MICROBIAL PRE-TREATMENT OF A GOLD-BEARING FLOTATION PYRITE CONCENTRATE BY MEANS OF MESOPHILIC AND MODERATE THERMOPHILIC BACTERIA AND BY EXTREME THERMOPHILIC ARCHAEA

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ABSTRACT. A gold-bearing flotation pyrite concentrate containing 23 g/t gold and 875 g/t silver as the most valuable components was subjected to microbial pre-treatment to liberate the precious metals from the sulphide matrix and to expose them for the subsequent extraction by means of suitable agents (thiosulphate, microbial protein hydrolysate, cyanide). The concentrate pre-treatment was performed initially in Erlenmeyer flasks and then in agitated bioreactors by means of different microorganisms: mesophilic and moderate thermophilic bacteria at 37 and 50 – 55^{o}C, respectively, as well as by means of extreme thermophilic archaea at 75 – 90^{o}C. The highest extractions of gold and silver (over 90%) from the pre-treated concentrate were achieved by means of moderate thermophilic bacteria at 10 – 15% pulp density, and by the extreme thermophilic archaea at pulp densities of 10%. The mesophilic bacteria were efficient for the concentrate pre-treatment at pulp density of 20%.

Key words: gold; sulphide concentrate; microbial pre-treatment; chemolithothrophs

ПРЕДВАРИТЕЛНО МИКРОБНО ТРЕТИРАНЕ НА ЗЛАТОНОСЕН, ПИРИТЕН ФЛОТАЦИОНЕН КОНЦЕНТРАТ ПОСРЕДСТВОМ РАЗЛИЧНИ МИКРООРГАНИЗМИ

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РЕЗЮМЕ. Златоносен пиритен флотационен концентрат, съдържащ 23 g/t злато и 857 g/t сребро, бе подложен на микробиологично въздействие с цел разкриване на благородните метали от сулфидната матрица и последваща екстракция чрез различни агенти (тиосулфат, микробен белтъчен хидролизат, цианид). Предварителната обработка беше извършена в Ерленмайерови колби и след това в биореактори с разбъркване, посредством различни микроорганизми: мезофилни и умерени термофилни бактерии съответно при 37 и 50 – 55°C, както и чрез екстремни термофилни археи при 75 – 90° C. Най-висока екстракция на злато и сребро (над 90 %) от третирания концентрат бе постигната при използване на умерени термофилни бактерии при 10 – 15 % плътност на пулпа и при екстремни термофилни археи при плътност на пулпа 10%. Мезофилните бактерии бяха ефикасни при третиране на концентрата при 20% плътност на пулпа.

Ключови думи: *злато, сулфиден концентрат, микробиологично третиране, хемолитотрофи*

Introduction

The microbial pre-treatment of gold-bearing sulphide concentrates is a well-known and largely applied technological approach to liberate the gold (and silver) from the sulphide matrix and to make these precious metals accessible for the subsequent extraction by means of suitable reagents (mainly by cyanides but also by some relatively non-toxic reagents such as thiourea and thiosulphate). In most cases, these precious metals are present in pyrite and arsenopyrite but sometimes parts of them are present in other sulphides such as chalcopyrite and galena. Furthermore, it is well-known that considerable portions of other rare and expensive elements are also present in sulphides, including in the pyrite and arsenopyrite. This increases the interest in the application of the microbial pre-treatment as an efficient and economically acceptable way to facilitate the recovery of these elements from the relevant sulphides. At present, different species of chemolithotrophic bacteria and archaea are used in such investigations and even under industrial conditions characterised by microbial pre-treatment of the relevant mineral substrata at pulp densities from 10 to 30% and temperatures from 35 to 90^{o}C (Brierley, 1995; Lawrence and Bruynesteyn, 1983; Lazer et al., 1986; Groudev et al., 1995. 1996; Wan and Brierley, 1997).

This paper contains data about investigations on the microbial pre-treatment of a gold-bearing pyrite concentrate performed under different conditions (with respect to the temperature and pulp density) by means of different microorganisms (mesophilic and moderate thermophilic bacteria at 37 and 50–55^{o}C, respectively, and extreme thermophilic archaea at 75 and 90^{o}C) at pulp densities from 10 to 30%.

Materials and Methods

Data about the chemical composition of the flotation concentrate used in this study are shown in Table 1. Data about the phase composition of the precious metals in the concentrate are shown in Table 2.

Table 1.
Data about the chemical composition of the flotation concentrate used in this study

Component	Content, %	Component	Content, %
S total	5.90	Zn	0.17
S sulphidic	5.14	Pb	6.10
Fe	7.10	Au	23 g/t
Cu	1.70	Ag	875 g/t

Table 2.
Phase composition of the precious metals in the concentrate

Phases	Au	Ag
	Distribution, %	
Free metal	10.7	-
Metal encapsulated in iron oxides	30.2	35.0
Metal finely dispersed in sulphide minerals	54.5	60.2
Metal finely dispersed in silicates	4.6	4.8
Total	100.0	100.0

The microbial pre-treatment of the concentrate was performed initially in Erlenmayer flasks and then in agitated bioreactors with a 1.0 l working volume by means of different chemolithotrphs able to oxidize the sulphide minerals. The pretreatment was performed in 9K nutrient medium (Silverman and Lundgren, 1959) containing the concentrate in pulp densities from 10 to 30%. The duration of the pre-treatment was up to 7 days (168 hours) at the temperature relevant for the different microorganisms: at 37 and 50–55^{o}C for the mesophilic and moderate thermophilic bacteria, respectively, and at 75 and 90^{o}C for the extreme thermophilic archaea.

The leaching of the initial concentrate and of the concentrate pre-treated by means of microorganisms was performed by means of different reagents: microbial protein hydrolisate in the presence of $KMnO_4$ or H_2O_2 in concentrations of 5 g/l each; ammonium thiosulphate in a concentration of 10 g/l in the presence of copper ions (0.5 – 1.0 g/l); and sodium cyanide.

Elemental analysis of the waters was performed by atomic absorption spectrometry and by inductively coupled plasma spectrometry.

The isolation, indentification, and enumeration of microorganisms were carried out by the classical physiological and biochemical tests (Karavaiko et al., 1988) and by the molecular PCR methods (Escobar et al., 2008; Sanz and Köchling, 2007).

Results and Discussion

The direct chemical leaching of the precious metals from the concentrate, i.e. without its pretreatment by means of the microbial oxidation, was not efficient (only 12.0% of the gold and 6.2% of the silver were extracted in this way) (Table 3). At the same time, the levels of extraction of the precious metals from the concentrate subjected to microbial pretreatment before the leaching was very efficient (the same table). It was found that the level of sulphide oxidation higher than 35% during the pretreatment was sufficient to extract more than 95% of the gold and more than 90% of the silver during the subsequent chemical leaching.

Table 3.
Leaching of precious metals from the flotation concentrate by means of different reagents before and after its pre-treatment by means of microbial oxidation

Leach solution	Initial concentrate		Pre-treated concentrate	
	Au	Ag	Au	Ag
	Extraction, %			
Protein hydrolysate	10.9	8.6	16.4	12.2
Protein hydrolysate + chemical oxidiser:				
- $KMnO_4$	40.1	32.3	90.7	85.2
- H_2O_2	30.7	24.5	86.2	84.0
Thiosulphate	46.4	34.7	90.5	88.4
NaCN	48.0	37.4	91.4	89.1

It is known that the different chemolithotrophic microorganisms attack the defect sites in the relevant mineral structures preferentially. However, the rates of oxidation by the different microbial species and even by the different strains related to one and the same taxonomic species can be quite different. In this study, the rates of microbial oxidation during the concentrate pretreatment by means of the extreme thermophilic archaea were the highest in comparison with the oxidation rates achieved by means of the moderate thermophilic and by means of the mesophilic bacteria. However, these rates were achieved during the pre-treatment performed at the relatively low pulp densities (10 – 15%) of the concentrate (Table 4).

Table 4.
Effect of the pulp density of the concentrate pre-treated by means of different microorganisms on the efficiency of the subsequent extraction of the precious metals

Pre-treatment by means of different microorganisms	Pulp density, %					
	10		15		20	
	Extraction, %					
	Au	Ag	Au	Ag	Au	Ag
Mesophilic bacteria	95.0	91.4	94.1	90.5	92.3	88.0
Moderate thermophilic bacteria	97.2	92.0	95.0	90.9	90.5	88.5
Extreme thermophilic archaea	95.2	90.5	90.1	89.4	88.5	87.5

The highest rates of pre-treatment at the highest pulp densities (20 – 30%) were achieved by means of the moderate thermophilic bacteria. It must be noted, however, that the rates of microbial pre-treatment, i.e. the rates of microbial sulphide oxidation, at these highest pulp densities were lower than those achieved at pulp densities of about 15%.

The data obtained during this study revealed that the efficient pre-treatment of the gold-bearing sulphide concentrates can be achieved by means of selected chemolithotrophic microorganisms from the three essential groups based on their optimum temperatures for growth and oxidative activity, i.e. by means of mesophilic and moderate thermophilic bacteria and by means of extreme thermophilic archaea. However, it must be noted that each of these three groups of microorganisms contains strains which can be quite different from each other with respect to many of their essential properties. Furthermore, the conditions used during the concentrate pre-treatment, especially such as the optimum temperature for the microbial growth and activity, the optimum pulp density, as well as the character of all specific properties of the relevant gold-bearing sulphide concentrate, are essential for the efficiency and the real economic effect connected with the activity of this type.

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