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STABILIZATION OF THE SOLID RESIDUE FORMED AFTER THE ACID LEACHING OF COPPER FROM FLOTATION TAILINGS

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Abstract

The mining waste, i.e., flotation tailings occurs in the flotation concentration of copper ore processing. Considering the copper content in tailings of about 0.2-0.3%, it can be seen as a potential material for the copper recovery. This paper presents the chemical characterization of sample of the flotation tailings, deposited at the Old Flotation Tailing dump in Bor, in the eastern Serbia. After the application of hydrometallurgical treatment for copper recovery, a toxicity characteristic of the leaching procedure and leachability procedure of the obtained solid residue were performed. Then, a study of possibility for its safe disposal at a non-hazardous waste landfill after stabilization with lime was carried out.

***Keywords**: flotation tailings, solid waste, stabilization*

1. INTRODUCTION

In the flotation process of copper ore, the flotation tailings containing metal sulfides are separated and represent a special challenge for the topic of mining waste management. Due to the formation of acid mine water (AMD) and exposure of tailings to the atmospheric oxygen, bacteria and water, the metals from tailings are dispersed into the environment and directly affect degradation the quality of surface and underground water, as well as the surrounding soil [1-3].

Due to the increased exploitation of copper ore and discovery the low-quality deposits, it can be expected that more tailings will be present in the coming years, which could cause more environmental problems and challenges to solve them [1-4,6]. The copper content in the old flotation tailings is about 0.4%, and is similar to the world average copper content in the ore being exploited. Considering the current price of copper on the stock market and predictions that a demand for copper will increase, the flotation tailings represent a significant potential future source of copper. In recent years, a large number of researchers have been investigating the treatment of flotation tailings and valorization of metals using the pyrometallurgical and hydrometallurgical processes [2,5-8]. In addition to the valorization of metals, applying the appropriate treatment, the environmental protection would be achieved at the same time, given that the solid residues, formed in the leaching process, can be disposed of in a safe manner after stabilization that does not have a negative impact on the environment.

In this paper, the chemical characterization of a composite sample of flotation tailings was performed. After application the acid leaching in order to copper recovery, the toxicity and leachability of the resulting solid residue were studied in terms of defining its impact on the environment and human health. In order to the safe disposal, the resulting solid residue was stabilized using lime.

2. EXPERIMENTAL

Chemical characterization of a representative sample of flotation tailings from the Old Flotation Tailings in Bor was carried out. Sample was taken from one drillhole, from a depth of 1-36 m.

After detailed study the application of hydrometallurgical process, i.e., the application of acid leaching process of the flotation tailings, the optimal conditions for the copper leaching process were defined, during which a copper leaching rate of 75% was achieved.

According to the Rulebook on categories, testing and classification of waste (Official Gazette RS Nos. 93/2019, 39/2021), considering the impact on the environment and human health after its disposal, the Toxicity Characteristic Leaching Procedure (TCLP test) and Leachability Procedure (LP test) were performed on a solid residue sample, obtained after the application of hydrometallurgical treatment to the aim of copper recovery from the representative sample of flotation tailings. Chemical testing of the waste was performed according to the accredited standard methods: SRPS EN 12457-2 for testing the material leachability and EPA 1311 for testing the material toxicity characteristics. After the obtained results, stabilization of the solid residue was carried out using lime to the aim of its safe disposal at the landfill.

3. RESULTS AND DISCUSSION

3.1 Chemical Characterization

The analysis results of a representative sample of flotation tailings are presented in Table 1. It can be noted that the copper content is 0.34%, what corresponds to the copper content in a certain low-quality copper ore and confirms the possibility of using the flotation tailings as a potential material for the copper valorization.

Table 1. *Chemical analysis of flotation tailings*

Content (%)	Cu	Fe	Al_2O_3	S	As	SiO_2	Ca	K	Mg	Zn	Na	Sr
	0.34	8.96	8.12	11.23	0.014	57.84	0.757	0.421	0.336	0.0052	0.458	0.052
Method	AAS	AAS/V	ICP-AES	ACS	ICP-AES	G	AAS	AES	AAS	AAS	AES	ICP-AES

3.2 Characterization and Stabilization of the Solid Residue after the Applied Hydrometallurgical Treatment

The LP test results of the solid residue, obtained after the applied hydrometallurgical treatment for copper recovery, have showed that it cannot be disposed of without a pre-treatment because the concentrations of zinc and copper in the LP extract are above the limit for disposal in a hazardous waste landfill. Also, the studied sample has showed an acidic character in the LP test due to the low pH value of 2.91.

Also, the TCLP test results have indicated that the studied sample of the solid residue does not show the toxic characteristics, giving the possibility to obtain waste through the stabilization process that can be permanently disposed of with the aim of disposal at a landfill for non-hazardous waste.

For the purpose of permanent treatment, the same solid residue sample underwent a stabilization process with the addition of 2.5% and 5% lime, after which the LP and TCLP tests were performed again. The results of the LP test for the after stabilization with 2.5% lime are presented in Table 2 and Table 3, while the results of the TCLP test after stabilization with 2.5% lime are presented in Table 4.

The LP test results after stabilization the solid residue with the addition of 5% lime also showed that all tested parameters in the LP and TCLP tests were below the prescribed limit values.

Table 2. *Results of physico-chemical tests of eluates for L/S = 10 L/kg (SRPS EN 12457-2:2008)*

Parameter	Method	Value
Temperature (eluate) (ºC)	EPA 170.1	23
Electrical conductivity (μS/cm)	EPA 120.1	2407
pH	SRPS EN ISO 10523	7.15

The reference value for pH according to the Rulebook 56/2010 Annex 10 is >6. The measured pH value is within the permissible range.

Table 3. *Results of chemical testing of waste according to SRPS EN 12457-2:2008*

Parameter	Unit	Found value	Reference value for inert waste1)	Reference value for non-hazardous waste2)	Reference value for hazardous waste3)	Method
Content in EP extract (neutral test, L/S=10/1)						
Antimony, Sb	mg/kg dm	<0.06	0.06	0.7	5	SRPS EN ISO 11885
Arsenic, As	mg/kg dm	<0.20	0.5	2	25	SRPS EN ISO 11885
Barium, Ba	mg/kg dm	0.13	20	100	300	SRPS EN ISO 11885
Copper, Cu	mg/kg dm	0.45	2	50	100	SRPS EN ISO 11885
Cadmium,Cd	mg/kg dm	<0.04	0.04	1	5	SRPS EN ISO 11885

Molibdenym, Mo	mg/kg dm	<0.07	0.5	10	30	SRPS EN ISO 11885
Nickel, Ni	mg/kg dm	<0.07	0.4	10	40	SRPS EN ISO 11885
Lead, Pb	mg/kg dm	<0.20	0.5	10	50	SRPS EN ISO 11885
Selenium, Se	mg/kg dm	<0.04	0.1	0.5	7	SRPS EN ISO 11885
Chrome, Cr	mg/kg dm	<0.05	0.5	10	70	SRPS EN ISO 11885
Zinc, Zn	mg/kg dm	1.4	4	50	200	SRPS EN ISO 11885
Mercury, Hg	mg/kg dm	<0.005	0.01	0.2	2	VMK C.h.1
SO_4^{2-}	mg/kg dm	15700	1000	20000	50000	VMK C.đ.1
Cl^-	mg/kg dm	55	800	15000	25000	VMK C.đ.1
F^-	mg/kg dm	1.1	10	150	500	VMK C.đ.1

1), 2), 3) Annex 10 of the Rulebook on categories, testing and classification of waste (Official Gazette of RS Nos. 56/2010, 93/2019, 39/2021), Article 2, Parameters for testing the waste and leachate from landfills of inert waste[1)] non-hazardous waste[2)] and hazardous waste[3)]

Table 4. *Results of physico-chemical tests of toxic characteristics waste intended for disposal - TCLP test (EPA 1311)*

Parameter	Unit	Found value	Reference value for non-hazardous waste[4)]	Method
Content in EP extract (TCLP test)				
Antimony, Sb	mg/L	<0.006	15	SRPS EN ISO 11885
Arsenic, As	mg/L	<0.020	5	SRPS EN ISO 11885
Barium, Ba	mg/L	0.025	100	SRPS EN ISO 11885
Copper, Cu	mg/L	2.4	25	SRPS EN ISO 11885
Cadmium,Cd	mg/L	0.019	1	SRPS EN ISO 11885
Molibdenym, Mo	mg/L	<0.007	350	SRPS EN ISO 11885
Nickel, Ni	mg/L	0.015	20	SRPS EN ISO 11885
Lead, Pb	mg/L	<0.020	5	SRPS EN ISO 11885
Selenium, Se	mg/L	<0.004	1	SRPS EN ISO 11885
Chrome, Cr	mg/L	<0.005	5	SRPS EN ISO 11885
Zinc, Zn	mg/L	13.4	250	SRPS EN ISO 11885
Mercury, Hg	mg/L	<0.0005	0.2	VMK C.h.1
Vanadium, V	mg/L	<0.007	24	SRPS EN ISO 11885
Silver, Ag	mg/L	<0.005	5	SRPS EN ISO 11885

4) Annex 10 of the Rulebook on categories, testing and classification of waste (Official Gazette RS Nos. 56/2010, 93/2019, 39/2021), Article 1, Parameters for testing the toxic characteristics of waste intended for disposal.

It can be concluded that both applied concentrations of lime (2.5% and 5%) gave the desired results, i.e., the analyzed parameters do not exceed the prescribed limit values provided for disposal at the landfill of non-hazardous waste, and that the solid residues, obtained after acid leaching of copper from composite samples of flotation tailings, can be disposed of without negative effects on the environment.

Considering that the stabilization process gave the good results with the lime application in a concentration of 2.5%, it can be concluded that its application achieves the required character of waste that can be safely disposed of at a non-hazardous waste landfill, which additionally affects the process economy due to the lower consumption of lime.

4. CONCLUSION

The copper content of about 0.3% in the studied sample of flotation tailings originating from the Old Flotation Tailing Dump in Bor shows that it can be used as a potential material for the copper recovery. At the same time, applying an appropriate treatment of tailings would reduce its negative impact on the environment. In this paper, the toxicity and leachability of the solid residue, obtained after the acid leaching process of copper from the flotation tailings, were studied. The obtained results have showed that the resulting solid residue shows an acidic character due to the low pH value and that it cannot be safely disposed of without prior treatment, given that the concentrations of zinc and copper in the LP extract exceed the limits prescribed by the legislation of the Republic of Serbia for disposal the hazardous waste. The results of the TCLP test have showed that the studied sample does not show the toxic characteristics giving the possibility to obtain waste through the stabilization process that can be disposed of permanently to the aim of disposal at a landfill for non-hazardous waste. After the applied stabilization process of the solid residue using the addition of 2.5% lime, the character of waste was achieved and can be safely disposed of in a non-hazardous waste landfill without a negative impact on the environment.

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