

LEACHING OF GOLD FROM FINE-GRAINED FLOTATION TAILINGS

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ABSTRACT

This study focuses on leaching of gold from fine-grained waste materials from flotation. The input raw material is the waste product after flotation containing about 1–2.5 g/t of Au. This paper makes part of wider research to identify all available methods and select the most appropriate technology to obtain residual gold from fine-grained waste materials. An alternative method to conventional cyanide methods, which have negative environmental impacts [1], has been tested under laboratory conditions, namely thiourea leaching. We observed the effect of the grain size of input raw materials with concentration of thiourea and Fe^{3+} ions in dependence on temperature and pH during research. The pH values were maintained low during all experiments to avoid dissociation of the leaching solution. In optimal condition of leaching we achieved 85% success rate of gold recovery. The data may be useful to improve the processes of recovery of useful constituents from unused wastes with the content of gold.

Keywords: Flotation; Gold; Leaching; Thiourea.

1 INTRODUCTION

Hodruša-Hámre is a Slovak mining village which has long been connected with mining of gold-silver ores. Today, there are rocks in the site of mining with relatively variable mineralogical composition. The basis of the ore is quartz along with other silicates such as illite, mica or feldspar. The proportion of silicate is relatively high up to 80–85 %.

The use of thiourea $\text{CH}_4\text{N}_2\text{S}$ as an extraction agent for leaching has proven to be a quality method to obtain precious metals in the metallurgical industry. Compared to the conventional cyanide method, the advantage of this method is lower environmental impacts, greater gold selectivity, and higher dissolution rates. The use of thiourea $\text{CH}_4\text{N}_2\text{S}$ as an extractant for leaching is used as a suitable method to recover precious metals in the metallurgical industry [2]. Thiourea leaching has also been applied in gold hydrometallurgy. As opposed to cyanide methodology, thiourea leaching is more economical due to a lower cost because in cyanidation the high acid solutions need to be neutralized [3].

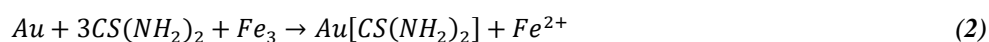
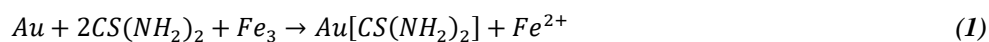
Another important factor in leaching of gold was the value of the redox potential which also affects the consumption of thiourea in gold mining. Sample pre-treatment with SO_2 addition is useful for reducing thiourea consumption. Pre-treatment also reduces SO_2 consumption but also improves extraction [4]. The disadvantage of this method is the high cost of the oxidizing agents, iron ions and higher consumption of thiourea required compared to cyanide. There are several types of oxidizing agents that are used in leaching gold. These include hydrogen peroxide, oxygen and sulfamide formamidine [5].

Typically, gold is leached from raw ore [2, 6] or from electrical waste [1]. This research is unique in the sense of the used sample to extract gold using leaching, i.e. gold mining flotation tailings (from waste flotation) have been recovered to leach the residual gold content.

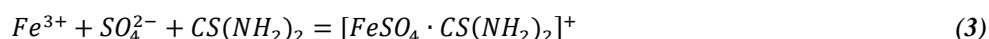
2 MATERIALS AND METHODS

Experimental principle

Since thiourea is not stable and decomposes readily in an alkaline environment, the reactions need to be carried out in acidic solutions. There are many oxidizing agents, but iron-ion solution has been shown to be the most suitable oxidizing agent based on research results [1, 6]. When an iron (III) ion is used as the oxidizing agent, the overall reaction showing the extraction of gold in the acidic thiourea solutions can be described as follows:



As thiourea is easily oxidized by iron ions, the compound disamide sulfide formamidine is formed. Since this compound is not stable, it decomposes to form elemental sulfur and cyanamide. In the end, thiourea is also lost and a stable ferric sulfate complex described by the following equation is formed (3) [1].



Experimental material and reagent

The tested samples come from the Slovak mining village of Hodruša-Hámre. Today, the mineralogical composition of the ore is relatively variable. The basis of the ore is quartz along with other silicates such as illite, mica or feldspar. The proportion of silicate is relatively high up to 80–85 %. Test samples are in powder form and are already waste after flotation, when gold is extracted from ore using flotation. Still, the waste samples contain about 1–2.5 g/t of residual gold (Au) and thus the thiourea leaching method was tested.

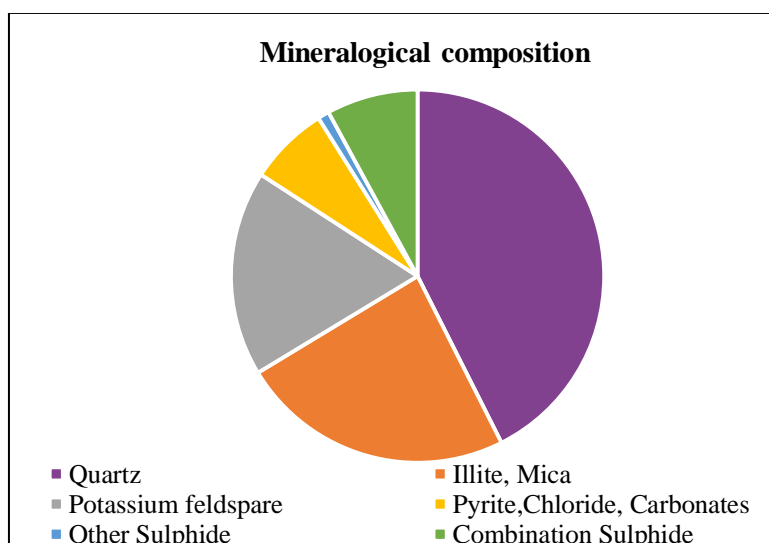


Figure 1. Mineralogical composition material

Experimental leaching

The samples were dry powder material which was first adjusted to the desired size. The untreated sample was ground, sieved to a grain size below 0.63 mm to open the matrices and the sample was ready for leaching. Gold waste leaching was performed in Erlenmeyer flasks in a laboratory shaker that regulates speed, time and temperature. These parameters are an integral part of the whole research. 200 g of the powdered sample was transferred to an aqueous solution and the addition of thiourea at a selected concentration of 24 g/l. During the

experiment, the temperature of 20.5 °C was chosen, a temperature that would approach the air temperature. The pH of the solution was 7.58 when the reagents were mixed. Along with the sulfuric acid, 10 ml of ferric ions in the form of 0.6 % ferric sulfate $\text{Fe}_2(\text{SO}_4)_3$ was added to the solution and the pH was adjusted to an optimal value of 2.05. The leaching was divided into 3 hours, after which a sample was taken for each experiment every hour and the gold content of each sample was determined. After collection, the pH was always measured and then withdrawn to a value close to pH 2. At all times, the speed in the laboratory shaker was set to 180 / min.

3 RESULTS AND DISCUSSION

Thiourea leaching has advantages not only in rapid leaching and low toxicity, but also in low cost and high efficiency, and last but not least, it is environmentally friendly. The experiments were carried out under laboratory conditions, during which time and temperature were monitored during leaching, which was kept in a laboratory shaker and approached the air temperature so that the results could be applied in industry. The acidic pH had to be maintained at all times to avoid the decomposition of thiourea. The use of ferric ions has proven to be the best extracting agent.

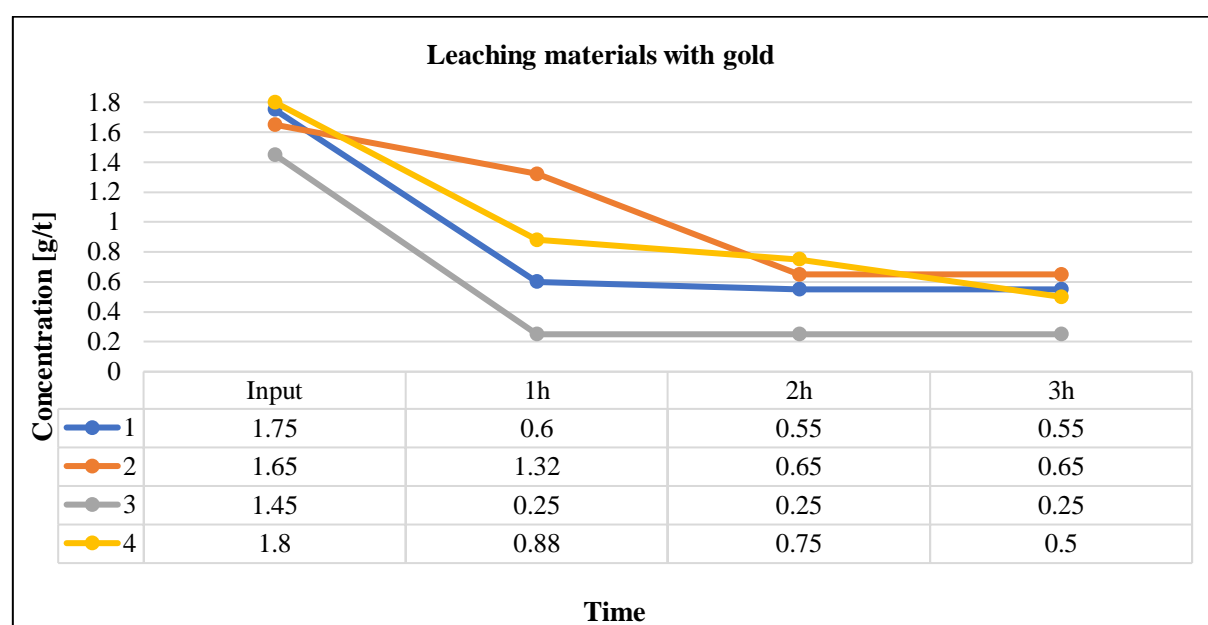


Figure 2. Leaching results as a function of time

The results show that the highest gold recovery was obtained in 1 hour of leaching most likely due to the structure of the sample matrix. As clear from Figure 2, the recovery rates fall with time. On average, the gold recovery was about 80 % using thiourea leaching and ferric ions applied on gold mining flotation tailings from Hodruša-Hámre.

A number of authors have dealt with the leaching of gold ore using thiourea, where the gold content in the used ores was variable and ranged from 76g/t [7] to 4g/t [4]. In our work, we built on the findings of the study by Ubaldini et al. [4], in which the authors point out the low gold content in the treated sample and similar, i.e. low grain-size waste generated from flotation. The mineralogical composition shows that quartz predominated in the sample. For comparison, the experimental work Ubaldini et al. [4] was devoted to the preliminary evaluation of the feasibility of thiourea leaching for the extraction of gold from a domestic gold-bearing ore (4 g/t Au) at laboratory scale. Similarly to our study, they observed the influence of temperature, leaching agent concentration, pulp density and leaching time on the gold dissolution. About 80 % of gold recovery was obtained, for the complete cycle of treatment; the consumption of reagents has been lower than ours (5 g/kg of thiourea, 5 g/kg of sulphuric acid and 0.5 g/kg of ferric sulphate). Ubaldini et al. [4] also claim in their study that at elevated temperatures the consumption of leaching agent also increases, which is undesirable in our case and therefore we chose a temperature of 20.5 °C.

Figure 2 shows that during 3 hours of leaching in thiourea, enriched with iron ions, there was a significant reduction in gold concentration. Study of Groenewald [5] was made of the dissolution of gold in acidic solutions of thiourea containing various oxidants, in order to evaluate the potential of acidic thiourea as a reagent for leaching gold. Experiments were conducted on rotating disks of pure gold and after that applied on ground gold ores. When solutions containing 1.4 kg thiourea per ton of treated ore were used, it was possible to extract gold from ore within 1 hour [5].

4 CONCLUSION

The experiments were carried out to determine the most suitable method of obtaining gold from fine-grained waste after flotation. During the experiment, parameters such as pH, temperature and time were monitored along with the most suitable choice of thiourea concentration, which was selected to be the most appropriate according to the experiment, 24 g/l, using the oxidizing agent $\text{Fe}_2(\text{SO}_4)_3$. During the research, the best time was shown that the leaching took place within the first hour and no longer occurred.

This research is unique as for the sample used for leaching to extract gold. Other reported research uses raw gold materials to leach gold, or crushed waste such as electrical waste. In this research, it is a question of leaching flotation tailings in connection with gold mining. Although after applying flotation, the gold content is small, there is still residual gold that may be extracted using thiourea leaching. Although other research reports higher yields, these may be affected by the overall higher gold content.

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