

EVALUATION OF SOME LEACHING REAGENTS FOR COPPER EXTRACTION FROM A GOLD COMPLEX ORE

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Resumen

Algunas menas complejas de oro presentan altos contenidos de cobre y esto inhibe el uso del proceso hidrometalúrgico clásico de cianuración para recuperar el oro debido al alto consumo de cianuro. Este artículo presenta los resultados experimentales para la extracción de cobre desde una mena compleja de oro-cobre procedente de Brasil, usando diferentes reactivos lixiviantes, así también como un pretratamiento para una mayor extracción de oro por cianuración. Algunos experimentos se realizaron usando H_2SO_4 , $Fe_2(SO_4)_3$, H_2O_2 , HCl , $HClO_4$ y NH_4OH . El mayor porcentaje de cobre extraído (50%) se obtuvo con una solución de ácido sulfúrico a 82 ± 2 °C y 15 minutos de lixiviación. Con una solución acuosa de ácido sulfúrico y peróxido de hidrógeno a 25 ± 2 °C con 15 minutos de lixiviación, también se obtuvo un 50 % de cobre extraído. Sin embargo, estos resultados están muy bajos respecto del valor mínimo considerado como económicamente factible (95%), para la etapa de recuperación de oro por cianuración.

Palabras claves: cobre, oro, lixiviación.

Abstract

Some gold complex ores present high copper content and it inhibits the direct use of classical hydrometallurgical cyanidation process for gold recovery due to the high cyanide consumption. This paper presents the experimental results for copper extraction from a Brazilian gold-copper complex ore using different leaching reagents as an ore pre-treatment for further gold extraction by cyanidation. Some experiments were carried out using H_2SO_4 , $Fe_2(SO_4)_3$, H_2O_2 , HCl , $HClO_4$ and NH_4OH . The highest percent of copper extracted (50%) was obtained for a sulfuric acid solution at $82 \pm 2^\circ C$ for 15 minutes leaching. A sulfuric acid and hydrogen peroxide aqueous solution at $25 \pm 2^\circ C$ for 15 minutes leaching also obtained 50% of copper extracted. However, these results were much lower than the minimum value considered economic feasible (95%) for the cyanidation stage to recover gold.

Keywords: copper, gold, leaching.

1. Introduction

Hydrometallurgical treatment for gold ores is based on the property differences between gold and its gangues. A high density, the solubility of this metal in dilute cyanide alkaline solutions, the formation of mercury amalgams capacity and its susceptibility to the flotation process have constituted the basis of the simplest and more common process routes.

Large reserves of gold-copper complex ore have been found and increasing the volume of researches projects related to the ore treatment for gold extraction. The high value associated to this metal, the generation of environmental problems and the perspective of economical feasibility justify the development of new technical solutions for a process route selection, which could maximize metals recovery with lower costs.

The technical literature indicates that acid leaching for copper extraction followed by cyanidation of the leach tailing is one of the most promising process alternatives for gold-copper complex ore treatment[1-6].

This paper presents the experimental results of a hydrometallurgical route for the treatment of the gold-copper ore from Igarapé Bahia mine (Pará-Brazil) aiming at the maximum copper extraction for the next stage of cyanidation for gold recovery.

2. Experimental Procedure

A mineral sample of Igarapé Bahia oxidized ore supplied by Companhia Vale do Rio Doce (CVRD-Brazil) was used at leaching experiments. The sample was submitted to chemical analysis by Atomic Absorption Spectrofotometry (Perkin Elmer model AAnalyst-300) to determine the copper concentration. Leach liquor samples and leach tailings after each experiment were also analyzed to determine the copper concentration.

Copper leaching experiments were conducted in a 300 mL long neck cylindrical glass flask reactor. A glass impeller with three circular blades, driven by a mechanical device with speed control was used to stir the leach pulp. The temperature of the leach solution was kept constant using a heating plate with

automatic control. A mercury thermometer was used to measure the temperature. The leaching time was measured by a manual chronometer.

3. Leaching Experiments

Leaching experiments using the Igarapé Bahia oxidized ore were carried out using different leaching reagents to determine the percentage of copper extracted. The ore sample had 0.55% Cu and 3.54 g/t Au.

The optimum experimental conditions used in the first test [A] are shown in Table 1. These conditions were based on MENDES (1999) work, which evaluated a hydrometallurgical route for the pre-treatment of the gold-copper transition ore of Igarapé Bahia mine (1.93% Cu and 1.76 g/t Au) using an open vessel sulfuric acid leaching.

Other experiments evaluated each parameter of greater influence in the sulfuric acid leaching and were carried out ranging between two experimental levels. In these tests [B], the goal was to verify if the conditions used in the first experiment based on MENDES (1999) work for the transition ore could also be used for maximum copper extraction for the oxidized ore.

Tests were carried out using the conditions for experiment [A] adding several concentration of different leaching agents. Table 2 shows the reagents and their concentration used in each test. Some tests were performed at room temperature (25°C) because the manipulation of strong oxidant substances under high temperatures, for instance H_2O_2 , is not recommended by security reasons.

Stoichiometric concentration for each test was determined assuming that all copper in the ore sample was chalcopyrite ($CuFeS_2$). This assumption was taken because $CuFeS_2$ is very resistant specie to the oxidation caused by inorganic acid reagents typically used in leaching experiments. So, enough amounts of leach reagent for the oxidation of all copper species would be guaranteed.

4. Results and Discussion

Table 3 shows the experimental results obtained for percentage of copper extraction using different leaching reagents and the respective experimental conditions adopted.

The experimental results show that test [A] using the optimum leach conditions determined by MENDES (1999), which reached 50% of copper extracted, and test [E] using a mixing solution of sulfuric acid and hydrogen peroxide, which reached 49% of copper extraction, were the tests that exhibited the maximum percentage of copper extraction.

Comparing the results for tests [A] and [B] in which leaching parameters were modified, it can be observed that the percent of copper extracted was close to 50%. This value shows that the optimum leach conditions determined by MENDES (1999) for the Igarapé Bahia transition ore can also be used to obtain the maximum copper extraction for the oxidized ore.

The analysis of the results for tests using sulfuric acid and ferric sulfate solution revealed that percent of copper extraction were lower than the ones obtained for the sulfuric acid leaching test [A], under the same experimental conditions without ferric sulfate. Besides that, the increase of 2% in the copper extraction obtained when ferric sulfate concentration was doubled (results [C1] and [C2]) does not justify the use of large amounts of this reagent.

Leaching tests using hydrogen peroxide as a leaching reagent [D] resulted in 1.4% of copper extracted. Low extraction values were expected because almost all the hydrogen peroxide in solution decomposed when it contacted the ore during the test.

Tests [E] using sulfuric acid and hydrogen peroxide solution resulted in 49% of copper extracted. When it is compared to the result for test [B1] (25% of copper extracted), it can be noticed a large increase for copper extraction by adding hydrogen peroxide to the sulfuric acid solution. Differently from experiments [D], only a small part of the H_2O_2 decomposed when it contacted the ore, probably because the acidic solution decreased its decomposition as depicted by DIMITRYEVIC et al. (1996).

The copper extraction values obtained for test [F] using sulfuric acid, hydrogen peroxide

and ferric sulfate solution resulted in just 29% of copper extracted and it was considered low. These results were expected because a large amount of hydrogen peroxide in solution decomposed even before it contacted the ore. It occurred due to the ferric ions presence in solution, which acted as catalyst for the decomposition of the hydrogen peroxide (DIMITRYEVIC et al., 1996).

Results obtained for percentage of copper extraction in experiments [G] using HCl resulted in 32% of copper extracted.

They were lower than the results for test [A] (50% of copper extracted) using the experimental conditions determined by MENDES (1999). However, when comparing this extraction value with the result for test [B1] (25% of copper extraction) obtained by the H_2SO_4 leaching at room temperature (25°C), it can be noticed that the HCl was more efficient to solubilize copper species than the sulfuric acid reagent under the same experimental conditions.

In the experiments using the perchloric acid as the leaching reagent [H] the percentages of copper extracted were around 22%. This value was lower than the results for test [A] (50% of copper extracted), for tests [B1] using sulfuric acid under room temperature (25% of copper extracted) and at test [G] using chloridric acid (32% of copper extracted). Therefore, it can be concluded that the perchloric acid was less efficient for copper extraction by leaching than the other reagents used in this work.

Tests [I] resulted in 43% of copper extracted using perchloric acid and hydrogen peroxide solution. Besides, this result showed a lower percentage of copper extraction than the one obtained for test [A] (50% of copper extraction). It can be observed a large increment in percentage of copper extraction by the addition of hydrogen peroxide when compared with the test [H] using only perchloric acid solution (22% of copper extracted).

The results obtained for the experiments [J] using copper oxide II, ammonium hydroxide and ammonium carbonate solution were close to 28% of copper extracted and considered low. These tests were carried out to compare the copper extraction values obtained in acid solutions (tests A, B, C, E, F, G, H and I) and in a basic solution.

5. Conclusions

The main conclusions obtained from the experimental results were:

Tests using sulfuric acid at $82 \pm 2^\circ\text{C}$ and combining sulfuric acid and hydrogen peroxide solution at room temperature (25°C) for 15 minutes leaching reached the best results for copper extraction (50%).

The optimum experimental conditions determined by MENDES (1999) for the Igarapé Bahia transition ore were also optimum for the oxidized ore, which reached the maximum copper extraction.

Addition of hydrogen peroxide to leach solutions generated a large increase in the percentage of copper extraction at room temperature. The percentage of copper extracted jumped from 25% to 49% and from 22% to 43% in the sulfuric acid solutions and in the perchloric acid solutions tests, respectively.

The experimental results obtained in this work can be considered representative for copper extraction by leaching. However, it has not been reached the minimum percentage of copper extraction necessary to be economically feasible (95%) for the next stage of cyanidation for gold recovery. An alternative to improve the experimental results of this work would be a previous oxidation of the sample using a pyrometallurgical treatment. However, pyrometallurgical treatments of sulfides would require intensive energy consumption and it is not attractive from an economical point of view.

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to enumerate the references and to mention them appropriately in the text

Is it possible to make a comparative drawing of the main obtained results?

variables	values used
Temperature*	82°C
Particle size	60% < 0.074 mm (200 Mesh)
Stirring intensity*	270 rpm
Solid percentage in the pulp*	40%
Sulfuric acid concentration*	98.5 kg/t
Leaching time*	15 min

Table 1: Experimental conditions used in the sulfuric acid leaching tests [A]. (*) MENDES, 1999.

test	Leaching Agents
C	H ₂ SO ₄ (98.5 kg/t) and Fe ₂ (SO ₄) ₃ (once and twice stoichiometric concentration (C1 e C2))
D	H ₂ O ₂ (25% of the stoichiometric concentration)
E	H ₂ SO ₄ (98.5 kg/t) and H ₂ O ₂ (25% of the stoichiometric concentration)
F	H ₂ SO ₄ (98.5 kg/t) and H ₂ O ₂ (25% of the stoichiometric concentration) and Fe ₂ (SO ₄) ₃ (stoichiometric concentration)
G	HCl (98.5 kg/t)
H	HClO ₄ (98.5 kg/t)
I	HClO ₄ (98.5 kg/t) and H ₂ O ₂ (25% of the stoichiometric concentration)
J	CuO, NH ₄ OH and (NH ₄) ₂ CO ₃ stoichiometric concentration

Table 2: Leaching reagents and their concentration used in the acidic leaching tests

Experiment	Leaching Agent (kg/t)	Temperature (°C)	Time (min)	Copper extraction (%)
A	H ₂ SO ₄ (98.5)	82	15	50
B1	H ₂ SO ₄ (98.5)	25	15	25
B1a	H ₂ SO ₄ (98.5)	50	15	34
B2	H ₂ SO ₄ (50)	82	15	39
B2a	H ₂ SO ₄ (150)	82	15	45
B3	H ₂ SO ₄ (98.5)	82	30	46
B3a	H ₂ SO ₄ (98.5)	82	60	47
B3b	H ₂ SO ₄ (98.5)	82	90	47
B3c	H ₂ SO ₄ (98.5)	82	120	49
C1	H ₂ SO ₄ (98.5)+ Fe ₂ (SO ₄) ₃ (69.2)	82	15	44
C2	H ₂ SO ₄ (98.5)+ Fe ₂ (SO ₄) ₃ (138.5)	82	15	46
D	H ₂ O ₂ (5.89)	25	15	1.4
E	H ₂ SO ₄ (98.5)+ H ₂ O ₂ (5.89)	25	15	49
F	H ₂ SO ₄ (98.5)+ H ₂ O ₂ (5.89) + Fe ₂ (SO ₄) ₃ (69.2)	25	15	29
G	HCl (98.5)	25	15	32
H	HClO ₄ (98.5)	25	15	22
I	HClO ₄ (98.5) + H ₂ O ₂ (5.89)	25	15	43
J	CuO (6.89)+ NH ₄ OH (12.1)+ (NH ₄) ₂ CO ₃ (10.4)	25	120	28

Table 3: Results for the leaching experiments using different reagents and their concentration

- A- 98.5 Kg/t H_2SO_4 , 82°C, 15 min
 C2- 98.5 Kg/t + 69.2 Kg/t $\text{Fe}_2(\text{SO}_4)_3$, 82°C, 15 min
 A- 5.89 Kg/t H_2O_2 , 25°C, 15 min
 B- 98.5 Kg/t H_2SO_4 + 5.89 Kg/t H_2O_2 , 25°C, 15 min
 C- 98.5 Kg/t H_2SO_4 + 5.89 kg/t H_2O_2 + 69.2 Kg/t $\text{Fe}_2(\text{SO}_4)_3$, 25°C, 15 min
 D- 98.5 Kg/t HCl , 25°C, 15 min
 E- 98.5 Kg/t HClO_4 , 25°C, 15 min
 F- 98.5 Kg/t HClO_4 + 5.89 Kg/t H_2O_2 , 25°C, 15 min
 G- 6.89 Kg/t CuO + 12.1 Kg/t NH_4OH + 10.4 Kg/t $(\text{NH}_4)_2\text{CO}_3$, 25°C, 120 min

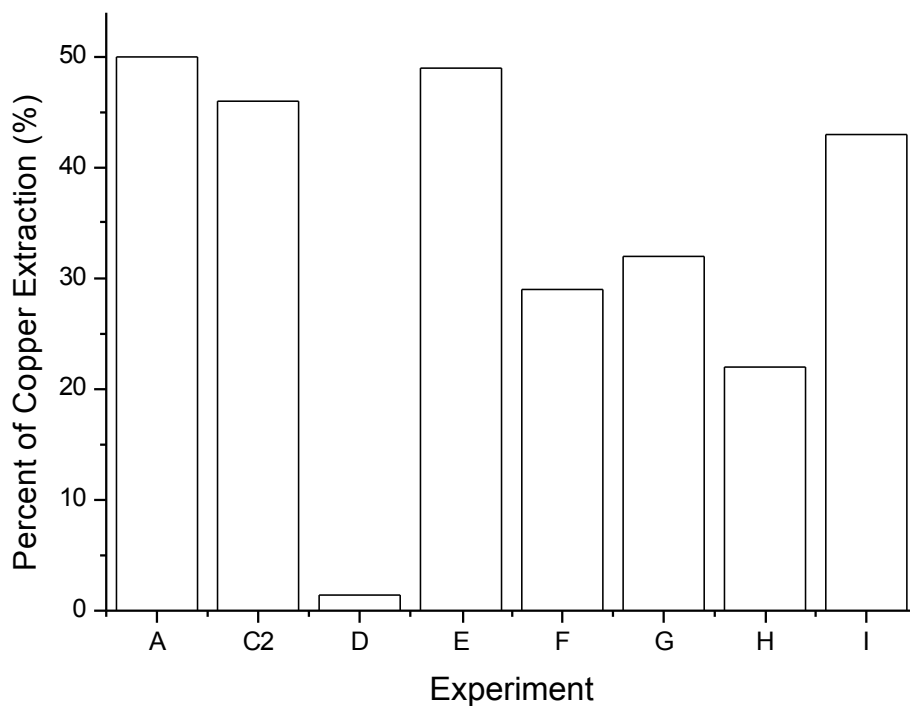


Figure 1 : Percent of copper extraction for the experiments using different leach reagents