Determining effective parameters on flotation of Islamabad-Tarom copper ore to increase copper recovery

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ABSTRACT

In this study, samples of cut cores from exploratory drilling were used to prepare a representative sample from the Islamabad area located in Tarom, then identification studies were conducted. Based on petrographic and mineralographic studies, the main minerals in the sample include pyrite, chalcopyrite, tennantite, and tetrahedrite. Based on XRD analysis, the sample mainly consists of the minerals quartz, dolomite, albite, muscovite-illite, calcite, potassium feldspar, kaolinite, and pyrite. AAS analysis results indicated that the copper and gold grades are 0.3% and 368 ppb, respectively. In scanning electron microscope studies, no free gold was observed; instead, gold is primarily present as a replacement in the lattice of the minerals galena, chalcopyrite, and pyrite. Based on liberation studies, the liberation degree of chalcopyrite at a particle size of d_{80} = 63µ is approximately 97.03%. For chalcopyrite flotation, effective parameters such as pH, collector concentration, type and concentration of frother, and concentration of depressant were examined. The results showed that under optimal conditions, pH 8.8, collector concentration of 150 g/t, a mixture of sodium isopropyl xanthate and potassium amyl xanthate in equal weight ratio (50%), a frother concentration of 40 g/t using a mixture of polypropylene glycol and methyl isobutyl carbinol in equal weight ratio (50%), and a depressant concentration of 60 g/t of sodium silicate, the copper grade and recovery were 12.2% and 82%, respectively. With a re-cleaner step on the obtained concentrate, a concentrate with a grade and copper recovery of 18.48% and 80.05% was obtained, respectively.

KEYWORDS

Flotation, Chalcopyrite, Copper, Gold, Effective parameters.

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1. Introduction

In nature, copper usually occurs as copper sulfide minerals. Chalcopyrite, bornite, and chalcocite are three of the most important copper sulfide minerals [1].

In 2005, Hangone et al. used different collectors for copper sulfide flotation. Their results showed that diethyl dithiocarbonate was the weakest collector for copper sulfide minerals. In contrast, the highest copper recovery was obtained with the diethyl dithiophosphate collector [2].

In 2013, Koleini et al. optimized the selective flotation process of chalcopyrite, sphalerite, and pyrite from copper ore at the Teknar mine. The results showed that the most effective factor for copper and zinc recovery in copper concentrate was the type of collector mixture. The optimization results revealed that by maximizing copper recovery, the copper recovery, zinc recovery, and pyrite content were 89.04%, 25.3%, and 2.02%, respectively, using a mixture of sodium isopropyl xanthate, sodium dibutyl dithiophosphate, and dextrin as collectors and pyrite depressants, with zinc sulfate at 500 g/ton and pH = 11.35 [3].

In 2016, Awosu et al. showed that, in the selective flotation of chalcopyrite, using a cannula collector instead of a sodium isopropyl xanthate collector resulted in decreased copper recovery. However, when a combination of two collectors, sodium isopropyl xanthate and cannula, was used in a 1:1 ratio, the concentrate grade increased [4].

In 2022, Barfehi and Parsapour studied the effect of pH and chemicals on foam stability using a sample prepared from the Mohammadabad Delijan Copper Processing Plant, applying the Taguchi method. The results showed that the highest foam stability was achieved at pH = 11.2, with 20 g/t sodium isopropyl xanthate collector, 15 g/t dithiophosphate collector, 20 g/t MIBC frother, and 15 g/t Dowfroth 250 frother [5].

The Islamabad area is located in the Tarom County, which, based on exploratory studies, has an acceptable reserve. However, no feasibility study has been conducted from the perspective of mineral processing. For this purpose, core samples from the exploratory drilling were first collected. The goal of this research is to accurately identify and assess the properties of the samples through instrumental analyses such as XRD, XRF, and SEM-WDX from the standpoint of mineral processing. Additionally, it aims to investigate the optimal values of key parameters such as pH, collector concentration, type and concentration of frother, and depressant concentration to achieve a concentrate with suitable copper grade and recovery, as well as a high gold grade, using flotation processes. The research also focuses on developing a flotation process flowchart.

2. Methodology

To prepare a representative sample from the Islamabad area located in Tarom County, core samples from exploratory drilling were first collected. The entire set of samples was then crushed to a particle size below 2 mm using jaw, cone, and roll crushers. Subsequently, the homogenized sample was divided into two equal parts using a riffle splitter. One portion was archived, while the other was subjected to grinding in a ball mill.

To determine the chemical composition of the sample, X-ray fluorescence (XRF) analysis was performed using the X Unique II model manufactured by Philips. For mineral identification, X-ray diffraction (XRD) analysis was conducted using the X'Pert MPD model, also by Philips. In addition, atomic absorption spectroscopy (AAS) was employed to quantitatively determine the elemental composition of the sample.

For detailed mineral identification and to calculate the degree of liberation of copper-bearing minerals, petrographic and mineralographic studies were carried out using optical and electron microscopy on polished and thin sections. After preparing the polished sections, investigations were conducted using a Philips XL 30 scanning electron microscope equipped with a WDX detector, and element distribution maps (X-Ray Mapping) were generated. Imaging with the BSE detector shows heavier phases or minerals as brighter regions; as the average atomic number of a phase or mineral decreases, the brightness in the image also diminishes.

3. Results and Discussion

3.1. Characterization of GO

The results of the XRD analysis confirmed the findings from microscopic studies. The XRD results are presented in Table 1, indicating that the main minerals in the sample are primarily composed of quartz, dolomite, albite, muscovite-illite, calcite, potassium feldspar, kaolinite, and pyrite. The XRF analysis results are provided in Table 2.

According to the AAS analysis, the copper and gold grades in the sample were 0.3% and 368 ppb, respectively. Due to the low concentration of gold, it was not possible to identify gold-bearing minerals using XRD or optical microscopy. Therefore, a scanning electron microscope equipped with a WDX detector was employed to identify the gold-bearing minerals.

Table 1. X-ray Diffraction Analysis

Mineral	Chemical composition
Quartz	SiO_2
Dolomite	$CaMg(CO_3)_2$
Albite	$NaAlSiO_3O_8$
Muscovite-illite	$KAl_2Si_3AlO_{10}(OH)_2$
Calcite	$CaCO_3$
Potassium Feldspar	$KAlSi_3O_8$
Kaolinite	$Al_2Si_2O_5(OH)_4$
Pyrite	FeS_2

Table 2: Chemical composition of sample determined by XRF

Composition	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5
Percentage	0.31%	2.97%	13.2%	52.5%	0.15%
Composition	S	Cl	K_2O	CaO	TiO_2
Percentage	0.44%	0.046%	3.75%	7.5%	0.78%
Composition	MnO	V_2O_5	Fe_2O_3	CuO	PbO
Percentage	0.33%	0.035%	6.5%	0.4%	0.3%
Composition	L.O.I				
Percentage	11.58%				

3.2. Optimum conditions

Based on the results of flotation experiments at various parameter levels, the optimal parameter values were determined. The optimal conditions included a pH of 8.8, a concentration of 150 g/ton of a mixture of sodium isopropyl xanthate and potassium amyl xanthate in an equal weight ratio of 50%, a concentration of 40 g/ton of a mixture of frothers A65 and A70 in an equal weight ratio of 50%, and a concentration of 60 g/ton of sodium silicate. To validate the optimal conditions, the flotation experiment was repeated three times, with the average copper grade and recovery obtained being 12.2% and 82%, respectively, confirming the validity of the optimal parameter conditions. Subsequently, to increase the grade, a re-cleaning stage was performed on the concentrate. As a result, a concentrate with copper and gold grades of 18.48% and 15.6 ppm, respectively, and a copper recovery of 80.05% was obtained.

4. Conclusion

In this study, the beneficiation of chalcopyrite ore from the Islamabad area in Tarom County was investigated using the flotation method. To better characterize the sample and to calculate the degree of liberation of copper-bearing minerals, petrographic and mineralographic studies were conducted using optical and electron microscopes. The chemical composition of the sample was determined through XRF analysis, while XRD was used to identify the constituent minerals. Additionally, AAS analysis was performed to quantitatively determine the elemental content of the sample. The copper and gold grades in the sample were 0.3% and 368 ppb, respectively. Key flotation parameters such as pH, collector concentration, type and concentration of frother, and depressant concentration were evaluated. Under optimal conditions—at a pH of 8.8, with 150 g/ton of a collector mixture composed of sodium isopropyl xanthate and potassium amyl xanthate in a 1:1 weight ratio, 40 g/ton of a frother mixture of A65 and A70 in a 1:1 weight ratio, and 60 g/ton of sodium silicate as a depressant—the copper grade and recovery were found to be 12.2% and 82%, respectively. Following two re-cleaning stages on the obtained concentrate, a final concentrate with copper and gold grades of 18.48% and 15.6 ppm, respectively, and a copper recovery of 80.05% was achieved.

5. References

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