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UTICAJ RAZLIČITIH KOLEKTORA NA ISKORIŠĆENJE BAKRA I PLEMENITIH METALA RUDNOG TELA TENKA 3[***]

Izvod

U ovom radu prikazan je deo tehnoloških ispitivanja koja su obavljena sa ciljem definisanja optimalnih uslova flotacijske koncentracije rude ležišta Tenka 3 – Severni revir, rudnika bakra Majdanpek. Dati prikaz odnosi se na ispitivanje uticaja kolektora NaIPX, 3418A i AP5500 kao i pH vrednosti pulpe na pojedine tehnološke pokazatelje (iskorišćenja bakra i plemenitih metala) procesa osnovnog flotiranja. Utvrđeno je da se generalno najbolja iskorišćenja bakra i zlata u osnovnom koncentratu bakra postižu primenom kombinacije kolektora 3418A i AP5500, dok se najbolja iskorišćenja srebra u osnovnom koncentratu bakra postižu primenom natrijum izopropil ksantata. Pored toga, veća iskorišćenja zlata i srebra dobijena su pri nižim pH vrednostima pulpe, dok, s druge strane, nije uočena jasna zavisnost iskorišćenja bakra od pH vrednosti pulpe u ispitivanom opsegu pH (10,0 – 11,5).

Ključne reči: *bakar, zlato, srebro, kolektor, iskorišćenje*

1. UVOD

Područje Tenke predstavlja obodni deo rudnog tela Severnog revira koji je, zahvaljujući tektonskim, fizičko-mehaničkim i termodinamičkim uslovima predstavljao pogodno tlo za nastanak različitih rudnih mineralizacija. Rudna tela su formirana u čvorištima rasednih zona u kojima je došlo do drastičnog opadanja temperature i pritiska hidrotermalnih, rudonosnih rastvora u odgovarajućoj litološkoj sredini [1,4].

Problematika ovog naučno-istraživačkog rada suštinski predstavlja ispitivanje mogućnosti valorizacije korisnih komponenti (bakra i plemenitih metala) iz kompleksne sirovine koja je karakteristična za ovaj deo ležišta površinskog kopa Seve-

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rni revir. To se, pre svega, odnosi na relativno visok sadržaj korisnih komponenti uz visok sadržaj pirita, strukturno-teksturne osobine rude i sadržaj glinovitih frakcija, mineraloški sastav i način srastanja korisnih i jalovih minerala itd [2]. Poznato je da su ležišta na lokaciji Tenka (Tenka 1, Tenka 2, Tenka 3) polimetaličnog tipa i da pored bakra, sadrže i minerale olova i cinka u određenoj meri [1]. Sa tog aspekta, definisanje optimalih uslova prerade rude ovih karakteristika i dobijanje komercijalnog proizvoda uz zadovoljavajuće tehnološke efekte, predstavlja komplikovan zadatak i zahteva ozbiljan istraživački pristup tehnološkim ispitivanjima.

Bitan faktor za koncepciju laboratorijskih ispitivanja predstavlja primena postojećih tehnoloških rešenja i parametara iz tekuće proizvodnje u flotaciji RBM [2,3].

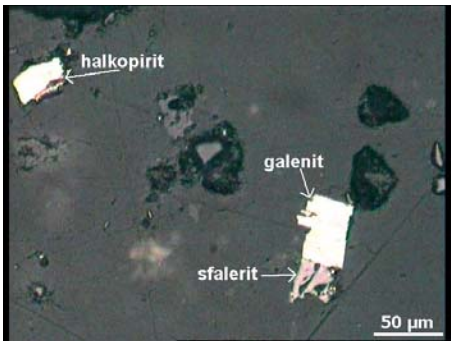
2. KARAKTERIZACIJA POLAZNIH UZORAKA

Polazni uzorci uzeti su sa 3 lokacije graničnog dela ležišta Tenka 3. Nakon drobljenja i homogenizacije svakog od uzoraka sa pomenutih lokacija, formiran je kompozitni uzorak (u masenom odnosu 1:1:1) na kome su izvršena planirana laboratorijska ispitivanja. Hemijski sastav pojedinačnih uzoraka, kao i kompozitnog uzorka prikazan je u tabeli 1. Sadržaj vlage u kompozitnom uzorku iznosio je 6,6%.

Tabela 1. *Hemijski sastav uzoraka iz rudnog tela Tenka 3*

Naziv uzorka	**Sadržaj komponente [%]**							
	Pb [%]	**Zn [%]**	**Cu [%]**	**Cu_{sulf} [%]**	**Cu_{ox} [%]**	**S [%]**	**Au [g/t]**	**Ag [g/t]**
T_3 lokacija 1	0,06	0,0075	0,63	0,608	0,0175	17,86	<0,03	1,65
T_3 lokacija 2	0,10	0,0160	0,30	0,288	0,0120	41,59	1,50	4,65
T_3 lokacija 3	0,06	0,0240	0,49	0,462	0,0320	6,11	<0,03	10,4
Kompozit	0,073	0,016	0,473	0,453	0,021	21,853	0,520	5,567

Kvalitativna mineraloška analiza urađena je pod polarizacionim mikroskopom za odbijenu svetlost u vazduhu, sa identifikacijom rudnih i nerudnih minerala. Kod uzorka uzetih sa sve tri lokacije utvrđeno je prisustvo minerala pirita, halkopirita, limonita, kvarca, silikata i karbonata. Uzorak sa lokacije 1 sadrži još i tetraedrit, dok su u uzorku sa lokacije 3 (slika 1) pored navedenih minerala prisutni i bornit, galenit i sfalerit.



Sl. 1. *Uzorak T_3 lokacija 3. Polimetalična ruda*

Kompozitni uzorak, čija je gornja granična krupnoća iznosila 2 mm, dalje je mlevenjem sveden na finoću od 60% –0,074 mm, čime je postignuta optimalna krupnoća mineralnih zrna (prema mineraloškoj analizi) za potrebe opita flotacijske koncentracije. Granulometrijski sastav samlevene mineralne sirovine prikazan je u tabeli 2. Prirodna pH vrednost pulpe sa masenim učešćem čvrste faze od 32% iznosila je 7,43.

Tabela 2. *Granulometrijski sastav samlevene rude (kompozit)*

Klasa krupnoće [mm]	**Učešće klase krupnoće [%]**	
	Parcijalno	**Kumulativno, prosev**
+0.589	0,36	100,00
-0,589+0.295	8,18	99,64
-0,295+0,104	25,29	91,46
-0,104+0,074	7,56	66,17
-0,074+0,052	13,77	58,61
-0,052+0,037	5,12	44,84
-0,037+0,000	39,72	39,72
Ukupno:	100,00	

3. TEHNOLOŠKI USLOVI ISPITIVANJA

Laboratorijska tehnološka ispitivanja uslova flotacijske koncentracije su obuhvatila promenu relevantnih tehnoloških parametara u opsegu postojećih vrednosti primenljivih u flotacijskom pogonu Majdanpek, i to:

- Ispitivanja su urađena kroz šest serija opita osnovnog flotiranja.
- Svaka serija se sastojala iz četiri opita, pri čemu je pH vrednost pulpe po opitima iznosila 10,0, 10,5, 11,0 i 11,5.
- Gustina pulpe u mlevenju je u svim opitima iznosila 70% čvrste faze.
- Gustina pulpe u flotiranju je u svim opitima iznosila 32% čvrste faze.
- Finoća mlevenja je u svim opitima iznosila 60% –0,074 mm (krupnoća pri kojoj se ostvaruje optimalno oslobađanje korisnih minerala)
- Kao penušač u svim opitima korišćen je AEROFROTH 76A uz preporučenu potrošnju od strane proizvođača
- Kao kolektori su korišćeni sledeći reagensi i njihove kombinacije:
  - NaIPX (natrijum izopropil ksantat) kao dobar kolektor sulfidnih minerala,
  - 3418 A (ditiofosfinat), kojeg karakterišu dobri rezultati u pogledu iskorišćenja zlata i srebra i
  - AP 5500 (etoksikarbonil tiourea), reagens koji je u teoriji i praksi poznat kao dobar kolektor sulfidnih minerala bakra i veoma selektivan u odnosu na sulfide gvožđa i pri nižim pH vredostima pulpe.

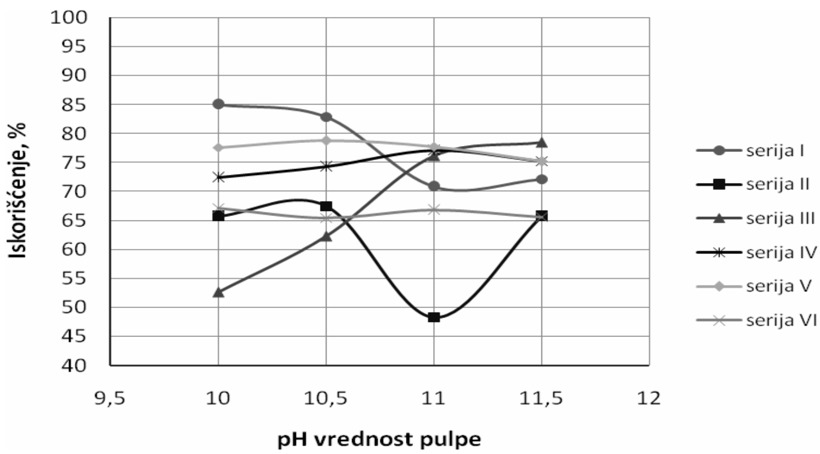
- Utrošak kolektora, bilo samostalno ili u kombinaciji iznosio je 40 g/t rude u svim opitima osnovnog flotiranja. Ova doza kolektora određena je na osnovu sadržaja sulfidnih minerala jer treba imati u vidu da je osim minerala bakra sadržaj pirita u rudi veoma visok (oko 30%). Potrošnja pojedinih kolektora po serijama opita prikazana je u tabeli 3.
- U svim opitima vreme kondicioniranja iznosilo je 7 minuta, a vreme osnovnog flotiranja 18 minuta. Kolektori su dodavani u tri jednake doze i to jedna doza u kondicioniranju i dve u osnovnom flotiranju.

Tabela 3. *Potrošnja kolektora u opitima flotacijske koncentracije, posmatrano po serijama opita*

Serija opita	Potrošnja kolektora [g/t suve rude]		
	NaIPX	3418 A	AP 5500
I	/	40	/
II	/	/	40
III	40	/	/
IV	24	16	/
V	/	20	20
VI	24	/	16

4. REZULTATI I DISKUSIJA

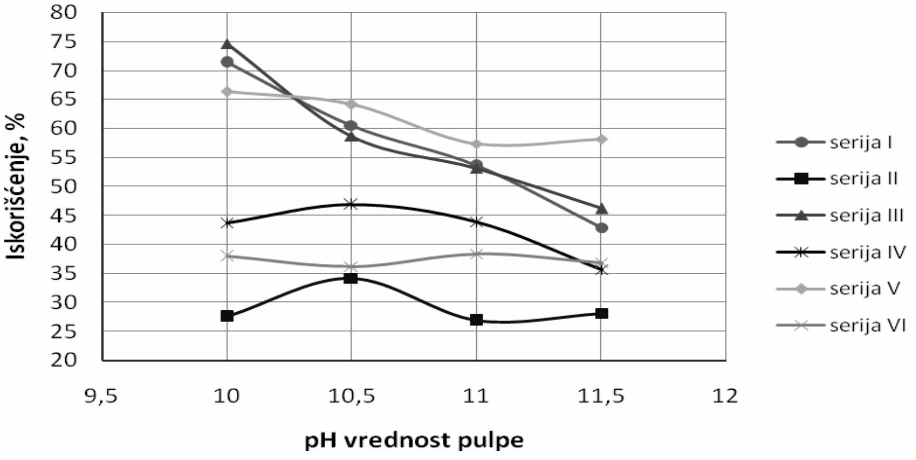
Iskorišćenje bakra u osnovnom koncentratu bakra po serijama opita prikazano je na slici 2.



Sl. 2. *Iskorišćenje bakra po serijama opita*

Sa slike 2 se vidi da su, generalno, najpovoljnija iskorišćenja bakra u osnovnom koncentratu bakra ostvarena u četvrtoj i petoj seriji opita. Očigledno je da primena kombinacije kolektora u osnovnom flotiranju (3418 A i NaIPX u IV seriji; 3418 A i AP5500 u V seriji) daje bolje rezultate u pogledu iskorišćenja bakra nego što je to slučaj kada se ovi kolektori primene pojedinačno (prve tri serije opita). Visoke vrednosti iskorišćenja bakra u osnovnom koncentratu (preko 80%) koje su dobijene u prvoj seriji opita objašnjavaju se velikim masenim učešćem osnovnog koncentrata [2]. Zavisnost iskorišćenja bakra od pH vrednosti pulpe u ovim ispitivanjima nije eksplicitno uočljiva.

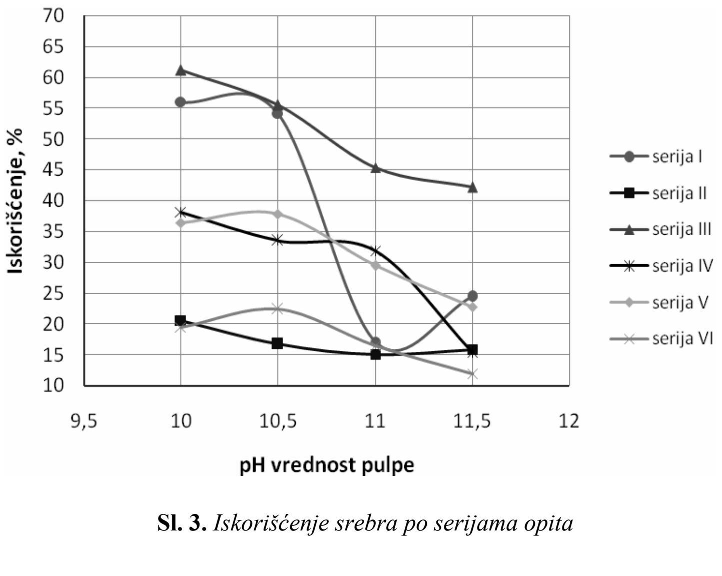
Iskorišćenje zlata u osnovnom koncentratu bakra po serijama opita prikazano je na Slici 3.



Sl. 3. *Iskorišćenje zlata po serijama opita*

Najpovoljnija iskorišćenja zlata u osnovnom koncentratu bakra ostvarena su u serijama opita I, III i V, što se može jasno uočiti na slici 3. Ipak, generalno gledano, najveća iskorišćenja zlata ostvarena su u seriji opita V u kojoj je korišćena kombinacija kolektora 3418A i AP5500 u procentualnom masenom odnosu 50:50. Pored toga, može se zaključiti da se, bez obzira na vrstu kolektora, veća iskorišćenja zlata u osnovnom koncentratu bakra dobijaju pri nižim pH vrednostima pulpe.

Iskorišćenje srebra po serijama opita prikazano je na slici br. 4.



Sl. 3. *Iskorišćenje srebra po serijama opita*

Sa slike 4 se vidi da su najpovoljnija iskorišćenja srebra u osnovnom koncentratu bakra ostvarena u seriji opita III u kojoj je kao kolektor korišćen NaIPX. Upotreba ostalih kolektora, kao i njihovih kombinacija sa natrijum izopropil ksantatom nije dala zadovoljavajuće rezultate u pogledu iskorišćenja srebra. Analogno iskorišćenju zlata, veća iskorišćenja srebra u osnovnom koncentratu bakra dobijaju se pri nižim pH vrednostima pulpe.

5. ZAKLJUČAK

Upotreba kolektora NaIPX samostalno (serija opita III), daje visoko iskorišćenje metala (posebno zlata i srebra), ali se mora napomenuti da je pri tom dobijena velika masa osnovnog koncentrata, sa relativno niskim sadržajem bakra [2].

Kombinovanje NaIPX sa ostala dva kolektora kao rezultat daje smanjenje mase osnovnog koncentrata [2], uz blago povećanje iskorišćenja bakra pri nižim pH vrednostima pulpe, pod uslovom da se koristi u istom odnosu kao što je to slučaj u proizvodnji flotacije RBM (40:60% u korist ksantata). S druge strane, ove kombinacije kolektora nepovoljno utiču na iskorišćenja zlata i srebra (serije opita IV i VI).

Samostalnom primenom kolektora 3418A (serija opita I) postižu se zadovoljavajuća iskorišćenja bakra, srebra i zlata samo pri nižim pH vrednostima pulpe, dok sa povećanjem pH vrednosti pulpe, iskorišćenja metala opadaju. Međutim, ponovo treba naglasiti da su razlike u masama osnovnih koncentrata u ovoj seriji opita velike [2].

Primenom kolektora AP5500 (serija opita II) nisu postignuti zadovoljavajući rezultati, dok je u kombinaciji sa 3418A (serija opita V) došlo do značajnog poboljšanja tehnoloških rezultata. Generalno se može tvrditi da su u ovoj seriji opita ostvarena najbolja iskorišćenja metala u toku celokupnog ispitivanja. Ovim se potvrđuje pozitivan efekat sinergijskog dejstva dva savremena kolektora različitog porekla i karakteristika.

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THE EFFECT OF DIFFERENT COLLECTORS ON RECOVERY OF COPPER AND PRECIOUS METALS OF THE ORE BODY TENKA 3***

Abstract

This work presents a part of technological testing that were conducted in order to define the optimum conditions of flotation concentration of the ore from the deposit Tenka 3 - North Mining District, Majdanpek copper mine. Provided description refers to testing the effect of collectors NaIPX, 3418 and AP5500 as well as the pH value of pulp to the certain technical indicators (recovery of copper and precious metals) of the rough flotation process.It was found that generally the best recoveries of copper and gold in the basic copper concentrate are obtained using a combination of collectors 3418 and AP5500, while the best silver recovery in the basic copper concentrate is obtained using the sodium isopropyl xanthate. In addition, higher recoveries of gold and silver were obtained at lower pH value of pulp, while, on the other hand, a clear dependence of copper recovery on pH value was not observed in tested pH range (10.0 to 11.5).
Keywords: *copper, gold, silver, collector, recovery*

1. INTRODUCTION

The area of Tenka is a peripheral part of the ore body North Mining District, which, owing to tectonic, physical-mechanical and thermodynamic conditions represented a fertile ground for formation different ore mineralization. The ore bodies were formed in the nodes fault zones, where a drastic decrease in temperature and pressure of hydrothermal ore bearing solutions occur in the corresponding lithologic environment [1,4].

The problems of this scientific-research work essentially present the research of possible valorization of useful components (copper and precious metals) from the complex raw material that is characteristic for this part of the deposit of the open pit North Mining District. This is primarily related to the relatively high content of useful components with high pyrite content, structural-textural properties of ore and content of clay fractions,

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mineralogical composition and method intergrowth the useful and barren minerals, etc. [2]. It is known that the deposits on the location Tenka (Tenka 1, Tenka 2, Tenka 3) are of polymetallic type and in addition to copper, they also contain lead and zinc minerals to some extent [1]. From that aspect, defining the optimum conditions of ore with these characteristics and obtaining a commercial product with satisfactory technological effects, presents a complicated task and requires a serious research approach to technological testing.

An important factor for the conception of laboratory testing is the application of existing technology solutions and parameters from current production in the flotation of RBM [2,3].

2. CHARACTERIZATION OF STARTING SAMPLES

The starting samples were taken from 3 locations of border part of the deposit Tenka 3. After crushing and homogenization of each samples from these locations, a composite sample was formed (in the weight ratio 1:1:1) in which the planned laboratory tests were carried out. Chemical composition of individual samples as well as composite sample is shown in Table 1. Moisture content in the composite sample was 6.6%.

Table 1. *Chemical composition of samples from the ore body Tenka 3*

Name of sample	Content of component [%]							
	Pb [%]	**Zn [%]**	**Cu [%]**	**Cu_{sulf} [%]**	**Cu_{ox} [%]**	**S [%]**	**Au [g/t]**	**Ag [g/t]**
T_3 location 1	0.06	0.0075	0.63	0.608	0.0175	17.86	<0.03	1.65
T_3 location 2	0.10	0.0160	0.30	0.288	0.0120	41.59	1.50	4.65
T_3 location 3	0.06	0.0240	0.49	0.462	0.0320	6.11	<0.03	10.4
Composite	0.073	0.016	0.473	0.453	0.021	21.853	0.520	5.567

Qualitative mineralogical analysis was carried out under the polarizing microscope for reflected light in the air, with identification the ore and barren minerals. The presence of minerals pyrite, chalcopyrite, limonite, quartz, silicate and carbonate is determined in samples taken from all three locations. Sample from the location 1 contains tetrahedrite, while bornite, galena and sphalerite are present in the sample from location 3 (Figure 1) in addition to the mentioned minerals.

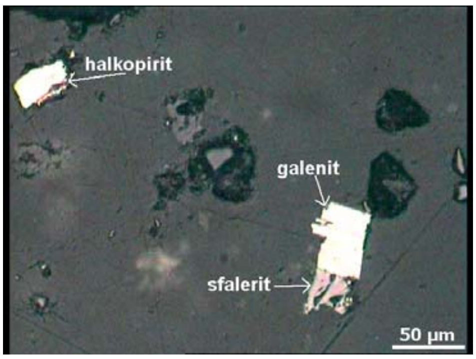

Fig. 1. *Sample T_3 location 3, polymetallic ore*

Composite sample with the upper limit coarseness of 2 mm, was further reduced by grinding to fineness of 60% -0.074 mm, thus achieving the optimum coarseness of mineral grains (according to the mineralogical analysis) for the needs of flotation concentration experiments. Grain-size distribution of ground mineral resources is shown in Table 2. Natural pH value of the pulp with mass participation of the solid phase of 32% was 7.43.

Table 2. *Grain-size distribution of ground ore (composite)*

Size class [mm]	**Participation of size class [%]**	
	Partial	**Cumulatively, undersize**
+0.589	0.36	100.00
-0.589+0.295	8.18	99.64
-0.295+0.104	25.29	91.46
-0.104+0.074	7.56	66.17
-0.074+0.052	13.77	58.61
-0.052+0.037	5.12	44.84
-0.037+0.000	39.72	39.72
Total:	100.00	

3. TECHNOLOGICAL CONDITIONS OF TESTING

Laboratory technological testing the conditions of flotation concentration included a change of relevant technological parameters in the range of existing values, applicable in the Flotation Plant Majdanpek, as follows:

- Tests were carried out through six series of experiments of rough flotation,
- Each series consisted of four experiments, in which the pH value of pulp by experiments was 10.0, 10.5, 11.0 and 11.5,
- Pulp density in grinding in all experiments was 70% solid phase,
- Pulp density in flotation in all experiments was 32% solid phase,
- Grinding fineness in all experiments was 60% -0.074 mm (coarseness at which the optimum release of useful minerals is realized),
- AEROFROTH 76A was used as a frother in all experiments with recommended consumption by the manufacturer,
- The following reagents and their combinations were used as collectors:
  - NaIPX (sodium isopropyl xanthate) as a good collector of sulphide minerals,
  - 3418 A (ditiofosfinate), characterized by good results in terms of gold and silver recovery, and
  - AP 5500 (ethoxycarbonyl thiourea), a reagent that is known, in theory and practice, as a good collector of copper sulphide minerals and it is very selective with respect to iron sulfides at low pH value of pulp.
- Consumption of collectors, either independently or in combination was 40 g/t of ore in all experiments of rough flotation. This collector dosage is determined based on content of sulfide minerals because it should be noted that in addition to copper mineral, pyrite content in the ore is very high (about 30%). Consumption of individual collectors by series of experiments is shown in Table 3.

In all experiments, the conditioning time was 7 minutes; the time of rough flotation was 18 minutes. Collectors were added in three equal doses and one dose in conditioning and two doses in rough flotation.

Table 3. *Consumption of collectors in the flotation concentration experiments, observed by series of experiments*

Series of experiments	**Consumption of collectors [g/t dry ore]**		
	NaIPX	**3418 A**	**AP 5500**
I	/	40	/
II	/	/	40
III	40	/	/
IV	24	16	/
V	/	20	20
VI	24	/	16

4. RESULTS AND DISCUSSION

Copper recovery in basic copper concentrate by series of experiments is present in Figure 2.

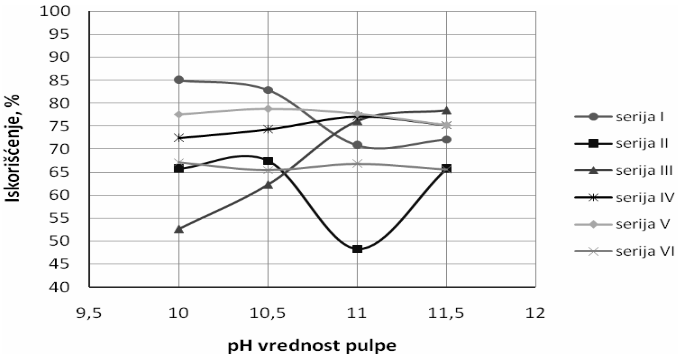

Fig. 2. *Copper recovery by series of experiments*

Figure 2 shows that, in general, the most favorable recoveries of copper in the basic copper concentrate were realized in the fourth and fifth series of experiments. It is obvious that the use of combination the collectors in the rough flotation (3418 A and NaIPX in the IV series; 3418 A and AP5500 in the V series) gives better results in terms of copper recovery than it is the case when these collectors are used individually (the first three series of experiments). High values of copper recovery in the basic concentrate (over 80%), obtained in the first series of experiments, are explained by a large mass participation of basic concentrate [2]. Dependence of copper recovery on pH value of the pulp in the present testing is not explicitly visible.

Gold recovery in the basic copper concentrate by series of experiments is present in Figure 3.

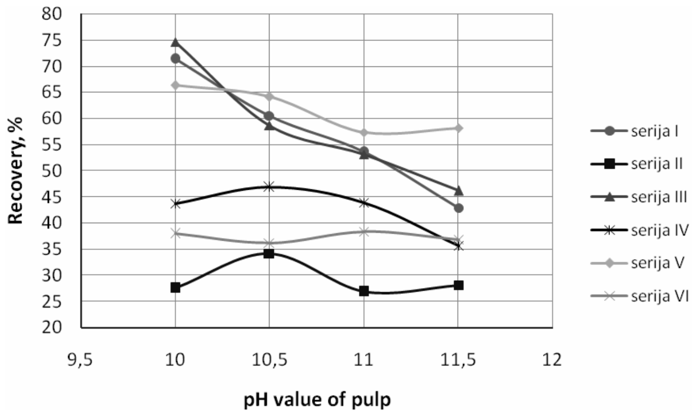

Fig. 3. *Gold recovery by series of experiments*

The most favorable gold recoveries in the basic copper concentrate were achieved in series of experiments I, III and V, as can be clearly seen in Figure 3. However, in general, the highest gold recoveries were realized in the V series of experiments in which a combination of collectors 3418A and AP5500 was used in the percentage mass ratio of 50:50. In addition, it can be concluded that, regardless of the collector type, the highest gold recovery in the copper concentrate are obtained at lower pH values of the pulp.

Silver recovery by series of experiments is present in Figure 4.

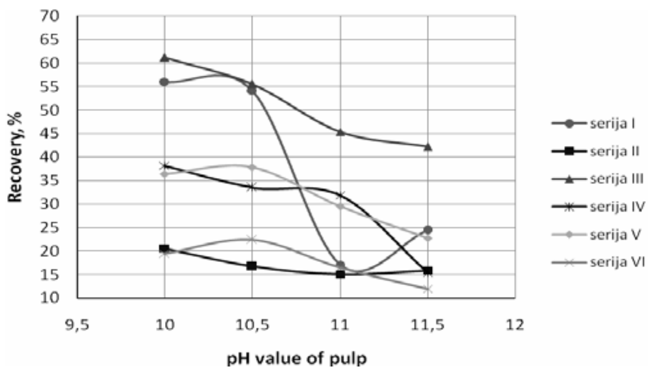

Fig. 4. *Silver recovery by series of experiments*

Figure 4 shows that the best silver recovery in the basic copper concentrate was realized in the III in series of experiments in which NaIPX was used as a collector. The use of other collectors as well as their combination with sodium isopropyl xanthate did not give the satisfactory results in terms of silver recovery. The analogue gold recovery and higher silver recoveries silver in the basic copper concentrate are obtained at lower pH values of the pulp.

5. CONCLUSION

The use of NaIPX collector independently (III series of experiments), provides high recovery of metals (especially gold and silver), but it must be noted that large mass of basic concentrate was obtained during this with a relatively low content of copper [2].

Combining NaIPX with the other two collectors as the result gives the weight reduction of basic concentrate [2], with a slight increase of copper recovery at lower pH values of the pulp, provided that it is used in the same ratio as it is the case in the production of the Flotation Plant RBM (40:60% in favor of xanthate). On the other hand, this combination of collector adversely affects gold and silver recoveries (series of the IV and VI experiments).

By independent use of 3418 collector (I series of experiments), the satisfactory recovery of copper, silver and gold was achieved only at lower pH values of the pulp, whereas with increasing pH value of the pulp, the metal recoveries decrease. However, it should be noted again that the differences in the masses of basic concentrates in this series of experiments are high [2].

Using AP5500 collector (II series of experiment) were not achieved the satisfactory results, until in combination with 3418 (V series of experiment) led to a significant improvement of technological results. Generally, it can be stated that, in this series of experiments, the best utilization of metals was realized throughout the entire testing. This confirms the positive effect of synergetic action of two contemporary collectors of different origins and characteristics.

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