TWO-STAGE MICROBIAL LEACHING OF COPPER AND PRECIOUS METALS FROM A SULPHIDE ORE

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ABSTRACT

A rich-in-pyrite copper ore containing also gold and silver as valuable components was treated by a two-stage microbial leaching. The leaching was carried out in a percolation PVC column containing 30 kg of ore crushed to minus 10 mm. The ore was firstly leached by means of acidophilic chemolithotrophic bacteria and 68.0% of the copper was solubilized in this way within 10 months. At the same time, a considerable portion of the precious metals which initially were finely disseminated in sulphide minerals was liberated from the sulphide matrix as a result of the bacterial oxidation. The dissolved copper was precipitated from the pregnant solutions by cementation with metallic iron. The oxidized ore was then leached by means of alkaline solutions containing amino acids of microbial origin and thiosulphate to solubilize the precious metals. 77.7% of the gold and 55.4% of the silver were solubilize in this way within 25 days. The pregnant solutions were treated by cementation with metallic zinc to precipitate the precious metals as mixed gold-silver concentrates.

INTRODUCTION

Different acidophilic chemolithotrophic bacteria are able to oxidize sulphide minerals to the relevant soluble sulphates (1-2). Such oxidation is used commercially to leach non-ferrous metals and uranium from mineral raw materials (ores and concentrates) and to liberate gold, which is finely disseminated in sulphide minerals (3-5). The liberated gold is then leached by different chemical reagents (mainly by cyanides) and or microbial metabolites. A very efficient leaching of gold from different mineral raw materials has been achieved by means of solutions containing amino acids of microbial origin and thiosulphate ions as gold-complexing agents (4-7). Leaching with such solutions is characterized by increased rates of gold and silver solubilization compared to these obtained by cvanidation. The final extraction of these metals by both methods are similar. However, the reagents used in this combined chemico-biological method are not toxic and the method as a whole is economically more attractive than cvanidation.

In this study a rich-in-pyrite copper sulphide ore containing gold encapsulated in sulphide minerals was initially treated by acidophilic chemolithotrophic bacteria to leach copper and to liberate the gold. The ore was then leached by solutions containing microbial amino acids and thiosulphate to solubilize the gold.

MATERIALS AND METHODS

Data about the chemical and mineralogical composition of the ore used in this study are shown in Table 1. Chalcopyrite was the main copper-bearing mineral in the ore but secondary copper sulphides such as covellite and bornite were also present. The ore was rich in pyrite and the total content of sulphides was about 10%. Most of the gold was finely disseminated in pyrite and chalcopyrite. The main portion of the gold particles was less than 1 micron. Quartz was the main mineral of the host rock.

The bacterial oxidative pretreatment and subsequent chemico-biological leaching of the ore were carried out in a PVC percolation column with an effective length of 800 mm and a 95 mm internal diameter. The column was charged with 30 kg of ore crushed to minus 10 mm.

Solutions containing acidophilic chemolithotrophic bacteria, iron ions (mainly in the trivalent state), some essential nutrients (mainly ammonium and phosphate ions), essential nutrients (mainly ammonium and phosphate ions), sulphuric acid and dissolved oxygen were pumped to the top of the column at a rate of 100 l/ton ore per 24 h. The pH of the columns effluents was adjusted to values in the range of 1.7 - 1.9 by addition of sulphuric acid. (MN₄)₂SO 4 and KH₂PO4 were added to produce final solutions concentrations of about 0.50 and 0.10 g/l, respectively/ The column effluents were treated in BACFOX units (8) in which the bacteria oxidized the ferrous ions to the ferric state under conditions of intensive aeration. The solutions were then recycled to the top of the column and were circulated continuously in this way allowing copper, iron and sulphate to accumulate. The pregnant column effluents were treated by cementation with metallic iron when their copper content exceeded 250 mg/l. The cementation was carried out in a reactor with mechanical stirring using iron shavings to precipitate the copper. The progress of the bacterial pretreatment of the ore was followed by analysis of the circulating solution for ferrous, ferric and total iron species, copper and sulphate ions, pH, Eh and number of iron-oxidizing chemolithotrophic bacteria.

Component	Content	Component	Content
Copper	0.32 %	Silver	9.1 g/t
Total sulphur Sulphide sulphur Sulphate sulphur	5.0% 4.7% 0.3%	Gold Gold phases (in % from the total gold content):	4.2 g/t
Iron	6.3%	 free gold gold encapsulated in iron hydroxides and oxides 	0.5% 12.2%
Sulphide minerals: - pyrite - chalcopyrite	8.5% 1.0%	 - gold finely disseminated in sulphides - gold finely disseminated in silicates 	84.8%
- other sulphides	0.5%	Total	2.5% 100.0%

Table 1. Data about the chemical and mineralogical analysis of the ore used in this study

After the sulphide oxidation and the copper leaching the ore was washed several times with fresh water and then was treated with solutions containing microbial protein hydrolisate – 1.0 g/l, thiosulphate ions (added as ammonium thiosulphate) – 15 g/l, copper ions (added as copper sulphate) – 0.5 g/l and sulphite ions – 0,5 g/l. The pH of the solutions was maintained in the range of the 9.5 – 10.0 by addition of ammonia. The protein hydrolysate was a mixture consisting of protein hydrolysates from waste biomass of three different microbial species. The hydrolysates contained different gold-complexing amino acids and were mixed together in suitable proportions.

The leach solutions were pumped to the top of the column as a rate of 200 l/ton ore per 24 h. The solutions percolated through the ore mass and dissolved gold and silver. The column effluents were treated by cementation with metallic zinc to precipitate the dissolved precious metals. The cementation was carried out in a fluidized-bed cementator which worked under continuous-flow conditions. The depleted solutions from the cementation unit were collected in a regeneration vessels where make up water and reagents were added to the desired levels. The leach solutions adjusted in this way were then recycled to the column.

RESULTS AND DISCUSSION

The treatment of the ore by means of the acidophilic chemolithotrophic bacteria was very efficient. Within a few days following initiation of the treatment, the column was densely populated with such bacteria. Acidithiobacillus ferrooxidans and Leptospirillum ferrooxidans were the prevalent microorganisms in the leach system. The total number of these bacteria in the circulating solutions was higher than 10⁸ cells/ml. However, most of the bacteria were firmly attached to the ore and their number exceeded 10⁹ cells/g ore in the upper ore layers.

68.0% of the copper was leached from the ore within 10 months of treatment (Figure 1). The treatment of the copperbearing pregnant column effluents by cementation was also efficient and cement copper concentrates containing about 80-82% copper were obtained in this way. The consumption of metallic iron during the cementation amounted to about 2.0 – 2.5 kg iron/kg copper.

The content of sulphidic sulphur in the ore at the end of the period of copper leaching was lowered to 2.1% and this reflected a degree of sulphide oxidation of about 55% (Figure 1). Preliminary experiments in small percolation columns (with 10 kg of ore each) revealed that this degree of sulphide oxidation was sufficient to liberate most of the gold from the sulphide matrix. This was probably to the fact that in the pyrite and chalcopyrite specimens present in this ore, like in many other similar cases, the gold was located mainly in the deffect sites of the sulphide crystal lattice and these sites were preferentially attacked by the chemolithotrophic bacteria (3). During the above-mentioned preliminary experiments it was found that the gold extraction from such pretreated ore samples exceeded 85%, while the extraction from the original, non-pretreated ore was less than 15%. It was also found that the rates of gold and silver solubilization obtained by the combined chemical and biological leaching were much higher those obtained by cyanidation, although the final

extractions obtained by cyanidation, although the final extractions obtained by the both methods were similar.



Figure 1. Leaching of copper (1) and degree of sulphide oxidation (2) by the chemolithtropic bacteria

The subsequent leaching of precious metals from the pretreated ore was also very efficient (Figure 2). 77.7% of the gold and 55.4% of the silver were solubilized in this way within 25 days. The number of undesired microbial contaminants

growing at the expense of the thiosulphate or of the amino acids in the leach system was low due to its relatively high pH.

The products from the cementation of the pregnant column effluents by Zn^o were mixed gold-silver concentrated which contained also copper and zinc as valuable components. These concentrates can be processed by the well-known conventional methods for recovering pure gold and silver.

The consumption of reagents during the leaching and cementation of the precious metals amounted to 4.1 kg ammonium thiosulphate, 0.25 kg protein hydrolysate, 0.8 kg copper sulphate and 0.14 kg metallic zinc per ton of ore.

The results from this study revealed that the subsequent leaching of copper and precious metals from rich-in-pyrite ores by means of microorganisms and non-toxic reagents is technically feasible and environmentally safe way to process such ores.



Figure 2. Leaching of precious metals from the pretreated ore

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