18th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2014, Budapest, Hungary 10-12 September, 2014

LEACHING OF FLOTATION TAILINGS

Ljiljana Avramović
Radojka Jonović
Dr. Mile Bugarin
Dr.Radmila Marković
Mining and Metallurgy Institute Bor
Zeleni bulevar 35, Bor
Serbia

Dr. Jasmina Stevanović
Marko Jonović
University of Belgrade, Institute of Chemistry, Technology and Metallurgy
Njegoševa 12, Beograd
Serbia

ABSTRACT
This paper contains an experimental study of the leaching process of flotation tailings in the aim of valorisation the present copper. The results obtained after experimental studies indicate that the presence of oxide forms of copper in tailings has a crucial impact on the acid leaching process of copper. The present copper oxide forms are completely leached in the experimentally determined optimal parameters of the process: time: 4 hours, temperature: 80°C, the ratio of solid: liquid is 1:2.5, pH of leach liquor is 1. The degree of copper leaching was about 60%, which is exactly the participation of oxide copper forms regarding to the total copper content of the flotation tailings. Mine waste water from the accumulation Robule were used as leaching solution with pH correction, what is a special contribution to solving the environmental problems using the integrated treatment of mine wastewater and tailings.
Keywords: *flotation tailings, leaching, copper*

1. INTRODUCTION
The off-balance resources present the environmental problem and potential resource for copper extraction. The most commonly used method in the world for copper valorization from off-balance mine resources is the hydrometallurgical process. The method consists of the following stages: comminuting, leaching, solvent extraction and electrolytic copper extraction. Hydrometallurgical treatment is applied in the countries (USA, Chile, Australia, and Peru), which have readily available off-balance deposits with low content of copper and with more oxide forms of [1.2]. Copper, present in the off-balance resources in the municipality of Bor, created during centuries of mining and processing of copper ore, presents an important economic resource if it is valorized in an appropriate way with affordable and sustainable technology. Otherwise, it presents the major generator of contaminated mine water that directly flow into the basin of the Bor River, with a significant impact on the quality of water downstream of the river Timok, and further to the Danube River [3-9]. This paper work deals with the physic-chemical and mineralogical characterization of the flotation tailing dump and chemical characterization of the mine waste water from the accumulation Robule. Technological composite samples are formed for laboratory testing of the leaching process of copper. The parameters of agitation leaching of flotation tailings with the mine waste water from the accumulation of Robule were defined.

2. EXPERIMENTAL TESTING AND DISCUSSION OF THE RESULTS

A sample of tailings from depth of 17 m was used for experimental testing from eight drill holes and a composite sample was made such as the same amount of tailings was taken from each drill hole (Figure 1).

Figure 1. Composite sample of flotation tailings prepared for experimental testing

Chemical content of a composite sample of tailings is shown in Table 1. Grain size distribution of a composite sample of the Bor flotation tailings is shown in Table 2.

Table 1. Chemical content of a composite sample of flotation tailings from depth of 17m

Element	Content, %	Element	Content %
Cu, total	0.43	Au, g/t	<0.05
Cu, ox	0.18	Ag, g/t	0.8
Fe	16.56	Hg, g/t	0.2
Cd	<0.0004	Pb	0.073
S	18.15	Zn	0.017
As	0.022	Mn	0.005
		Cr	<0.001

Table 2. Grain size distribution of a composite sample of the Bor flotation tailings

Sieve mesh, mm	+0.295	+0.208	+0.147	+0.104	+0.074	-0.074+0
Sample mass, %	1.3	4.6	7.9	10.1	8.2	67.9

Based on the qualitative-quantitative mineralogical analysis, the presence of pyrite (21.57%) was determined as the dominant sulphide mineral and then the other minerals: covellite (0.21%), enargite-sulphoarsenate of copper (0.14%), chalcopyrite (0.15 %), chalcocite (0.04%), bornite (0.02%), tetrahedrite (0.02%), rutile (0.30%), limonite (0.30%), magnetite (0.09%), leucoxene (0.08%), sphalerite (<0.01%), luzonite (<0.01%), arsenopyrite (<0.01%), molybdenite (<0.01%) and malachite (<0, 01%), and minerals in tailings (77%), which are mainly present as quartz, silicate, and carbonate.

Table 3. Results of carried out leaching test and TCLP test on a sample of flotation tailings

Element	Unit measure	Content		
		Leaching test	TCLP test	MDK of water(for III and IV class)*
Cu	mg/l	200	96	0.1
Fe	mg/l	270	110	1.0
Pb	mg/l	<0.1	<0.1	0.1
Zn	mg/l	14	6.7	1.0
Mn	mg/l	3.1	1.7	/
Ag	mg/l	<0.02	<0.02	/
As	mg/l	<0.1	<0.13	0.05
Hg	mg/l	<1	<1	0.001

**Regulations on Hazardous Substances in Water (Official Gazette of SRS, No.31/82)*

Leaching test and TCLP (Toxity Characteristic Leaching Procedure) test were carried out on a composite sample of flotation tailings. Test results are shown in Table 3.
Based on the results of leaching test (conducted according to the standard procedure SRPS EN 12457-2) and the TCLP test (conducted according to the standard procedure of EPA Test Method 1311), where the concentrations of heavy metals are several hundred times higher than the legally prescribed MRLs values, it can be concluded that the tailing dump present the major environmental problem for the surrounding waterways.
Experimental testing the leaching process of flotation tailings in order to determine the optimal parameters of copper extraction were performed on a laboratory scale.
Samples from flotation tailing dump were treated by the agitation leaching method. The mine water from the accumulation Robule (mine waste water) was used as leaching solution with the following chemical composition: Cu-69,10 mg/dm^3; Pb <0.05 mg/dm^3; Zn-26.30 mg/dm^3; Cd-0.12 mg/dm^3; Ni-0.34 mg/dm^3; Cr<0.02 mg/dm^3; Se<0.020 mg/dm^3; As<0.010 mg/dm^3; Fe-739.00 mg/dm^3; suspended matters 12.0 mg/dm^3; $SO4^{2-}$ -8243,10 mg/dm^3.
The content of metals in mine water from the accumulation Robule is above the legally prescribed maximum allowed values, and the measured pH value of 3.5 indicates the acidic character of waste water. Before leaching, pH value of mine waste water was corrected to pH = 1 with concentrated sulfuric acid.
The experiments were performed in a laboratory glass reactor with mechanical stirring. The leaching results of samples of the old flotation tailing dump are shown in Figures 2, 3 and 4. The highest degree of copper leaching of 56.21% was achieved at temperature of 80^{o}C.

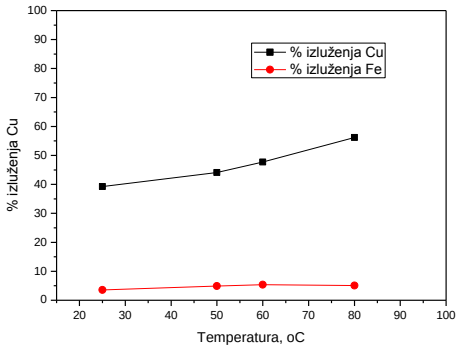

Figure 2. Dependence of copper leaching degree on temperature in relation S:L = 1:2.5, pH = 1, time: 4h

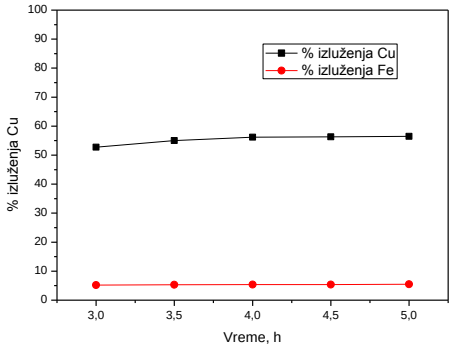

Figure 3. Dependence of the copper leaching degree on leaching time in relation S:L = 1:2.5, pH = 1, temperature: 80^{o}C

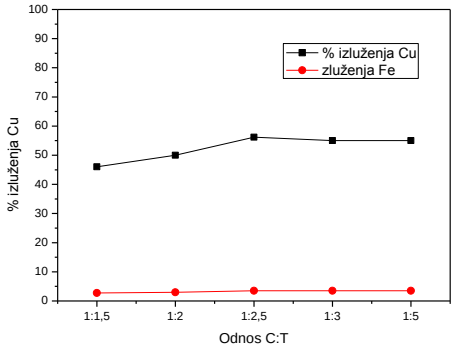

Figure 4 Dependence of the copper leaching degree on relation solid:liquid at pH=1, temperature: 80^{o}C, time: 4 h

Based on the results of leaching, shown in Figure 3, it can be stated that the time of development the leaching process has no significant effect on degree of copper. Optimum leaching time is 4 h.
Based on the results, shown in Figure 4, the optimal ratio of S:L for the copper leaching process from flotation tailings is 1:2.5. The highest degree of copper leaching of 56% was achieved in the following

process parameters: temperature of 80°C, time 4 h and ratio S:L = 1:2.5. Solutions after leaching with copper content up to 1.5 g/dm^3 are suitable for the SX-EW process.

3. CONCLUSION

Results of experimental laboratory testing of copper leaching from flotation tailings indicate that the highest degree of copper leaching was achieved in the following process parameters: time: 4 h, temperature: 80°C, ratio of solid: liquid is 1:2.5, pH of leaching solution: 1. The mine water from the accumulation Robule with correction of pH value was used as leaching solution, what presents a special contribution to solving the problems of use the integrated treatment of waste mine water and flotation tailings. After leaching process of flotation tailings, the enriched copper bearing solution was obtained with favorable qualitative-quantitative characteristics for the process of solvent extraction and electrolytic copper extraction (SX-EW process). This would be result both into economic and ecological effect by collecting the mine water, their recirculation in the controlled leaching process of mine waste.

ACKNOWLEDGEMENT

The authors are grateful to the Ministry of Education and Science for the financial support (Project TR 37001: The Impact of Mine Waste from RTB Bor to the Pollution of Waterways with a Proposal of measures and Actions to Reduce the Harmful Effects on the Environment).

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