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A COMBINED CHEMICAL AND BIOLOGICAL HEAP LEACHING OF AN OXIDE GOLD-BEARING ORE

A heap consisting of an oxide gold-bearing ore containing 3.5 g/t of gold and 14.0 g/t of silver was leached by solutions containing amino acids of microbial origin and thiosulphate as gold-complexing agents. 68.4% of the gold and 53.6% of the silver were leached within 20 days in this way. The pregnant solutions after leaching were treated by cementation with metallic zinc. Mixed gold-bearing concentrates containing also zinc and copper as valuable components were the products from the cementation.

Key words – gold leaching, microbial amino acids, gold cementation

INTRODUCTION

It has been shown that a very efficient leaching of gold from ores is achieved by means of alkaline solutions containing both amino acids and thiosulphate as complexing agents as well as some ions acting as catalysts in the oxidation of the native gold to an ionic state and/or in the complexation of the gold ions (Groudev and Groudeva, 1993; Groudev et al., 1993; Groudev et al., 1994). In the presence of amino acids the leaching rates and the final extractions of gold are similar to those obtained by solutions containing only thiosulphate as gold-complexing agent but the optimum concentrations and overall consumption of thiosulphate are lower than those in the absence of amino acids. The optimum composition of the leach solution depends on the mineralogical composition and some essential properties of the ore being leached, such as the type of the mineralisation, phase distribution of the gold and acid generation and net neutralization potentials. However, in any case, apart from the amino acids and thiosulphate, the presence of copper, ammonium and sulphite ions is essential for achievement of an efficient leaching.

The ability of the different amino acids to form stable complexes with the gold is different. The formation of such complexes involves nitrogen of the amino group but other functional groups may also participate. Silver is solubilized together with gold during the leaching.

The future industrial application of this method is connected mainly with the fact that the amino acids and thiosulphate are not toxic reagents. Furthermore, the leaching by means of solutions containing both amino acids and thiosulphate is characterized by higher rates of gold and silver solubilization than those obtained by cyanidation although the relevant final extractions of these precious metals by the both methods are similar.

The above-mentioned leaching method is economically more attractive than the cyanidation only in the cases when cheap sources of efficient gold-complexing amino acids are available. Protein hydrolysates obtained after hydrolysis of waste microbial biomass with a suitable amino acid composition has been used as such sources (Groudev et al., 1994).

In 1993-94 the method was applied under pilot scale conditions as heap leaching in two Bulgarian gold deposits (Groudev et al., 1994; Groudev et al., 1995) and a commercial scale operation was commissioned recently at the Elshitza gold deposit. Some data about the heap leaching of an ore batch from this deposit are shown in the present paper.

MATERIALS AND METHODS

The ore consisted of secondary, highly modified quartzites, with a high content of iron oxides (Table 1). The ore contained 3.5 g/t of gold, which was present mainly as clean-fine-grained particles and as particles encapsulated in iron oxides. The size of particles was less than 2 microns. Only small part of the gold was finely disseminated in sulphide (mainly pyrite) and silicate minerals. The ore contained also 14.0 g/t of silver.

A heap containing 1000 tons of the above-mentioned ore crushed to minus 15 mm was formed on a slightly steep ground covered by corrosion-resistant cement to facilitate the collection and to prevent the seepage of solutions. The heap had the shape of a truncated pyramid and was 15 m long, 1.80 m high, 12 m wide at the top end and 16 m wide at the bottom end.

The ore was initially treated by alkaline solutions (with a pH in the range of 10.0 - 10.5 by addition of ammonium hydroxide) which were pumped to the top of the heap and after percolation through the ore mass and readjustment of the pH were recycled to the heap. When the pH of the heap effluents was stabilized in the range of 10.0 - 10.5, the leaching of the precious metals was started with leach solutions

containing protein hydrolysate from microbial biomass (at a concentration from 0.5 to 1.0 g/l), thiosulphate ions (added as ammonium thiosulphate) - from 10 to 20 g/l, copper ions (added as $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) - from 0.1 to 0.3 g/l, sulphite ions (added as ammonium sulphite) - from 1.0 to 2.0 g/l. The pH of the solutions was maintained in the range of 10.0 - 10.5 by addition of ammonium hydroxide.

Table 1. Data about the chemical analysis of an oxide ore sample from the Elshitzza gold deposit
Tabela 1. Analiza chemiczna tlenkowej rudy złota ze złoża Elshitzza

Component	Content	Component	Content
SiO_2	56.70 %	Silver	14.0 g/t
Fe_2O_3	18.45 %	Gold	3.5 g/t
Al_2O_3	5.03 %	Gold phases (in % from the total gold content):	
CaO	1.85 %	-free gold	-
MgO	1.67 %	-gold encapsulated in iron oxides (recoverable by cyanidation)	91.25 %
S total	0.78 %	-gold finely disseminated in sulphides	4.40 %
S sulphatic	0.64 %	-gold finely disseminated in silicates	3.75 %
Cu	0.09 %	-Total	100.00 %
Zn	0.03 %		
Pb	0.01 %		
Mn	0.01 %		

The protein hydrolysate consisted of a mixture of protein hydrolysates from waste biomass of three different microbial species. Each hydrolysate contained different gold-complexing amino acids and the hydrolysates were mixed in suitable proportions to obtain the above-mentioned mixture.

The leach solutions were pumped to the top of the heap at rates in the range of 150 - 200 l/ton ore.24 h. The solutions were introduced onto the heap by means of spraying, using plastic sprinkler heads.

The solutions percolated through the heap and dissolved gold and silver. The heap effluents were collected in a collection pond and then were treated by pre-coat clarification to remove the suspended solids. During the treatment, a partial removal of dissolved oxygen was achieved. Then solution entered a vacuum tower, where the deoxygenating was completed. The vacuum deaeration also removed carbon dioxide.

The clarification and deaeration of the pregnant solutions were essential steps in the flowsheet of the technology because the suspended solids and the dissolved oxygen cause passivation of the zinc surface and drastically reduce the efficiency of the subsequent cementation during which the precious metals were precipitated from the solutions being treated. The carbon dioxide can react to form calcium carbonate and blind precipitate filters.

The clarified, deaerated, pregnant solutions were pumped to the cementation unit where the dissolved precious metals were precipitated by means of cementation reactions with metallic zinc. Lead nitrate was added to facilitate the cementation. The cementation unit consisted of two fluidized-bed cementators, which worked simultaneously but independently from each other under continuous-flow conditions. The depleted solutions from the cementation unit were collected in a regeneration pond where make up water and reagents were added to the desired levels. The leach solutions adjusted in this way were recycled to the heap.

After the end of the leaching the ore was washed with water and a sampling was carried out to determine the residual contents of gold and silver in the different classes of ore particles.

All analytical procedures used in this study have been described earlier (Groudev et al., 1995).

RESULTS AND DISCUSSION

The leaching of precious metals from the heap was very efficient (Figure 1 and Table 2). 68.4% of the gold and 53.6% of the silver were leached within 20 days. The degree of extraction highly depended on the size of the ore particles (Table 2). The concentrations of the dissolved gold and silver during the first five days of the leaching exceeded 2 mg/l and 5 mg/l, respectively. The concentrations of heavy metals other than gold, silver and copper in the pregnant solutions were very low (less than 1 mg/l) regardless of the fact that the ore contained some of these metals (namely, zinc, lead, cadmium, manganese and iron) in concentrations much higher than those of the precious metals (gold and silver). However, part of the copper initially present in the ore was solubilized during the leaching and this

reduced the amount of copper added from outside to the leach solutions as gold oxidizing agent.

The pH of solutions during their percolation through the ore heap decreased by 0.1 - 0.3 points and the evaporation rates amounted to about 10%.

Table 2. Particle size analysis of the ore before and after the leaching of the heap

Tabela 2. Analiza składu ziarnowego rudy przed i po ługowaniu na hałdzie

Ore size, mm	Yield, %		Gold content, g/t		Gold extraction, %
	I	II	I	II	
+ 15	8.2	7.7	2.8	2.1	25.0
- 15 + 10	16.8	17.7	3.1	1.5	50.1
- 10 +4	24.9	25.5	3.4	1.1	68.0
- 4	50.1	49.1	3.8	0.8	78.9
Total	100.0	100.0	3.5	1.1	68.4

Note: I - Before leaching;

II - After leaching.

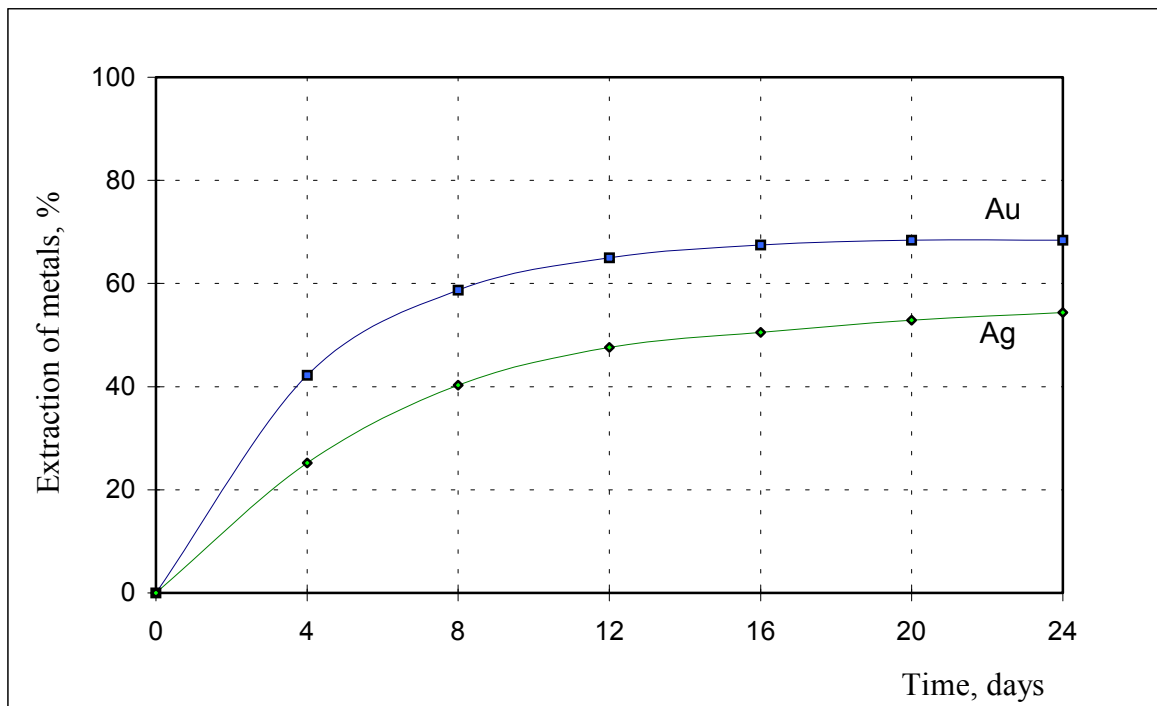


Figure 1. Combined chemical and biological leaching of a gold bearing ore.
Rys. 1 Kombinowane chemiczne i biologiczne ługowanie rudy złotonośnej.

It was found that different chemolithotrophic bacteria and heterotrophic microorganisms grew in the ore heap and in the recycled solutions. Most of the chemolithotrophs were related to the species *Thiobacillus thioparus* and they grew at the expense of the thiosulphate. The heterotrophs grew mainly at the expense of the amino acids in the leach solutions. Most of these microorganisms were related to the genera *Bacillus* and *Pseudomonas*. Some moulds and yeasts were also present.

However, it was possible to eliminate to a great extent these undesirable microorganisms by maintaining the pH of the leach solution to levels higher than pH 10.0. In such cases the total number of the microbial contaminants was lower than 10^3 cells/ml and their negative effect on the reagent consumption was negligible.

The degree of extraction of the precious metals from the pregnant solutions by cementation was higher than 95%. The products from the cementation unit were mixed gold-silver concentrates which contained also zinc and copper as valuable components. The leaching of these concentrated by sulphuric acid at high temperatures (75 - 80°C) and in the presence of oxygen resulted in selective dissolution of the zinc and copper. These non-ferrous metals were recovered from the pregnant solutions after leaching. The contents of gold and silver in the final concentrates obtained after the removal of zinc and copper were higher than 15 kg/ton and 50 kg/ton, respectively. These concentrates were then processed by the conventional procedure for obtaining pure gold and silver.

The consumption of reagents during the leaching and cementation amounted to 8.2 kg ammonium thiosulphate, 0.3 kg protein hydrolysate, 1.0 kg copper sulphate and 0.14 kg metallic zinc per ton of ore.

In the near future the above-mentioned combined chemical and biological leaching will be applied for recovering gold and silver also from sulphide ores initially subjected to oxidative pretreatment by means of chemolithotrophic bacteria.

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Hałda tlenkowej rudy złotonośnej, która zawiera 3,5 g/t złota i 14,0 g/t srebra była ługowana roztworami zawierającymi aminokwasy pochodzenia biologicznego (produkowane przez mikroorganizmy i tiosiarczany jako odczynniki kompleksujące złoto. 68,4 % złota i 53,6 % srebra zostało wylugowane w ciągu 20 dni. Roztwory po ługowaniu były poddawane procesowi cementacji z użyciem metalicznego cynku. Mieszane koncentraty złotonośne zawierające cynk i miedź zostały otrzymane po procesie cementacji.