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COPPER RECOVERY FROM ORE DUMPS BY ACIDITHIOBACILLUS FERROOXIDANS

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ABSTRACT: Acidithiobacillus ferrooxidans is lithotrophic microorganism involved in many transformation and cyclic reactions of elements in nature, with an important role in biochemical cycles of sulfur and iron. Natural ability of this microorganism has been widely used by man in processes of metal exploitation. More precisely, to convert low-soluble metal compounds, mostly sulfides, into solutions. Practically, naturally occurring reactions have been directed and enhanced, in such a way to get useful metals, mostly from low-grade metal ores and waste materials. By the means of microbial leaching solution, in the case when the type of ore and the geological characteristics of the soil are suitable, it is possible to recover certain metals with minimum investment and threats to environment. In order to extract copper from ore dumps, microbial leaching has been conducted in laboratory using the culture of Acidithiobacillus ferrooxidans. Samples were taken from twelve different locations on Bor ore dumps. Leaching experiments were performed by the shake flask testing technique at 28^{0}C, during two-week period. Parameters, like solid-liquid ratio, number of bacteria, rate of leaching, physical and chemical characteristics of ore, were determined. Obtained results show 7.5-fold higher copper leaching efficiency in the suspension with Acidithiobacillus ferrooxidans, then in control suspension. Microbial leaching of low-grade ores and ore dumps plays very important role in the concept of environmental protection, because it allows use of relatively simple technology to control and redirect uncontrolled loss of metals into the soil and water-streams.
KEYWORDS: Acidithiobacillus ferrooxidans, leaching, ore dumps

INTRODUCTION

Lithotrophs are involved in many transforming and cyclic reactions of elements in nature, having an importan role in biochemical cycles of sulfur and iron, as well of nitrogen and other elements. The term "lithotroph" is created from the terms "lithos" (rock) and "troph" (consumer), meaning the "eaters of rock".

By the means of microbial leaching solutions, in the case when the type of ore and the geological characteristics of the soil are suitable, it is possible to recover certain metals with minimum investment and threats to environment. It is usually utilized when conventional mining procedures are too expensive or ineffective in recovering a metal such as copper, gold, lead, nickel and zinc [1, 2].

According to the international experience biomining of sulfide minerals is an established global biotechnology for recovering gold and copper.

Up to this point, significant number of procedures for metal recovery by microbial leaching had been developed, and almost all of the most important technological and biological parameters which affect the efficiency of leaching metals are well known. However, it should be noted that those parameters are different in each case, and that they are dependant on the characteristics of region and type of mineral raw material. Each specific case of bacteria application in leaching system requires detailed study of mineral raw material which is to be treated, environmental conditions for leaching and the microflora which will be used. It is recommended to use native bacterioflora in order to intensify the already existing natural processes [3].

In order to extract copper from ore dumps, microbial leaching has been conducted in laboratory using the culture of Acidithiobacillus ferrooxidans. Samples were taken from twelve different locations on Bor ore dumps.

Leaching experiments were performed by the shake flask testing technique at 28^{0}C, during two-week period. Parameters, like solid-liquid ratio, number of bacteria, rate of leaching, physical and chemical characteristics of ore, were determined.

The obtained results should serve as a basis for reuse this widely accepted technology for exploitation of mineral row materials in order to obtain useful components from poor ores as well as for remediation of contaminated soils.

EXPERIMENTAL. Chemical analysis of the ore dumps

Silicate analysis of the ore dumps was conducted using the conventional method, by alkaline fusion with $NaKCO_3$ and dissolution in HCl [4]. From the filtrate Fe, Al, Ti, Ca and Mg, were determined while the residue was further treated with HF in order to obtain volatile SiF_4, from which the SiO_2 content was determined. The remaining precipitate was treated again as silicate material. For the determination of alkaline metals and trace elements, the sample was decomposed with a mixture of $HClO_4$ and HF, while for the determination of phosphorus, the sample was decomposed with a mixture of aqua regia and $HClO_4$.

The alkaline metals were determined by atomic emission flame spectrophotometry; Fe, Al, Ti, Ca, Mg and trace metals by atomic absorption flame spectrophotometry, while phosphorus was determined by spectrophotometry, as yellow phosphomolybdate complex.

X-ray diffraction (XRD) analysis

The XRD patterns were obtained on a Philips PW-1710 automated diffractometer using a Cu tube operated at 40 kV and 20 mA. The diffraction data were collected in the 2θ Bragg angle range from 5 to 60°, counting for 0.5 s at every 0.02° step. The divergence and receiving slits were fixed at 1 and 0.1 units, respectively. The XRD measurements were performed at room temperature in a stationary sample holder. The minerals were determined using MPDS software and JCPDS diffraction library.

Leaching experiments

The leaching experiments were carried out with bacterium Acidithiobacillus ferrooxidans from the microorganism collection of the Department of Chemistry, ICTM, Belgrade. Experiments were carried out within leaching period of 14 days. Volume of 100 ml of leaching solution was used, with following content (g/dm3): $Fe(SO_4)_2$ (44.8), $(NH_4)_2SO_4$ (3), K_2HPO_4 (0.5), $MgSO_4 \cdot 7H_2O$ (0.5), KCl (0.1), Ca(NO3)2 (0.01), (9K) at a pH of 2.5 in 500mL Erlenmeyer flasks at a pulp density of 10% (m/V) (10 g leaching substrate in 100 ml solution).

The initial number of microgranisms was $8.5x10^8$ per ml, determined by the Most Probable Number Method [5]. The control suspension had the same chemical content and pH value as the suspension with A. ferro-oxidans, but the A. ferro-oxidans culture had been inactivated by sterilization. Experiment was performed on a horizontal shaker New Brunswick Scientific.

The incubation temperature was 28°C and the rotation speed 100 rpm.

RESULTS AND DISCUSSION

X-ray diffractogram of ore dumps is shown on Figure 1.

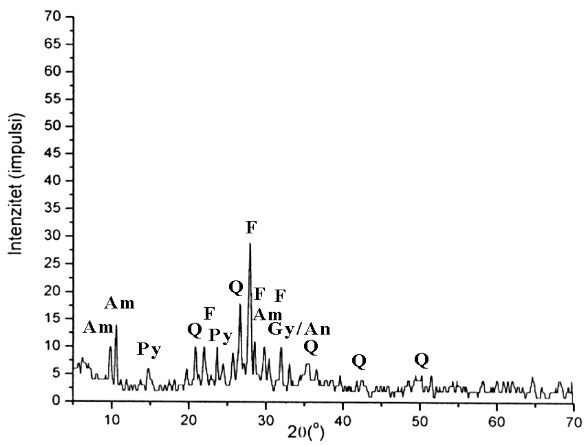

Figure 1. XRD diffractogram of ore dumps. Q-quartz; F- feldspars; Am-i amphibole; Py- pyrite; Gy/An- gypsum/anhydride

Occurrence of gypsum and quartz are good indicators for biogeochemical activity of bacteria, such as flushing of alkaline and alkaline earth metal components. These metal components remain in matrix as insoluble metal minerals identified by X-ray diffraction analysis. Chemical analyses of ore dumps are presented in Table 1.

Table 1. Chemical analyses of ore dumps

SiO_2 %	Al_2O_3 %	CaO %	MgO %	Na_2O %	K_2O %	S %	P_2O_5 %
58.92	15.12	2.98	0.91	0.90	1.12	2.96	0.071
Fe_{uk} %	Fe^{2+} %	Cu %	Cu_{ox} %	Zn %	Pb %	MnO %	LOI %
8.60	4.70	0.205	0.015	0.060	0.15	0.028	6.99

Table 2. Content of Cu in solution and pH, after 14 days leaching

	Cu (mg/l)	pH
Suspension with A. ferrooxidans	155	1.84
Control suspension	21	3.92

Table 3. Percentage of Cu leached after 14 days

	Suspension with A. ferrooxidans	Control suspension
Content of Cu in ore dumps (ore dumps before)	0.205 %	0.205 %
Content of Cu in ore dumps after leaching (ore dumps after)	0.074 %	0.187 %
Effective leaching	64 %	8.5 %

Gathered results, presented in Table 2, show that at the end of the experiment, in Erlenmeyer flask in which was 9K solution with bacteria, concentration of copper increased, while the pH of solution decreased compared with baseline. In the Erlenmeyer flask No. 2 (control) in which was only 9K solution, acid leaching was observed. In other words soluble minerals were dissolved by acidic solution.

Obtained results show 7.5-fold higher copper leaching efficiency in the suspension with Acidithiobacillus ferrooxidans, then in control suspension.

CONCLUSIONS

Microbial leaching is an inexpensive method for treatment of poor secondary copper sulfide ores. Therefore, it would be significant and beneficial, for country like Serbia, to focus scientific and technical efforts toward separation of useful components from raw materials by this method. Furthermore, microbial leaching of low-grade ores and ore dumps also plays very important role in the concept of environmental protection, because it allows use of relatively simple technology to control and redirect uncontrolled loss of metals into the soil and water-streams.

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