EXTRACTION OF PRECIOUS METALS FROM A PYRITIC CONCENTRATE PRETREATED BY MICROBIAL OXIDATION

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Abstract: *A sulphide flotation concentrate containing 15.2 g/t gold and 893 g/t silver finely disseminated in pyrite (4.1 % sulphidic sulphur in the concentrate) was treated by a two-stage process to recover these precious metals. Initially the concentrate was subjected to microbial oxidation by means of different acidophilic chemolithotrophic microorganisms (bacteria at 37 ^oC and archaea at 59 and 86 ^oC) to expose the precious metals encapsulated in the pyrite. The precious metals liberated in this way were then subjected to leaching by means of solutions containing different reagents (protein hydrolysate, thiosulphate, cyanide and some chemical oxidizers). The leaching was carried out in agitated reactors and up to 93.6 % of the gold and 80.8 % of the silver were solubilised in this way for 48 hours from a pulp density of 20 % at 57 ^oC.*

Keywords: PRECIOUS METALS, MICROBIAL OXIDATION, EXTRACTION

1. Introduction

Gold-bearing sulphide concentrates, ores and wastes in which the gold is finely disseminated as submicron size particles in the sulphide matrix are refractory to hydrometallurgical treatment for gold extraction since the leachants cannot penetrate into the interior of the minerals to reach the enclosed gold. However, since a relatively long period of time it is known that several acidophilic chemolithotrophic microorganisms (bacteria and arhaea) are able to oxidize efficiently the sulphides containing these precious metals and to make them exposed for leaching by means of suitable reagents. Furthermore, it has been found that in most cases such microorganisms are able to attack preferentially just the defect sites of the sulphide minerals in which the precious metals are located (Livesey-Goldblatt et al., 1983; Groudev, 1989; Rawlings and Johnson, 2007; Karavaiko et al., 1985; Van Aswegen et al., 2007). The gold and silver can be extracted from the pretreated sulphidic concentrates by means of cyanides or by other less toxic reagents. The present paper contains some data about laboratory experiments for microbial pretreatment and subsequent leaching of a sulphide concentrate containing gold and silver present mainly as metals finely dispersed in sulphide minerals.

2. Materials and Methods

The concentrate used in this study was produced by flotation of low-grade sulphide ore taken from a dump located near the deposit Zlata in the north-west part of Bulgaria, in a short distance from the small town Trun. The concentrate contained 4.8 % of sulphur (from which 4.1 % was sulphidic, present in pyrite), 8.2 % of iron, 1.49 % copper, 15.2 g/t gold and 893 g/t silver as the valuable components. Data about the phase composition of the precious metals in the concentrate are shown in Table 1.

Table 1: *Phase composition of the precious metals in the flotation concentrate.*

Phase composition	Distribution, %	
	Au	Ag
Free exposed metals	11.3	-
Metals capsulated in iron oxides	35.2	37.0
Metals finely dispersed in sulphide minerals	50.3	59.4
Metals finely dispersed in silicates	3.2	3.6
Total content, %	100.0	100.0

The preliminary microbial oxidation of the concentrate to expose the precious metals encapsulated in the sulphides was performed by means of different acidophilic chemolithotrophic microorganisms (bacteria at 37 ^oC, and archaea at 57 and 86 ^oC). The microbial pretreatment was carried out in the 9K nutrient medium (Silverman and Lundgren, 1959).

The pretreatment was connected with an efficient extraction of the sulphur, copper and iron from the concentrate. The progress of the microbial oxidation was followed by analysis of the leach solutions for ferrous, ferric and total iron species, copper, sulphates, pH, Eh and number of the chemolithotrophic microorganisms. Solvent extraction plus electrowinning were used to recover copper from the pregnant solution after bioleaching. The solvent extraction was carried out by means of the reagent LIX 984N (10 volume percents in a kerosene diluents).

The precious metals exposed in the solid residue as a result of the acidic pretreatment of the concentrate were subjected to leaching by means of different solutions for the comparative testing of their leach efficiency:

Solution type No 1: microbial protein hydrolysate consisting of mixture of protein hydrolysates produced from the biomass of three different microbial species with different amino acids composition and mixed in different correlations with pH from 9 – 11 (by NaOH);

Solution type No 2: microbial protein hydrolysate from the type mentioned above but containing also a chemical oxidizer of the precious metals ($KMnO_4$, $NaNO_2$ or H_2O_2) used in concentrations from 5 to 10 g/l, at pH from 9 – 11 (by NaOH);

Solution type No 3: thiosulphate in concentrations from 5 to 20 g/l, at pH from 9 – 11;

Solution type No 4: combinations of the microbial protein hydrolysate and thiosulphate at different ratios and in concentrations from 10 to 20 g/l, at pH from 9 – 11;

Solution type No 5: solutions of NaCN in concentrations from 5 to 10 g/l, at pH from 9 – 11 (by NaOH).

The microbial pretreatment and the subsequent chemical leaching of the pretreated concentrate were formed in agitated reactors with a working volume of 500 ml each and a pulp density from 10 to 20 g/l. The duration of these two operations was within 72 to 168 hours for each of them.

Elemental analysis of the liquid samples was carried out by means of atomic adsorption spectrometry and induced coupled plasma spectrometry. Elemental analysis of the solid samples before and after the leaching were carried out by the above-mentioned methods. Control analyses of the gold and silver in the solid samples before and after the leaching were carried out by cuppelation (fire assay).

The isolation, identification and enumeration of microorganisms were carried out by methods described elsewhere (Karavaiko et al., 1988; Hallberg and Johnson, 2001, Rawlings and Johnson, 2007).

3. Results and Discussion

The extraction of precious metals from the initial concentrate not subjected to preliminary oxidation was not efficient due to their significant dispersion and encapsulation in the sulphide minerals, mainly in the pyrite. The addition of chemical oxidizers ($KMnO_4$, $NaNO_2$ or H_2O_2) to the protein hydrolysate acting as a complexing agent for the precious metals increased to some extend the level of their extraction but even in these cases the effectiveness of leaching was relatively low (Table 2).

Table 2: *Leaching of gold and silver from the flotation concentrate by means of different leach solutions.*

Leach solutions	Initial concentrate		Concentrate subjected to preliminary oxidation	
	Metals extraction, %			
	Au	Ag	Au	Ag
Thiosulphate	48.2	37.0	92.3	77.0
NaCN	49.5	39.2	93.6	78.5
Protein hydrolysate	14.0	8.6	20.3	14.5
Protein hydrolysate+ chemical oxidizer:				
- $KMnO_4$	43.1	32.0	90.5	74.3
- $NaNO_2$	36.1	28.2	85.1	69.1
- H_2O_2	32.0	24.2	84.2	64.0

Portions of the precious metals solubilised during the leaching, especially of silver, precipitated in the cases in which the pH of the leach solution was lower than 9. The maintenance of the pH at levels higher than 9 decreased considerably the precipitation of the dissolved precious metals. The most efficient chemical leaching of these metals was performed within pH of about 9.5 – 10.5.

The optimum concentrations of the chemical oxidizers during the leaching were within the limits of about 5 – 10 g/l. These concentrations were sufficient to maintain the Eh of the leach solutions of values higher than 400 mV for a period of about 55 – 60 hours. The addition of the oxidizers in portions during the leaching was more efficient and decreased to some extent the consumption of these reagents. Regardless of this, the consumption of the reagents were high (within 0.5 – 0.8 g/g concentrate). These high consumptions were due to the fact that the oxidizers reacted not only with the precious metals but also with the sulphides in the concentrate and with the amino acids contained in the protein hydrolysate.

The leaching of the concentrate by means of thiosulphate was much more efficient than this by means of protein hydrolysate alone and even from these achieved by means of the protein hydrolysate in combinations with the chemical oxidizers (Table 2). However, the combination of the protein hydrolysate with the tiosulphate was the most efficient and practically equal to the extraction achieved by means of cyanide.

The microbial oxidative pretreatment of the sulphidic concentrate by means of acidophilic moderately thermophilic chemolithotrophic bacteria at 55 – 60 ^oC or by means of the extremely thermophilic archaea at 86 – 90 ^oC gave similar results during the subsequent leaching of the precious metals by means of the leach solutions mentioned above. The extraction of these metals was clearly connected with the level of oxidation of the sulphidic minerals containing the precious metals (Table 3). It must be noted, however, that the subsequent leaching of the pretreated concentrate by means of thiosulphate at temperatures highest than 50 ^oC was connected with a considerable increase of the consumption of this reagent. The further decrease of the content of sulphidic sulphur in the concentrate (to about 0.7 – 0.8 %) by means of the microbial pretreatment had partially no additional effect on the extraction of silver.

Table 3: *Effect of microbial oxidative pretreatment of the sulphidic concentrate by means of moderately thermophilic chemolithotrophic bacteria on the subsequent extraction of the precious metals*

Content of sulphide sulphur in the concentrate	Levels of the sulphidic sulphur oxidation, %	Extraction of the precious metals, %	
		Au	Ag
4.1	0	30.7	14.5
3.2	24.4	55.4	41.0
2.6	36.6	73.8	59.0
2.1	51.2	92.3	78.6
1.5	63.4	93.0	80.2
1.0	75.6	93.2	80.8

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