

Study on the Gold Recovery Potential from Tailings at Ta Phoi Copper Processing Plant – Lao Cai

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Abstract: *The beneficiation technology employed at the copper ore processing plant of Ta Phoi Copper Joint Stock Company is both selective flotation and bulk flotation technologies that yield relatively good technical indicators. During the process, Au also recovers in the copper concentrate with a grade content of 5 g/t at a recovery 60%. The gold remaining is in the tailings with a content of approximately 0.1–0.3 g/t. Currently, there have been no studies in Vietnam specifically targeting the recovery of Au from tailings. The beneficiation process at Ta Phoi Copper Processing Plant has also not focused on the recovery of this valuable component. This paper presents several research findings on the potential recovery of gold from the tailings of the Ta Phoi Copper Processing Plant. While the Knelson concentrator indicated the ineffective recovery of Au, the concentrate product after upgrading by shaking table and flotation has the Au grade content of 3.37 g/t at a recovery 30% and 1.56 g/t at a recovery of 33%, respectively. Preliminary research opens up prospects for recovering valuable, rare metals from tailings of mineral processing plants, contributing to conserving natural resources and energy, reducing environmental degradation, lowering treatment costs, minimizing the discharge of solid waste into the environment, ensuring the safety of the tailings pond, and supplying mineral raw materials for downstream processing industries.*

Keywords: Flotation; Knelson concentrator; shaking table; gold grade; gold recovery; tailings

1. Introduction

Gold has been produced on an industrial scale worldwide for a long time, with approximately eight countries reporting annual gold outputs exceeding 150 tonnes. In the past, gold production was primarily based on placer (alluvial) ores. Today, most gold is recovered from primary (hard rock) ores using a combination of gravity concentration, flotation and hydrometallurgical methods. Particularly, refractory gold ores often require the integration of multiple processing technologies. Among these, cyanidation and other hydrometallurgical techniques are the most widely used due to their high recovery efficiency, large throughput, low capital investment and ability to treat both finely disseminated and complex ores.

Most studies to date focus on specific deposits, ore types, or individual plants (Tran Thi Hien et al., 2011; Nguyen Hoang Son et al., 2009). Globally, the majority of gold ores are hard rock ores that require crushing, grinding and flotation, sometimes combined with gravity separation, to produce a concentrate for metallurgical processing (Valentin Choquenaira Bombilla, 2002; Nadia Lotter, 2005; Ngo Ngoc Dinh et al., 2011; Ta Quoc Hung et al., 2016). In contrast, placer gold ores are typically processed using gravity methods. The Knelson concentrator has been successfully applied in numerous mines, including Morila (Mali), Serra Grande (Brazil), Sunrise Dam, Kundana Gold, WMC (Australia), Norilsk Nickel (Russia), BHP Tintaya (Peru), and Geita (Tanzania), with gold recoveries exceeding 30% (Bulatovic, 2007).

Although many technologies for recovering gold from primary ores have been studied and applied both in Vietnam and around the world, technologies for recovering gold from tailings are quite limited. The main challenges are low gold content, complex mineral composition, ultra-fine dissemination, and the requirement for expensive or environmentally unfriendly technology. Several authors have conducted studies using flotation to recover Au (Trifunović et al., 2024; Velizar et al., 2018; Özdemir et al., 2024) or using environmentally friendly microbial leaching methods (Schueler et al., 2024; Castro et al., 2021; Tien Aminatun et al., 2025; Zhang et al., 2022). The above methods have shown effectiveness in specific studies, but when processing gold recovery from tailings, a criterion that should be noted is the use of simple technology, low investment and production costs. In addition to the above methods, chemicals such as cyanide and mercury have also been used in gold recovery; however, their use is now limited due to the potential risk of environmental pollution.

Vietnam currently has two main copper processing plants, which annually discharge millions of tons of tailings with an Au content of about 0.1 g/t. According to gold assay results from Ta Phoi copper processing plants between 2022 and 2024, ROM ore typically contained ~0.3 g/t Au, while tailings had ~0.1 g/t. Currently, there has been no study evaluating the possibility of recovering gold from copper tailings in Vietnam, especially in the case of tailings from the Ta Phoi copper processing plant. The objective of this study is to recover gold concentrates from tailings with gold content in the range of a few grams per tonne. These concentrates can then be further processed to extract metallic gold. It is thus essential to develop and master an efficient technology for recovering gold concentrates from copper flotation tailings, aiming to maximize resource utilization and minimize environmental impact.

2. Research methods and equipment

This study employed analytical and laboratory-scale experimental methods to determine the mineral composition and characteristics of the tailings, as well as the distribution of gold (Au) across different particle size fractions. Based on these findings, various beneficiation technologies were tested to identify the optimal processing parameters that would maximize gold concentrate recovery.

The main equipment used in the experiments included:

- + Knelson concentrator
- + Shaking tables (for both slurry and sand fractions)
- + Flotation machine.

3. Results and discussion

3.1. Characteristics of the tailings sample from Ta Phoi copper processing plant

The tailings sample was thoroughly homogenized and subsampled for mineralogical analysis, chemical composition, and particle size distribution using sieve analysis. These analyses also provided the basis for subsequent experimental testing. The analytical results are presented in Tables 1, 2, and 3.

Tab. 1. Mineralogical Composition of the Tailings Sample

Minerals	Approximate Content, %
Mica (Illite) – $\text{KAl}_2\text{AlSi}_3\text{O}_{10}$	33 – 35
Amphibole	11 – 13
Chlorite – $\text{Mg}_2\text{Al}_3\text{AlSi}_3\text{O}_{10}$	4 – 6
Quartz – SiO_2	10 – 12
Feldspar – $\text{K}_{0.5}\text{Na}_{0.5}\text{AlSi}_3\text{O}_8$	1 – 3
Albite – $\text{NaAlSi}_3\text{O}_8$	25 – 27
Calcite – CaCO_3	4 – 6
Maghemite – $\gamma\text{Fe}_2\text{O}_3$	1 – 3
Pyrrhotite – Fe_{1-x}S	≤ 1
Chalcopyrite – CuFeS_2	≤ 1

Tab. 2. Particle Size Distribution and Gold Content in the Tailings Sample

Particle Size, mm	Yield, %	Cumulative Yield, %	Au Grade, g/t	Au Recovery, %	Cumulative Au Recovery, %
+0.2	8.22	8.22	0.15	12.33	12.33
0.1-0.2	20.01	28.23	0.07	14.01	26.34
0.074-0.1	16.74	44.97	0.07	11.72	38.06
0.04-0.074	17.61	62.58	0.07	12.33	50.39
0.02-0.04	8.17	70.75	0.07	5.72	56.11
-0.02	29.25	100	0.15	43.89	100
Sum	100	-	0.1	100	-

Tab. 3. Chemical Composition of the Tailings Sample

Component	Unit	Content (%)
Al ₂ O ₃	%	13.46
CaO		1.24
TFe ₂ O ₃		7.32
K ₂ O		1.31
MgO		4.47
MnO		0.06
P ₂ O ₅		0.22
TiO ₂		0.82
Ag		< 2
Au		< 0.1
As	ppm	< 20
B		< 10
Ba		157.3
Be		< 5
Bi		< 10
Cd		< 2
Ce		181.8
Co		32.6
Cr		143.5
Cu		572.4
Ga		< 10
Ge		< 20
La		96.2
Li		7.7
Mo		< 5
Nb		16.9
Ni		42.7
Pb		8.3
Sb		< 10
Sc		< 5
Sn		< 10
Sr		243.5
Ta		< 10
V		121.6
W		< 20
Y		32.7
Zn		66.7

The analysis of the material composition of the tailings sample from the Ta Phoi copper processing plant indicates the presence of residual copper sulfide minerals, primarily chalcopyrite, along with pyrite and pyrrhotite. The gold content in the tailings is approximately 0.1 g/t. As gold is commonly associated with sulfide minerals, its recovery requires the separation of these sulfide phases from the gangue minerals. This study is therefore oriented toward applying a combination of gravity concentration methods (such as Knelson concentrator and shaking tables) and flotation techniques to process the copper tailings from the Ta Phoi processing plant, to maximize recovery of gold-bearing concentrates.

3.2. Experimental Results

3.2.1. Tests Using the Knelson Concentrator

The experimental setup is illustrated in Figure 1. The operating parameters were as follows:

- Water flow rate: 3.6 m³/h
- Feed pulp concentration: 60% weight solids
- Ore feed mass: 1 kg
- Centrifugal force settings: 30 G, 50 G, 70 G, and 90 G

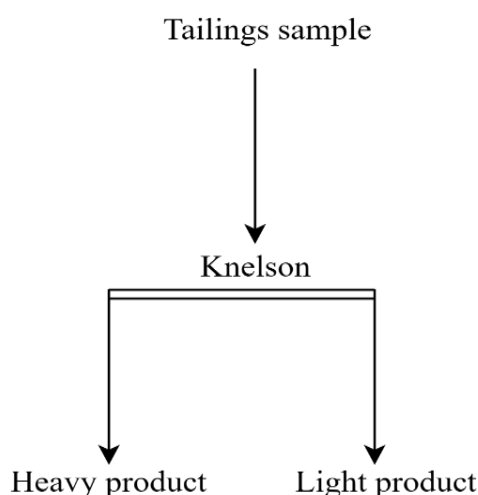


Fig. 1. Flow diagram of tailings sample processing using the Knelson concentrator

Observation of the experimental process using the Knelson concentrator and analysis of Au content in the products indicate that the separation efficiency of the laboratory-scale Knelson unit (operated by the Mineral Processing Department) was relatively low. This may be attributed to limitations in the equipment itself or the very low gold content in the feed material. The gold grades in the heavy and light fractions did not differ significantly.

At a centrifugal force of 70 G, the highest gold grade in the concentrate achieved was 0.52 g/t, with a recovery of approximately 80%. The experiment was also repeated with two-stage concentration using the Knelson device; however, the resulting concentrate only reached a gold grade of ~0.8 g/t, which remains below the target set for the study.

3.2.2. Tests Using the Shaking Table

The tailings sample was processed on a shaking table to separate it into four products: concentrate, middling, tailings, and slime. Each product was dried, weighed to determine yield, and sampled for chemical analysis to determine Au content. The experimental setup is illustrated in Figure 2.

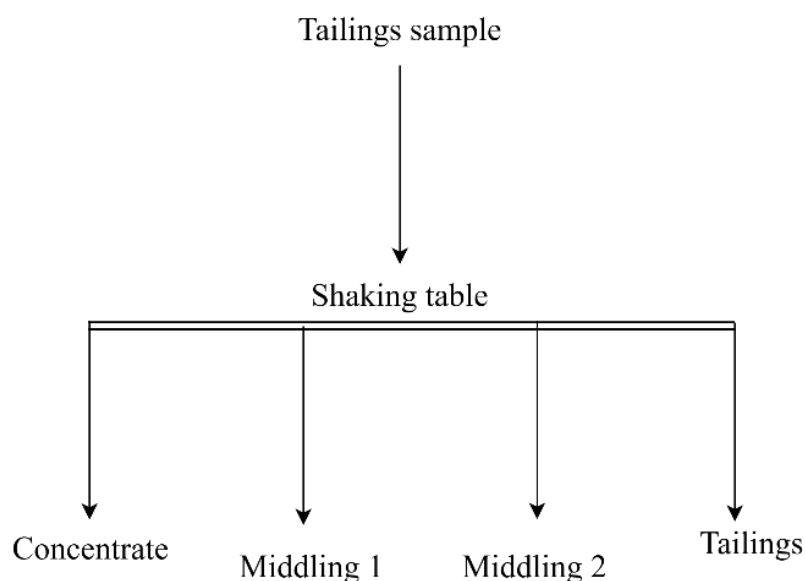


Fig. 2. Flow diagram of tailings processing using a shaking table

The experiment was conducted to determine the optimal amplitude and table inclination angle. The table vibration frequency was set at 100 cycles per minute. The experimental results are presented in Tables 4 and 5.

Tab. 4. Effect of Vibration Amplitude on Shaking Table Separation Results for Tailings Sample

Amplitude (mm)	Product	Yield (%)	Gold Grade (g/t)	Gold Recovery (%)
8	Concentrate	0.38	3.38	12.84
	Middling 1	2.45	0.38	9.31
	Middling 2	27.56	0.03	8.27
	Tailings	69.61	0.1	69.59
	Feed sample	100	0.1	100
9	Concentrate	0.66	3.37	22.24
	Middling 1	2.58	0.39	10.06
	Middling 2	24.23	0.04	9.69
	Tailings	72.53	0.08	58.01
	Feed sample	100	0.1	100
10	Concentrate	1.05	1.12	11.76
	Middling 1	5.75	0.64	36.8
	Middling 2	34.5	0.03	10.35
	Tailings	58.7	0.07	41.09
	Feed sample	100	0.1	100
11	Concentrate	1.25	1.07	13.38
	Middling 1	6.12	0.9	55.08
	Middling 2	37.56	0.04	15.02
	Tailings	55.07	0.03	16.52
	Feed sample	100	0.1	100

Tab. 5. Effect of Table Inclination Angle on Shaking Table Separation Results for Tailings Sample

Inclination Angle (degrees)	Product	Yield (%)	Gold Grade (g/t)	Gold Recovery (%)
1	Concentrate	1.01	1.25	12.63
	Middling 1	3.59	0.88	31.59
	Middling 2	20.13	0.09	18.12
	Tailings	75.27	0.05	37.66
	Feed sample	100	0.1	100
1.5	Concentrate	0.92	1.3	11.96
	Middling 1	3.04	0.92	27.97
	Middling 2	24.13	0.07	16.89
	Tailings	71.91	0.06	43.18
	Feed sample	100	0.1	100
2	Concentrate	0.66	3.37	22.24
	Middling 1	2.58	0.39	10.06
	Middling 2	24.23	0.04	9.69
	Tailings	72.53	0.08	58.01
	Feed sample	100	0.1	100
2.5	Concentrate	0.45	3.04	13.68
	Middling 1	3.02	0.49	14.8
	Middling 2	28.56	0.06	17.14
	Tailings	67.97	0.08	54.38
	Feed sample	100	0.1	100

Based on the results of the shaking table experiments, the optimal vibration amplitude was determined to be 9 mm, and the optimal table inclination angle was 2 degrees. Under these conditions, a gold concentrate was obtained with the following indicators: yield of 0.66%, gold grade of 3.37 g/t, and gold recovery of approximately 30%.

3.2.3. Flotation test

The flotation reagent regime was as follows (Bulatovic, 2007):

CaO: 2000 g/t (pH = 9);

Na₂S: 300 g/t;

CuSO₄: 100 g/t;

Butyl xanthate / Ammonium dibutyldithiophosphate: 50/50 g/t;

Pine oil: 10 g/t.

The flotation flowsheet is shown in Figure 3. The flotation test results are presented in Table 6.

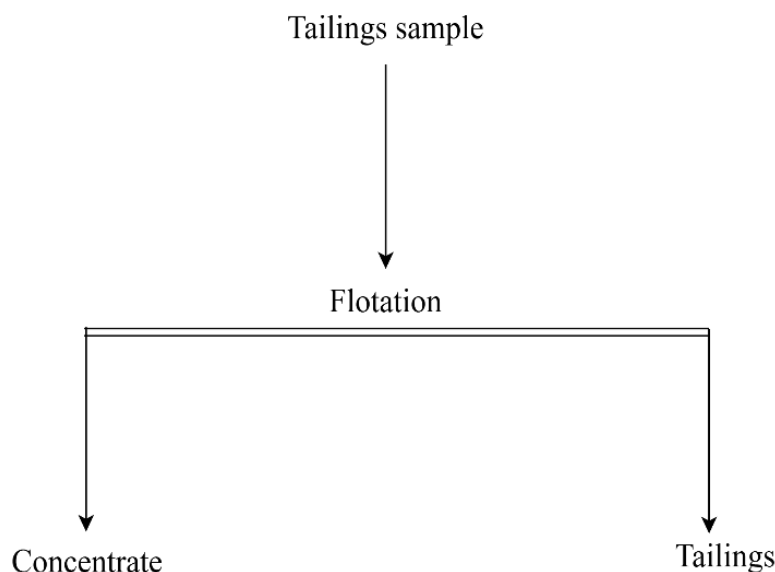


Fig. 3. Flotation Flowsheet for Tailings Sample

Tab. 6. Flotation Test Results for Feed Sample

Products	Yield (%)	Gold Grade (g/t)	Gold Recovery (%)
Concentrate	2.11	1.56	32.9
Tailings	97.89	0.02	67.1
Total	100	0.1	100

The preliminary flotation results were as follows: the gold concentrate had a grade of 1.56 g/t, a recovery of approximately 33%, and the tailings contained 0.02 g/t Au.

In general, the gold separation process using flotation and shaking table technology is much more efficient than using the Knelson concentrator, with enrichment ratios of 33.7 and 15.6 times, respectively, compared to 8 times. Because the experiments are only preliminary, the process results have not been as good as those of similar subjects treated in the world. The basic challenges with this beneficiation process are the fine and ultra-fine gold dissemination in minerals, low gold grade content, gold-bearing minerals can have a density equivalent to that of unvaluable minerals, the flotation process has hydrophilized a large part of the gold-containing minerals, leading to difficulty in recovering them into froth products when re-flotating the tailings. In order to increase the Au content to meet the metallurgical requirements with an acceptable recovery ratio, it is necessary to have a combination of technologies such as panning + flotation + acid leaching. The results open up the prospect of gold enrichment in Ta Phoi tailings by traditional methods.

4. Conclusions And Recommendations

4.1. Conclusions

The mineral composition of the tailings sample from the Ta Phoi copper flotation plant includes a small amount of copper sulfide minerals, primarily chalcopyrite, accompanied by pyrite and pyrrhotite. The main gangue minerals are quartz and silicates. The copper and gold grades in the tailings are approximately 0.06% Cu and 0.1 g/t Au, respectively.

The study applied gravity concentration methods (Knelson concentrator and shaking table) and flotation to recover gold concentrate from the tailings of the Ta Phoi Copper Processing Plant.

The separation process using the Knelson concentrator has not yield effective results.

Optimal operating conditions for the shaking table were determined as follows: amplitude 9 mm, frequency 100 cycles/min, and inclination angle 2 degrees. Under these conditions, the gold concentrate obtained had a grade of 3.37 g/t Au at the recovery of approximately 30%.

The flotation test results showed a gold concentrate with a grade of 1.56 g/t at the recovery of approximately 33%.

4.2. Recommendations

The gold concentrates obtained under the tested conditions using the Knelson concentrator, shaking table, and flotation had relatively low grades and recoveries. Further research is recommended on combined gravity–flotation flowsheets to improve separation efficiency and maximize gold recovery from the tailings of the Ta Phoi Copper Processing Plant.

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