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Gold recovery from waste dam of Moute Gold Mine by flotation and optimization the process via Taguchi method

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ABSTRACT: *The waste dam of Mouteh Gold Mine in Iran has a gold content of about 0.5ppm mainly as constituents of activated carbon. Flotation is used for concentrating the gold bearing activated carbon. Effects of factors such as pulp pH, impeller speed and frother concentration in flotation experiments has been determined through Taguchi method. Using this method, maximum recycling rate of gold and concentrate gold carat are predicted about 74.5%, and 9.6ppm respectively.*

Key words: *Gold recovery, Flotation, Activated carbon, tailing treatment.*

I. INTRODUCTION

1.1. Mouteh Gold Mine

The treatment of flotation tailings is a subject of interest in mineral processing because of the potential of wasted materials as an actual mineral resource and also environmental reasons. As shown in Table 1 carat of gold in Mouteh Gold Mine is about 0.4ppm. Gold excavation in this mine is conducted using CIP method and activated carbon in waste is highly rich in gold, about 1280 ppm. Total amount of gold in the waste dam is calculated as 688 kg. The purpose of this work is to separate the activated carbon via flotation method for recovery of gold. Taguchi method also is used for finding the optimum condition of flotation in order to reach to the highest gold recovery and carat of gold in concentrate.

Table 1 carat and amount of some elements in waste dam of Mouteh Gold Mine and carat of elements on carbon

element	carat of element in waste dam (ppm)	carat of element placed on carbon (ppm)	amount of elements in wast dam (kg)
Au	0.43	1280	688
Ag	5	5	8,000
W	209	5	334,400
Ce	120.37	3	
Yb	6.04	1.5	
Nd	56.43	5	
Sm	12.18	0.1	
Lu	0.927	0.3	
Eu	1.78	0.2	
Tb	1.62	0.5	
Sc	10.24	1.1	
Ir	5	5	
La	73.37	0.5	

1.2. Gold flotation

Recovery of native gold from gold ores and base metal ores is an important industrial practice. Conventional gold recovery methods are gravity, flotation, amalgamation and leaching processes [1]. Gardner and Woods [2,3] showed that electrochemically-cleaned pure gold had a zero contact in buffer solution and zero natural flotation in alkaline of acid solution when using purified nitrogen gas bubble. However there are evidences that show native gold has natural hydrophobicity. Some possible explanation for natural floatability of native gold are: surface charge, variation in composition of native gold in presence of other minor alloying elements like silver and copper and surface contamination with organic maters and oils that can increase floatability of native gold. More-over, floatability of native gold is different depend on type of host mineral (pyrite, arsenopyrite, base metal sulfide minerals, quartz) [4,5].

1.3. Carbon flotation

Carbon and carbonaceous minerals surfaces has natural hydrophobicity. In different efforts for recovery of unburned carbon and carbonaceous sulfide ores by flotation, diesel oil and pine oil are used as collector and frother respectively. Diesel oil known as an effective reagent for increasing natural floatability of carbon and carbonaceous minerals [5, 6 , 7].

1.4. pH in gold flotation

The pH of flotation feed is an important factor in gold flotation even though gold can float over a pH range of about 3 to 11. The value used in plants depends on nature of feed, type of host mineral (pyrite, arsenopyrite, base metal sulfide minerals, quartz) and composition of collector. For some examples, in Australia, native gold (and pyrite) flotation has been conducted in soda ash circuit at pH 8-9. In south Africa, the preferred pH ranges are 3-4 and 10-11.5. Acidic circuits (pH 3-4) are preferred for floating uranium acid leach residues, old tailing dumps which are acidic, and some cyanidation residue. Alkaline circuits (pH 10-11.5 with lime) are preferred when the ore contains pyrophyllite [4].

II. EXPERIMENT

2.1. Flotation

Following materials are used in flotation:

- booster : diesel oil
- frother : pine oil
- pH regulator : sulfuric acid

Three factors, pH, impeller speed (rpm) and concentration of frother have been changed in three levels for finding the optimum condition. There could some other effective factors in flotation that have been taken constant in this work like: temperature, water composition, type of booster and its concentration, amount of aeration and bubble-size [4]. Denver-cell was used hear for performing the flotation experiments. Pulp concentration was taken 25% and was prepared by tap-water. After adding frother and booster, 20 minutes of agitating and aerating was done on pulp.

Measuring the amount of gold in concentrate was performed in five steps: 1) the concentrate was calcinated for getting rid of activated carbon that strongly adsorbs gold on itself. 2) gold was washed and separated from concentrate by hot aqua regia (nitric acid and hydrochloric acid in a volume ratio of 1:3 respectively). 3) gold in aqua regia was gained via activated carbon adsorption. 4) the activated carbon bearing gold was calcinated. 5) remained ash washed with hot aqua regia for separating gold. And finally carat of gold in the last solution measured by Atomic Adsorption Spectroscopy.

Tests results are reported in two viewpoints 1) concentrate carat 2) recycling percentage. The ideal situation is the one that both concentrate carat and recycling percentage are high in.

2.2. Optimization

Orthogonal array L9 that is shown in Table 2 is introduced by Taguchi method for three factors varying in three levels. In this table factors are in columns, symbolized by A, B and C. Different combinations of factors with three different levels are in rows. Numbers in three columns under A, B and C show levels of factors. Number of all possible tests in case of three 3-level factors is $3^3 = 27$, however Taguchi test designing method enables us to find the optimum condition by nine tests only. And of course it is possible that optimum condition wouldn't be among these nine tests [8].

Table 2. orthogonal array L9

Experiment number	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2
Sum	18	18	18

For this work, factors are A: pH, B: impeller speed (rpm) and C: concentration of frother and each of them change in three levels Table 3. Qualitek-4 software is used for design and analysis of experiment according to Taguchi method.

Table 3. Factors and levels for flotation experiment

		Quantity of factors in three levels		
		1	2	3
pH	A	5	4	3
rpm	B	1600	1200	1000
concentration	C	2000 g/ton	1000 g/ton	200 g/ton

III. RESULTS AND DISCUSSION

3.1. Results

Results of the nine performed tests are reported in two different ways, 1) concentrate carat, 2) recycling percentage Table 4. Each test has been conducted two times.

Table 4. results of flotation

				concentrate carat (ppm)		recycling percentage	
test number	A	B	C	result 1	result 2	result 1	result 2
1	1	1	1	3.25	3.6	32.37	35.85
2	1	2	2	3.44	8.84	24.86	63.88
3	1	3	3	3.9	6	22.98	35.36
4	2	1	2	2.4	3.8	29.4	46.56
5	2	2	3	6.3	11.2	35.7	63.46
6	2	3	1	8.1	11.8	49.24	71.74
7	3	1	3	5.8	6	85.9	88.88
8	3	2	1	5.16	4.9	51.46	48.87
9	3	3	2	11.5	10	72.37	62.93

3.2. The larger, The better, for gold recycling percentage

With target of maximum amount of gold recycling the predicted optimum condition is $A_3B_3C_3$, Table 5. The predicted gold recycling in this situation is 74.5% although there was a 88.8% gold recycling among the performed tests (test 7 in Table 4). Probably this disagreement results from experimental error.

Factor's contribution on the answers are shown In Table 5 quantitatively. Figures show that the role of pH on results is 10 times more active than of two other factors.

Table 5. optimum condition for gold recycling percentage

factors		levels	factors' contribution	predicted gold recycling
A:	pH	3	3.347	
B:	Rpm	3	0.368	74.5%
C:	Concentration	3	0.359	

3.3. The Larger the better, for concentrate carat

With target of maximum concentrate carat the predicted optimum condition is $A_3B_3C_3$. The predicted concentrate carat in this situation is 9.6ppm. The desirable result obtained here is that both optimums for concentrate carat and gold recycling happen is same condition which is $A_3B_3C_3$.

Table 6 shows factors contribution on concentrate carat quantitatively. Figures show that the role of rpm on results is 1.5 times more active than of pH and also contribution of concentration of frother is not significant.

Table 6. optimum condition for concentrate carat

factors		levels	factors' contribution	predicted concentrate carat
A:	pH	3	1.827	
B:	Rpm	3	2.96	9.6 ppm
C:	Concentration	3	0.666	

As mentioned earlier, regarding the case in which higher recycling rate is under consideration, pH contribution on results is about 10 times higher than for two other factors, Table 5. According to These results pH and Rpm play the main role on recycling rate and concentrate carat respectively.

IV. CONCLUSION

Conducting tests for predicting the optimum points for recycling rate and concentrate carat were performed. Luckily, both optimums happened in same condition, $A_3B_3C_3$, which implies for pH equal to 3 (the lowest pH level), Rpm equal to 1000 (the lowest Rpm level) and frother concentration equal to 200g/ton (the lowest concentration). Predicted maximum gold recycling percentage and concentrate carat in this condition were 74.5% and 9.6ppm respectively. For having optimum recycling rate and highest carat of concentrate, pH and Rpm play the main roles respectively.

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