Beneficiation of Talc-Magnesite Ore with Cu-Co Mineralization

Ivan BREZÁNI[1)] Martin SISOL[2)], Michal MARCIN, Maroš SÝKORA, Michal MAŤAŠOVSKÝ, Peter VARGA

[1)] Technical University of Košice, Faculty of Mining, Ecology, Proces Control and Geotechnology, Letná 9, 042 00 Košice, Slovak Republic; email: ivan.brezani@tuke.sk
[2)] Technical University of Košice, Faculty of Mining, Ecology, Proces Control and Geotechnology, Letná 9, 042 00 Košice, Slovak Republic; email: martin.sisol@tuke.sk

http://doi.org/10.29227/IM-2019-01-26

Submission date: *11-07-2018* | Review date: *02-04-2019*

Abstract

Magnesite ore with a low chalcopyrite – cobaltite mineralization was subjected to a series of separations designed to evaluate the possible concentration of the two accessory minerals. Although the Cu-Co grade in the ore (> 0.01% Co, > 0.1% Cu) is significantly lower than the typical economic grades, content of the main valuable mineral for which the ore is mined and processed in combination with a listing of cobalt as a critical raw material, coupled with their higher price might compensate for the additional beneficiation stages. The ore was first crushed and subsequently classified to -100 μm and +100 -400 μm size fractions. The fine fraction was upgraded by froth flotation processing in laboratory froth flotation cell. The coarser fraction was processed in several separation stages including gravity separation on shaking table, magnetic separation and corona electrostatic separation. The same procedure was also repeated with a higher-grade sample as a verification of the procedures. Preliminary results suggest that the accessory minerals can be separated from the talc-magnesite ore and individual mineral concentrates with about 19% Co and 28% Cu were prepared. However, further work must be done to achieve desirable recoveries for the processing to be economically viable.

Keywords: mineral processing; cobalt; cobaltite; talc; beneficiation

Introduction

Classification of Cobalt as a Critical Raw Material (EUROPEAN COMMISSION, 2018) led to an increased interest in finding new possible sources of this metal. Increased production an also consumption of Co in recent years is mainly associated with increased demand for rechargeable batteries (nearly 80% of the annual consumption) and the forecast is that the trend will continue in the following years (USGS, 2018). According to the historical and latest US Geological Survey (USGS) numbers summarized in Figure 1, the overall trend of the mine production of Co seems to be positive. However, the production seems to have achieved its peak several years ago in 2015.

There are only two mines where Co-bearing minerals are considered primary valuable minerals – Bou-Azzer deposit in Morocco and Tenke Fungurume Mine in Democratic Republic of Congo (USGS, 2018). Cobalt is more commonly recovered as a by-product of other mineral processing activities, usually, it is associated with zinc, copper, nickel, silver, etc (RAO, 2014). Average ore grades range from 0.2 to 1%, accompanied by 1 to 3% Cu (MUDD et al., 2013).

Cobalt sulfide ores are usually beneficiated by froth flotation at acidic pH (~ 4) with xanthates, cobalt oxide ores at about pH 7.5 using nitrosonaphthol chelating reagents, while their combination can be used if the ore is partially oxidized. The high specific gravity of cobalt-bearing minerals (5.7–6.8) also allows the use of gravity-separation as the first step of concentration (RAO, 2014).

In this contribution recovery of Cu and Co bearing minerals from magnesite ore with low Cu and Co mineralization. Methods for the beneficiation of larger particles included gravity separation on shaking table, magnetic separation and corona electrostatic separation, while froth flotation method was tested for the fine fraction.

Materials and methods

Gravity concentration was carried out using the LY2100 shaking table (China) with a deck size of 2100*1050*850 mm and 1.1 kW motor power. 40 kg sample with 100 to 400 μm particles was used as a feed. Midlings resulting from the separation was mixed with fresh feed and there were thus only two final products of each step of gravity concentration on the shaking table.

Magnetic separation was conducted using dry high-intensity magnetic separator Mechanobr at 0.9 T. Corona electrostatic separation (Sturtevant, UK) was conducted at about 25 kV and 100 rpm. The sample was not heated during the test.

Froth flotation was carried out in a custom 3 l laboratory froth flotation cell. Fine fraction (-100 μm) of the ore was used. The test was carried out after at least 15 minutes of conditioning. The agitation speed of 1600 rpm and air flow rate of 4 l.min-1 was used in all tests. Variable flotation time was used during the tests – froth was scraped until it was no longer produced in considerable amounts.

Results and discussion

Flowsheets of the physical separation of the two different samples are shown in Figure 1 and Figure 2. Gravity separation of magnesite ore even with low Cu-Co mineralization is a suitable pre-processing method to produce preliminary Cu-Co concentrates. In a single operation, concentration factor (calculated as a ratio of the metal content in the concentrate and feed) of 10 and 12 was achieved for Co and Cu, resp. when processing the low-

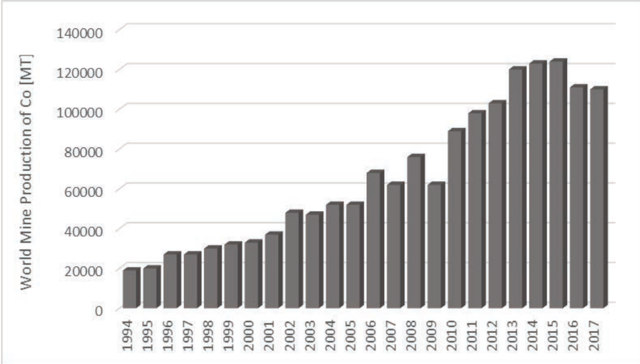

Fig. 1. World Mine Production of Cobalt over the years (USGS)
Rys. 1. Światowa produkcja kobaltu na przestrzeni lat (USGS)

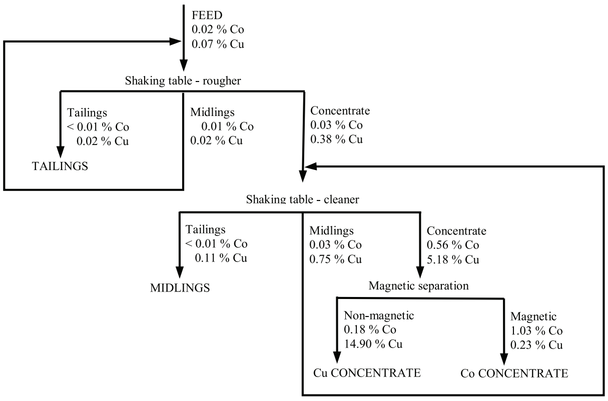

Fig. 2 Flowsheet of the processing of sample with lower Cu-Co content
Rys. 2 Schemat przeróbki próbki o niższej zawartości Cu-Co

grade ore with higher content of the metals (0.04 % Co, 0.57% Cu in the feed).

Two-stage gravity separation of the low-grade ore with lower metal content (0.02% Co, 0.07% Cu) resulted in a concentration factor of 28 and 38 for Co and Cu, resp. In both cases, Co content in the gravity concentrates with over 0.4% Co content achieved the grade of the usual primary cobalt ores. Copper content in the gravity concentrates with over 5% Cu severalfold exceeded the necessary grade.

Although the usual next step of mineral processing would be froth flotation of the concentrates (after grinding), two other physical separation methods were successfully tested. Further upgrading of the concentrate can be achieved using magnetic separation or a combination of magnetic and corona electrostatic separation. While magnetic separation alone (see Figure 2) was enough to produce a copper concentrate (non-magnetic product) with almost 15% Cu, cobalt concentrate (magnetic product) contained relatively low content of just over 1% Co. When an alternative approach of processing the gravity concentrate was used (see Figure 3) with corona electrostatic separation prior to magnetic separation, copper concentrate with over 22% Cu and cobalt concentrate with over 23% Co was produced. These results achieved with a sample of 100 to 315 μm suggested that the liberation of the valuable minerals is sufficient as both the theoretical Co content in cobaltite mineral and Cu content in chalcopyrite mineral is about 35%.

Although the overall recoveries of the valuable minerals during the laboratory tests aimed at testing the possibilities of physical separation methods were not high, this could be overcome by employing one or more stages of scavenging operations of the tailings and the midlings. It must also be noted that due to a low content of the Cu and Co minerals in the feed, processing of 40 kg of feed sample led to a preparation of only several grams of final concentrates.

For the fine fraction of the ore (-100 μm), froth flotation was tested. Three flotation tests were done – bulk Cu-Co flotation at lower 350 $g.l^{-1}$ density and natural pH, bulk Cu-Co flotation at higher 700 $g.l^{-1}$ density and natural pH and flotation at pH~4.5 (see Figure 6).

The result of the bulk Cu-Co flotation shown in Figure 4 suggested that chalcopyrite can be effectively recovered from the ore using a simple reagent scheme – only by using a xanthate collector (50 $g.t^{-1}$ SIPX) and frother (20 $g.t^{-1}$ MIBC). pH of the slurry was not adjusted and due to a large magnesite content in the ore, it was at around 8. This approach resulted in a production of concentrate with about 7.4% Cu content (concentration factor of over 90) in a single stage flotation with a recovery of chalcopyrite about 97%. However, no concentration of cobaltite was achieved. Also, the yield of the froth product was very low, only a little over 1%.

To avoid problems with froth scraping due to a low yield of the froth product, the higher slurry density of 700 $g.l^{-1}$ was tested and the results are shown in Figure 5. While the dosage of the collector was kept constant at 50 $g.t^{-1}$ in relation with the solids, the dosage of the frother was kept constant in terms of its concentration in the slurry and thus lowered to 10 $g.t^{-1}$ (as the amount of the

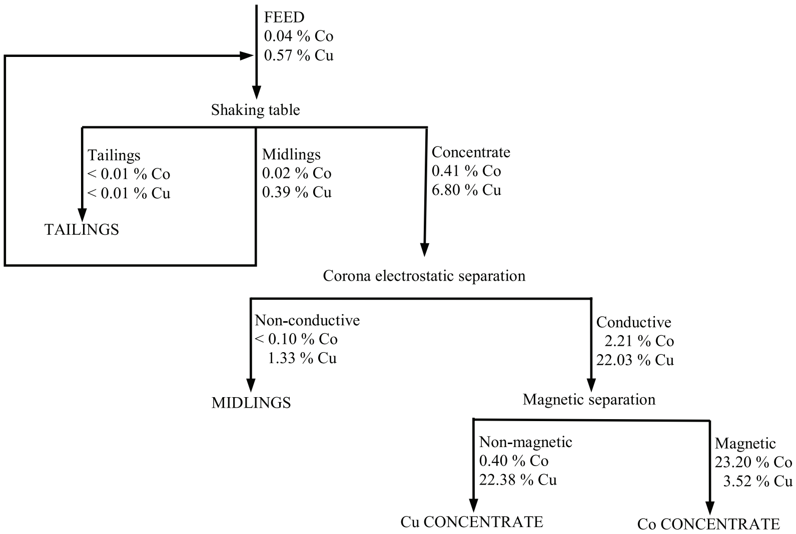

Fig. 3 Flowsheet of an alternative approach of processing used for the sample with a higher Cu-Co content

Rys. 3 Schemat alternatywnego podejścia do przeróbki rudy o wyższej zawartości Cu-Co

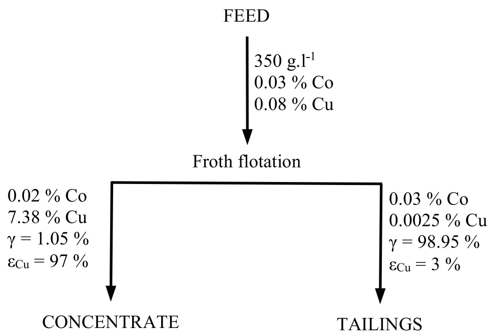

Fig. 4. Results of the bulk Cu-Co flotation

Rys. 4. Wyniki flotacji kolektywnej Cu-Co

solids in the slurry have doubled). Again, the test was conducted at natural pH.

Despite a slightly positive effect on the recovery of cobalt to concentrate, this has also significantly lowered the recovery of copper to concentrate (68% against 9 % in the previous test) as well as concentrate grade in terms of the Cu content (1.8% against 7.4%).

Third flotation test was aimed at the flotation recovery of cobaltite from the ore, which was expected to be highest in acidic conditions when using xanthate collectors. pH was therefore adjusted to about 4.5 and kept at that level during entire flotation. Other than that, the conditions were the same as in the previous flotation.

Results of the flotation shown in Figure 6, however, suggest, that not even adjustment of the pH increased the recovery of the Co to concentrate. By contrast, when compared with the results of the flotation using the same reagent scheme but natural pH (see Figure 5), Co content is even lower.

This suggests that the cobaltite found in the ore cannot be effectively recovered using SIPX collector. This might be due to a lower suitability of the collector as other xanthates – SEX (sodium ethyl xanthate) and PAX (potassium amyl xanthate) are usually used in these applications (RAO, 2014). However, the drop in the recovery in acidic conditions suggests that the cobaltite in the sample might be oxidized and flotation at natural pH using nitrosonaphthol chelating reagents might provide better results in terms of the Co recovery.

Overall, based on the preliminary results of the froth flotation processing it is advisable to test the bulk Cu-Co flotation at natural pH using a combination of xanthates and nitrosonaphthol reagents. It must also be noted that cleaning flotation aimed at the production of high-grade concentrate could not be tested due to the low yield of the froth product from rougher flotation.

Conclusion

Separation of Cu (chalcopyrite) and Co (cobaltite) from magnesite ore with low Cu-Co mineralization was tested. Gravity concentration was found to be a good method for preliminary concentration of the minerals (size fraction of 100 to 400 μm) and bulk concentrates with over 0.4% Co and over 5% Cu content was produced. When considering physical separation methods, it was found that using a combination of corona electrostatic separation and magnetic separation, individual mineral concentrates with relatively high metal content can be produced – over 22% Cu in the copper concentrate and over 23% Co in the cobalt concentrate. However, scavenging stages would have to be deployed to achieve satisfactory recoveries.

Fine fraction (-100 μm) was processed using froth flotation. By using of xanthate collector and frother (at natural slurry pH), recovery of Cu to concentrate of almost 97% was achieved at a grade of nearly 7.4% Cu in a single stage flotation. However, we were unable to concentrate Co (not even when pH of the slurry was adjusted to~4.5, which is reported to be the optimum). This

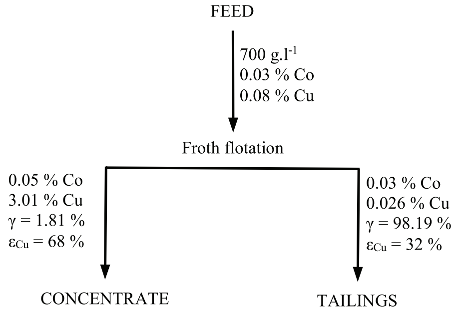

Fig. 5. Results of the bulk Cu-Co flotation with high slurry density

Rys. 5. Wyniki flotacji kolektywnej Cu-Co o wysokiej gęstości zawiesiny

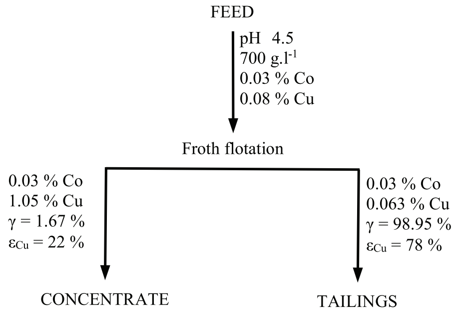

Fig. 6 Results of the flotation in acidic conditions

Rys. 6 Wyniki flotacji w warunkach kwasowych

was attributed to oxidation of the sample and use of a combination of xanthates and nitrosonaphthol collectors at natural pH was suggested in further tests.

Overall, a conclusion can be drawn that Co and Cu bearing minerals can be recovered by only using the physical separation methods from the supplied magnesite ore even when they are present only in small concentrations. Flotation was found to be a very promising method for the recovery of chalcopyrite. However, further tests must be conducted to find a suitable reagent regime for the recovery of cobaltite.

Acknowledgments

This work was supported by the research grant project VEGA, no. 1/0472/18.

Literatura – References

1. EUROPEAN COMMISSION. Report on Critical Raw Materials and the Circular Economy. Brussels: EU, 2018. 69 pages.
2. RAO, G.V. Nickel and Cobalt Ores: Flotation, In Reference Module in Chemistry, Molecular Sciences and Chemical Engineering, Elsevier, 2014, ISBN 9780124095472.
3. USGS. Mineral Commodity Summaries 2018. Reston, Virginia: U.S. Geological Survey, 2018. 204 pages. ISBN 978-1-4113-4199-9.
4. MUDD, G.M., WENG, Z. JOWITT, S.M., TURNBULL, I.D. GRAEDEL, T.E. Quantifying the recoverable resources of by-product metals: The case of cobalt, Ore Geology Reviews, Volume 55, 2013, Pages 87-98, ISSN 0169-1368.

Wzbogacenie rudy talku-magnezu z mineralizacją Cu-Co

Ruda magnezu o niskiej mineralizacji chalkopirytu – kobaltytu została poddana serii separacji mających na celu ocenę możliwego uzysku dwóch minerałów towarzyszących. Chociaż zawartość Cu-Co w rudzie (> 0,01% Co,> 0,1% Cu) jest znacznie niższy niż wartości opłacalne ekonomicznie, zawartość głównego cennego minerału (magnezytu) , dla którego ruda jest wydobywana i przetwarzana w połączeniu z zawartością kobaltu jako surowca krytycznego może zrekompensować koszt dodatkowych etapów wzbogacania. W pierwszym etapie rudę kruszono, a następnie klasyfikowano do frakcji o wielkości -100 µm i +100 -400 µm. Drobną frakcję poddawano flotacji pianowej w laboratoryjnej maszynce flotacyjnej. Grubsza frakcja była przetwarzana w kilku etapach, w tym separacja grawitacyjna na stole wstrząsanym, separacja magnetyczna i separacja elektrostatyczna. Ta sama procedura została powtórzona z próbką o wyższych zawartościach. Wstępne wyniki sugerują, że minerały towarzyszące można oddzielić od rudy talku i magnezytu i zyskano koncentraty mineralne z zawartością około 19% Co i 28% Cu. Jednakże konieczne są dalsze prace w celu osiągnięcia pożądanych uzysków, aby przetwarzanie było opłacalne ekonomicznie.

Słowa kluczowe: przeróbka minerałów, kobalt, kobaltyt, talk, wzbogacanie