	17.56
	Presoak circulation		0.20	33.64	22.95
	Presoak circulation		0.85	38.28	26.46
4	Lean 1	30	1.13	141.64	51.72
	Lean 1		1.96	363.04	53.62
	Lean 1		4.26	697.40	41.47
5	Presoak 2	18	5.75	978.80	35.37
	Presoak 2		8.659	1181.6	27.06
	Presoak 2		10.806	1305.6	21.69
	Presoak 2		12.252	1367.6	18.73
6	Lean 2	95	12.481	1337.6	16.83
	Lean 2		12.352	1258.8	12.08
	Lean 2		11.572	1107.6	9.56
	Lean 2		13.466	987.6	5.84

	Lean 2		20.127	841.6	3.42
	Lean 2		27.485	752.36	1.77
	Lean 2		34.101	586.72	0.77
	Lean 2		36.518	459.28	0.7
	Lean 2		39.525	357.68	0.43
	Lean 2		37.906	263.8	0.24
	Lean 2		37.82	216.56	0.18
7	Water Elution 1	20	35.644	167.56	0.11
	Water Elution 1		32.242	121.72	0.01
8	Water Elution 2	65	29.568	92.92	0.01
	Water Elution 2		22.969	74.4	0.01
	Water Elution 2		18.33	28.82	0.01
	Water Elution 2		18.208	26.2	0.01
	Water Elution 2		14.676	18.95	0.01
	Water Elution 2		12.036	15.75	0.01
	Water Elution 2		12.375	15.34	0.01
9	Cooling	30	9.226	12.19	0.01
	Cooling		7.495	10.02	0.01
	Cooling		6.105	8.96	0.01
	Cooling		3.483	4.95	0.01
	Final	7	2.376	3.26	1.48
	Total Elution Time	**345**			

In this desorption process, the temperature is the parameter that is controlled. It gradually increases in each stage and then decreases once the valuable metals have been fully desorbed from the carbon. According to the elution profile data, the process temperature increases in each stage but decreases during the Water Elution 1 to the cooling stages.

During the Water Elution 1 and Water Elution 2 stages, the temperature remained relatively high because there was still a significant amount of gold (Au) to be extracted from the carbon. However, in the Cooling stage, there is a noticeable decrease in temperature. This decrease occurs because, by this stage, the valuable metals in the carbon have already been completely desorbed into the solution. Therefore, Cooling stage is necessary to ensure that the regenerated carbon is not at a high temperature. It's important to avoid transferring carbon at high temperatures, as this could lead to high pressure inside the column and potentially damage the equipment.

In the process of desorbing valuable metals, higher temperatures are necessary to extract the metals from the carbon into the solution. It was observed that the Lean 2 process reached the highest temperature, ranging from 115 to 123°C, indicating the optimal desorption of gold during this stage. Consequently, extra time is allocated to the Lean 2 stage to ensure significant desorption of gold into the solution. The elution process parameters at each stage are illustrated in Figure 3.

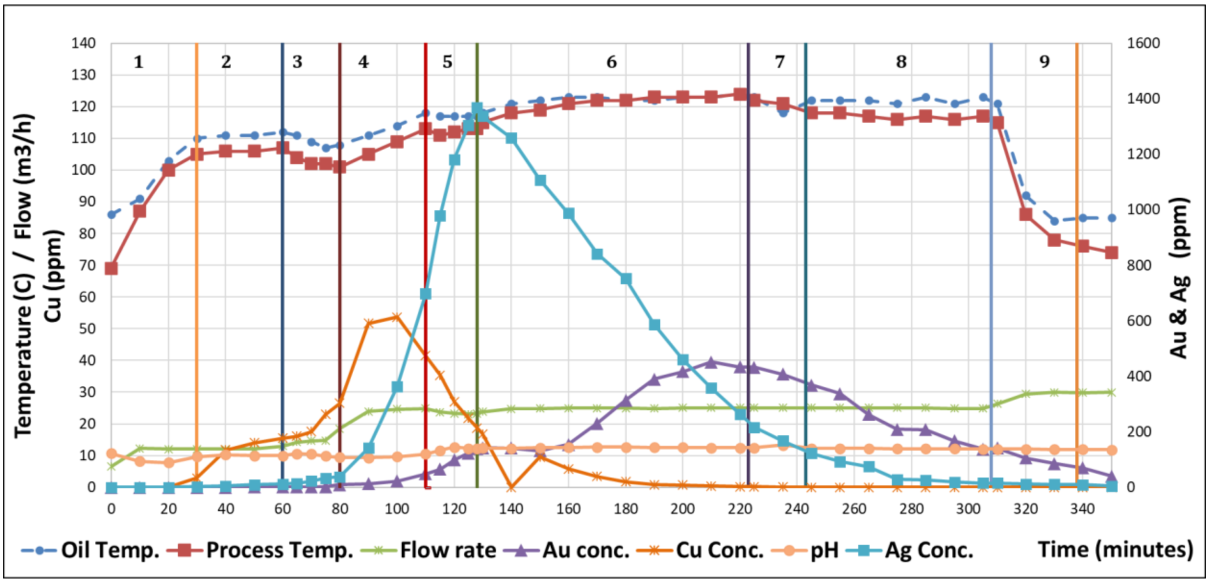

Figure 3. Elution Process Parameters

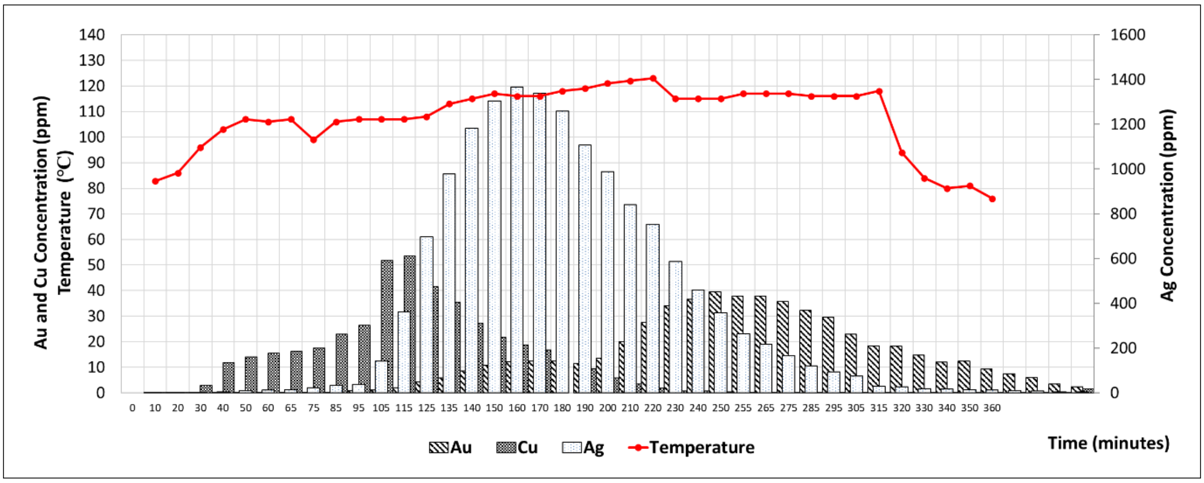

Figure 4. Precious Metal Concentration and Process Temperature

Figure 4 illustrates that the initial valuable metal desorbed from the carbon into the solution is copper (Cu). Copper's significant desorption begins during the Pre-soak 1 stage and reaches its peak during the Lean 1 stage, after which it gradually declines. The solution containing only copper from Pre-heat and Pre-soak 1 was fed to the tailings tank. This step was taken to reduce the copper concentration in the electrowinning process feed so that the efficiency of the electrowinning process would be better. Meanwhile, silver (Ag) desorption increases during the Lean 1 stage, peaks during the Pre-soak 2 stage, and then decreases. In contrast, gold (Au) desorption rises during the Pre-soak 2 stage, reaches its peak during the Lean 2 stage, and then starts to decrease. The research found that the highest concentration of gold is found in the Lean 2 stage at 87.25 ppm at a temperature of 123°C. The highest concentration of silver is obtained in the Pre-soak 2 stage at 1531.20 ppm with a temperature of 113°C, while the Lean 1 stage yields the highest concentration of copper at 24.41 ppm with a temperature of 107°C.

The desorption of Ag takes place as the copper content in the carbon diminishes, and likewise, the release of Au occurs as the silver content in the carbon reduces. This process is influenced by the stability of metal cyanide complexes [8], as a lower stability value for a metal complex facilitates the detachment of the metal from the carbon.

The cyanide concentration in the inlet and outlet of the elution process is shown in Figure 5. High cyanide concentrations were given olly in Pre-soak 1, Pre-soak Circulation, and Pre-soak 2. The other processes such as Pre-heating, Water Elution 1&2, and Cooling were using raw water. For the lean 1&2 stage, use a recycled solution from Water Elution 1&2 from the preview batch.

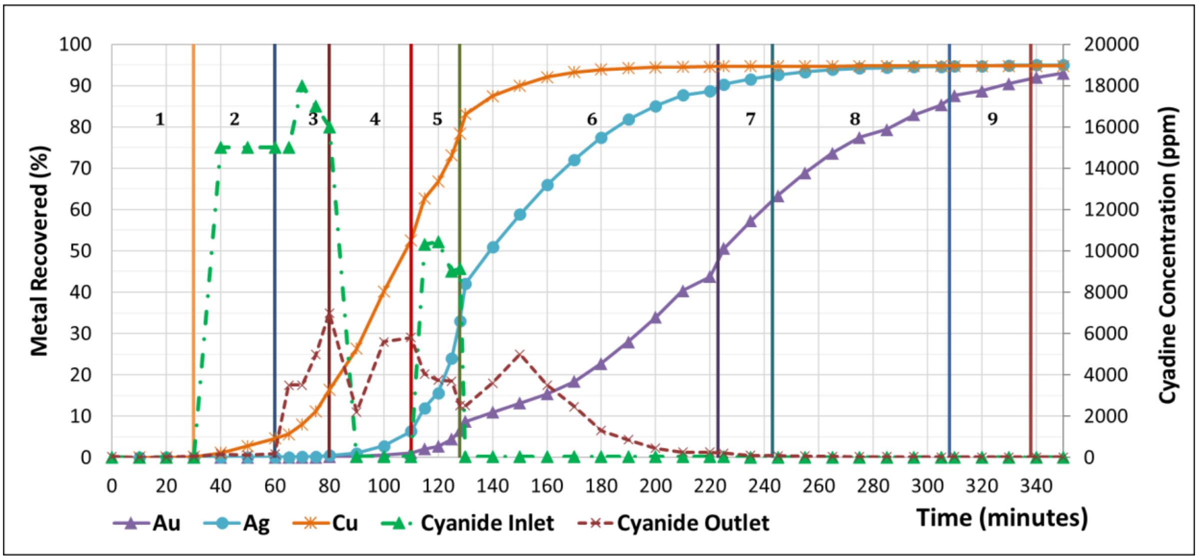

Figure 5. Cyanide Concentration and Cumulative Metal Recovered

The initial recovery of Cu (copper) appears to be higher compared to Ag (silver) and Au (gold). However, at minute 220, it becomes evident that the recovery of Ag starts to surpass that of Cu, and it continues to dominate until the final minute. The increase in the recovery of Au begins at minute 120, subsequently surpassing the recovery of Cu at minute 320. However, the recovery of Au does not surpass the recovery of Ag until the final minute. This is because the ore conditions at PT Indo Muro Kencana contain a higher amount of Ag than Au. The total recoveries for gold (Au), silver (Ag), and copper (Cu) were 93.1%, 95%, and 94.7%, respectively. After the Cooling stage (the last stage), the final metal concentrations were 2.38 ppm for Au, 3.26 ppm for Ag, and 1.48 ppm for Cu. This solution is flowed to the Lean tank to be used again for the next elution process.

4. CONCLUSION

Based on the results and discussions above, the following conclusions can be drawn from the sampling at each time interval and stage:

1. At high temperatures, valuable metals are easily desorbed from carbon into the solution. Therefore, as the temperature increases, the desorption of valuable metals also increases.
2. Based on the conducted research, desorption in the elution process is influenced by high process temperatures, specifically 123°C in the Lean 2 stage, which is capable of desorbing Au (gold) at its optimum point.
3. Based on the stability values, Cu (copper) desorbs first, followed by Ag (silver), and Au (gold) desorbs last.
4. Increasing the contact time between carbon and the solution at each stage will enhance the desorption of metals from the carbon.
5. High cyanide concentrations were given olly in Pre-soak 1, Pre-soak Circulation, and Pre-soak 2.
6. The solution that only contains copper from the initial 60 minutes of the Pre-heat and Pre-soak 1 processes was transferred to the tailings tank to improve the efficiency of the refining process.
7. The total recoveries for gold (Au), silver (Ag), and copper (Cu) were 93.1%, 95%, and 94.7%, respectively.

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