

# Research of the Application of Roasting in the Processing of the Foamy Product of the Process of Bacterial Oxidation of Flotation Concentrate in a Separate Cycle

*Rustam Khamidov*<sup>1</sup>, *Zhakhongir Narzullayev*<sup>1</sup>, and *Evgeniy Kuznetsov*<sup>2,\*</sup>

<sup>1</sup>Navoi State Mining Institute, 210100, Navoi, St. Galaba 27, Uzbekistan

<sup>2</sup>T.F. Gorbachev Kuzbass State Technical University, Mezhdurechensk Branch, 652881, 36 Stroiteley av., Mezhdurechensk, Kemerovo region-Kuzbass, Russia

**Abstract.** Among the methods of preliminary opening of refractory gold before sorption cyanidation, the technology of bacterial oxidation is widely used today. Although this technology has many advantages, the specialists of most enterprises around the world using this technology are faced with the problem of foaming in bio-oxidation reactors. This article discusses the possibility of using oxidative roasting in the processing of the foam product of the process of bacterial oxidation of flotation concentrate in a separate cycle.

## 1 Introduction

Everyone is well aware of the widespread use of gold in human life, the need for it only increases over the years. However, the reserves of gold that can be easily processed are inexorably depleted, and hard-to-process refractory ores are involved in processing [1-3]. At present, the processing of refractory gold sulfide ores and concentrates abroad is carried out using methods of preliminary roasting, autoclave or bacterial leaching followed by cyanidation [4, 5]. There are also known methods of opening refractory gold such as ultrafine grinding, microwave irradiation, electrohydraulic processing, magnetic pulse processing, etc. [6-9]. Bacterial leaching is the simplest and least expensive technology [10].

Batch foaming is a problem in most bio-oxidation plants. An increase in the level of foam reduces the useful working volume of the reactors, which leads to a decrease in the process time and an increase in the residual sulfur in the bio-oxidation product [11].

Increased foaming leads to the removal of metal from the process into the foam product and its accumulation in the sump of bio-oxidation reactors. The return of the product from the tray to the bio-oxidation process leads to an increase in the pulp flow through the reactors, thereby further reducing the bio-oxidation time and causing an increased carryover of the bacterial culture from the reactors, which also leads to an increase in residual sulfide sulfur [12].

---

\* Corresponding author: [kevlad@mail.ru](mailto:kevlad@mail.ru)

## 2 Materials and Methods

In order to study the structural characteristics of the foam, samples were taken from bio-oxidation reactors and a study was carried out to determine its composition. The X-ray powder diffraction pattern of a foam sample from bio-oxidation reactors indicates the presence of the following minerals in the sample: pyrite, arsenopyrite, quartz, muscovite / illite, albite, chlorite, stibnite, jarosite, gypsum double-water, talc, anatase, czomolnokite, mercallite, graphite, sulfur, copiapite. X-ray phase analysis in the foam also revealed hematite, chalcocite, gypsum, calcite, chalcocite, alum, soda, dolomite, halite, goethite, and sphalerite.

The total amount of pyrite and arsenopyrite in the sample is 20.4%. Moreover, arsenopyrite is much less than pyrite, which indicates the oxidation of arsenic in the process of bio-oxidation.

The amount of graphite carbon is about 4.6%. A high amorphous background indicates a high content of an amorphous substance in the sample, most likely carbon. There are iron sulfates in the form of jarosite, copiapite, somolnokite, mercallite and gypsum. Antimony sulfide mineral, antimonite, is also observed. Elemental sulfur is also observed in the sample. Mass percentages of minerals in a foam sample from BIOX reactors, calculated as a result of Rietveld's refinement, are shown in Table 1.

**Table 1.** Mass percentages of minerals in a foam sample from BIOX reactors, calculated as a result of Rietveld's refinement.

Mineral	Content, %
Pyrite	19.5
Arsenopyrite	0.9
Quartz	12.4
Muscovite / Illite	29.8
Albite	9.4
TiO <sub>2</sub>	2.1
Chlorite	2.2
Stibnite	0.8
Jarosit	1.3
Gypsum dihydrate	0.6
Talc	5.53
Anataz	1.46
Szomolnokit	2.2
Mercallite	2.55
Graphite	4.64
Sulfur	2.15
Copiapite	2.67

The content of the main valuable component of gold was determined by the method of assay analysis. It was found that the gold content in the primary reactors is about 44 g / t

and its value increases towards the last reactor, where the gold content reaches 286 g / t. The sample contains silver, the average content of which is about 98 g / t. Sulfur and carbon contents were determined by combustion on a LECO analyzer, and their values are 10-15% and 7-20%, respectively (Table 2).

**Table 2.** Initial data of foam bioreactors.

Sample name	Content of elements in samples					
	Au, g / t	Ag, g / t	S <sub>total</sub> , %	Ss, %	C <sub>total</sub> , %	C <sub>org</sub> , %
Reactor – I, II, III (primary)	44.3	34.7	15.29	10.99	7.09	5.78
Reactor – IV	183.5	88.63	18.04	11.94	18.26	15.48
Reactor – V	230.2	116.1	15.76	10.01	17.14	16.44
Reactor – VI	286.5	164	10.57	6.83	20.29	19.7

The above factors confirm the feasibility of the way of withdrawal and separate processing of foam from bio-oxidation reactors. The high content of sulfur and carbon indicates the need for oxidative roasting with further sorption cyanidation of the cinder [13]. The results of research on firing the foam product of bio-oxidation reactors followed by sorption cyanidation are presented in Table 3. The studies were carried out on a sample taken from reactor 6, since it has the highest content of the valuable component.

**Table 3.** Results of firing the foam product of bio-oxidation reactors followed by sorption cyanidation.

Sample name	Au, g / t	Ag, g / t	S <sub>total</sub> , %	Ss, %	C <sub>total</sub> , %	Gold recovery during sorption cyanidation of cinder, %
Reactor – VI	Content of elements before roasting					93.17
	286.5	10.57	6.83	20.29	19.7	
	Content of elements after roasting					
	328.10	2.23	0.06	0.17	0.08	

### 3 Results

Studies on the separate processing of the foam product of the bio-oxidation process have shown that sulfide sulfur and organic carbon are almost completely oxidized, releasing the gold contained in them, which is confirmed by the high extraction of the valuable component of 93.17% during sorption cyanidation. Thus, the expediency of processing the foam product of the bio-oxidation process in a separate cycle with metal recovery up to 93.17% has been proved. It is expected that the process of sorption cyanidation of biokek will also show a relative increase, since the main part of the sorption active natural carbon in the pulp is concentrated in the bio-oxidation foam.

## 4 Discussion

Due to the separate processing of the foam product of the bio-oxidation process, the problem of the formed foam during the process is solved, and, as a result, the efficiency of the bacterial oxidation process increases.

## References

1. W.J. Li, Y.S. Song, Y. Chen, L.L. Cai, G.Y. Zhou, IOP Conf. Series Mater. Sci. Eng., **231**, 12169 (2017)
2. X. Guo, Y. Xin, H. Wang, Nonferrous Metals Soc. China, **27**, 1888-1895 (2017)
3. A.Ya. Baudouin, S.B. Fokina, G.V. Petrov, M.A. Serebryakov, Modern problems of science and education, **6** (2014) URL: <https://www.science-education.ru/ru/article/view?id=15619>
4. R.K. Asamoah, W. Skinner, J. Addai-Mensah, Powder Technol. **331**, 258-269 (2018)
5. Xu Wang, Wenqing Qin, Fen Jiao, Congren Yang, Yanfang Cui, Wei, Zhengquan Zhang and Hao Song, *Mineralogy and Pretreatment of a Refractory Gold Deposit in Zambia* (Minerals, Manchester, 2019). URL: <https://www.mdpi.com/2075-163X/9/7/406/pdf>
6. O. Celep, P. Altinkaya, E.Y. Yazici, H. Deveci, *Effect of ultrafine-grinding on cyanide leaching of copper bearing pyritic gold concentrate* (15th International Mineral Processing Symposium, Istanbul, 2016)
7. S. Ellis, *Ultra-Fine Grinding - A Practical Alternative to Oxidative Treatment of Refractory Gold Ores*. URL: <https://www.isamill.com>
8. Choi N.C., Kim B.J., Cho K., Lee S., C.Y. Park, Metals, **1**, 404 (2017)
9. Xiaoliang Zhang, Chunbao Sun, Yi Xing, Jue Kou, Min Su, Hydrometallurg, **180**, 210-220 (2018)
10. L.N. Krylova, K.A. Wigandt, L.E. Sarokhanova, E.V. Adamov, Zheng Zhihong, Non-ferrous metals, **11**, 26 (2013)
11. K.S. Sanakulov, U.A. Ergashev, R.A. Khamidov, *Foaming problem in biooxidation reactors* (UGDS, Tashkent, 2020)
12. K.S. Sanakulov, U.A. Ergashev, K.U. Gafurov, Mining Journal, 1(special issue), 58-63 (2017)
13. J. Hammerschmidt, J. Guntner, B. Kerstiens, A. Charitos, *Roasting of Gold Ore in the Circulating Fluidized-Bed Technology in Gold Ore Processing* (Adams, London, 2016)