Mineralia Slovaca, 42 (2010), 305 – 308
ISSN 0369-2086

Possibilities of processing and utilization of tailings from the settling pit nearby the Rudňany village (Eastern Slovakia)

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Abstract

The contribution deals with the mineral and chemical composition of the sandy tailings in the settling pit nearby the Rudňany village. The distribution of the mineral components in the pit body and their zonation in the dependence on beneficiation technologies change during the siderite, tetrahedrite and barite concentrates production are described. The results of magnetic separation and flotation of sands from the pit and the flowsheet proposal of wasteless processing technology are also presented.

Key words: settling pit, tailings, magnetic separation, flotation, flowsheet

Introduction

The tailings coming from the mining and mineral processing technologies are considered to be the secondary raw materials. They often contain utility components of interesting grade being a result of application of obsolete technologies in the past. Their complex utilization is significant for national economics not only from the economic point of view but also from the ecological one. The tailings represent already disintegrated material of the various grain sizes, i.e. lumpy, coarse, fine-grained, often flotation fineness, which are deposited on the surface as refuse piles and settling pits. Thus, as to their further use the operations of crushing and grinding will be reduced or they may be totally excluded from the technological flowsheet. Moreover, an excavating of these materials on the surface is less expensive than the underground mining of the ores. For these reasons the processing of such secondary materials may bring a profit despite of lower content of utility components in comparison with the crude ores. Taking it all, a removal of dumping areas results in the reduction of harmful loading, unfavourably influencing the environment.

Characteristics of the Rudňany settling pit

The settling pit nearby the Rudňany village was managed by the so-called New industrial plant (mineral processing plant) of the former Rudňany branch of closed Iron Ore Works, Inc., later ŽELBA, Inc., Spišská Nová Ves. It was formed by the silting-up of the tailings coming from the processing of complex siderite-sulphidic and barite--sulphidic ores exploited in the Rudňany and Poráč-Zlatník deposits in 1963 – 2003. The ore processing consisted of crushing, grinding, classifying, gravity concentration, magnetic separation, flotation and also roasting.

The settling pit is located in the cadastral districts of the Markušovce and the Závadka villages in the bottom part of the Markušovce valley. Its area is of 35.1 hectares, the length attains of 1,085 meters and the width ranges from 165 to 345 metres. The thickness of deposited materials varies in the dependence on initial ground levels and it may achieve maximally about 38 metres. The settling pit is bounded by the natural ground level of the valley and also by three earthen dams. There is no water stream there. Recently, the settling pit is in operation. The tailings from the flotation of the barite ore exploited in the Rudňany deposit are silting-up on the back part of settling pit opposite the key dam.

Altogether 9,800,000 tons of the tailings of so-called flotation sands at a density of 1.59 $t \cdot m^{-3}$ and a total volume of 6,200,000 m^3 are deposited in the settling pit. The presented data has been calculated on the basis of statistical observation of deposited tailings amount, i.e. the increases by silting-up and the decreases caused by the excavation of sands from the settling pit (Karoli et al., 2008).

Naturally, the deposited tailings come from lodestuff and accompanying rocks of exploited deposits. Firstly, as to minerals from the lodestuff, the quartz, siderite, barite, dolomite, ankerite, tetrahedrite, chalcopyrite and pyrite are present as dominant minerals. Moreover, albite, specularite and fuchsite also occur. Secondly, as to accompanying rocks, basalts, basalt tuffites and pelitic metasediments, namely graphite phyllites prevail. Paragneisses, chlorite phyllites, sandstones, conglomerates and hydrothermally

Tab. 1
Model material balance recalculation of the Rudňany settling pit

layer	weight of layer [t]	volume density of layer [t.m^{-3}]	content of component in layer [%]		
			weight of component in layer [t]		
years	part by weight in settling pit [%]		part by weight in layer [%]		
			$BaSO_4$	Fe	Cu
upper layer	2,789,409	1.42	13.01	17.23	0.054
1985 - till now	28.34		353,525	480,588	1,509
			20.17	23.61	24.76
middle layer	3,835,823	1.40	17.39	21.77	0.071
1975 - 1984	38.98		666,905	835,083	2,723
			38.04	41.04	44.68
bottom layer	3,215,768	1.89	22.78	22.37	0.058
1963 - 1974	32.68		732,621	719,496	1,862
			41.79	35.35	30.56
sum / average	9,841,000	1.54	17.81	20.68	0.060
	100.00		1,753,051	2,035,167	6,094
			100.00	100.00	100.00

Tab. 2
Grain size and chemical analysis of the material from settling pit

grain size [mm]	mass yield [g]	[%]	content [%] Fe	SiO_2	$BaSO_4$	Cu	recovery [%] Fe	SiO_2	$BaSO_4$	Cu
+1.000	90.0	0.86	13.65	31.49	6.69	0.089	0.77	0.72	0.71	1.74
0.500 – 1.000	190.0	1.81	8.22	49.85	0.64	0.033	0.98	2.40	0.14	1.35
0.160 – 0.500	2,930.0	27.92	10.68	48.48	2.74	0.035	19.55	36.01	9.43	22.16
0.090 – 0.160	2,458.0	23.42	15.92	34.37	8.24	0.030	24.45	21.42	23.79	15.93
0.071 – 0.090	566.0	5.39	19.52	31.21	12.10	0.052	6.90	4.48	8.04	6.36
0.020 – 0.071	2,022.0	19.26	17.82	36.03	9.98	0.047	22.50	18.46	23.70	20.53
– 0.020	2,240.0	21.34	17.76	29.07	12.99	0.066	24.85	16.51	34.18	31.94
feed	10,496.0	100.00	15.40	38.12	8.11	0.046	100.00	100.00	100.00	100.00

altered varieties of these rocks are also often present. An average chemical composition may be characterized by the results of the semiquantitative analysis as follows:

$10^2 – 10^1$ Fe, Si

$10^1 – 10^0$ Al, Ba, Ca, Mg, Mn

$10^0 – 10^{-1}$ Cu, K, Na, Ti

$10^{-1} – 10^{-2}$ Hg, Sb, Sr, Zn

$10^{-2} – 10^{-3}$ B, Co, Cr, Ni, Pb, V, Ag, Be, Ga, Sn

Thus, the major elements represent: Fe, Si, Al, Ba, Ca, Mg and Mn. All these elements are bonded in the above mentioned dominant utility and the gangue minerals of exploited deposits. The content of the non-ferrous heavy metals in order may attain about $10^{-0} – 10^{-3}$ %. These metals are bonded in the insoluble form, namely in sulphides.

On the basis of data about the amounts and quality of deposited tailings a study on material balance and composition of individual layers of the settling pit has been carried out. So a performance of the settling pit was divided to two periods (Jančura and Čechová, 2001):

– 1st period – from 1963 to 1974, so called "old settling pit",

– 2nd period – from 1975 to present time, after realization of the project on the capacity increase of the settling pit in 1974.

Naturally, as time goes on a material of various qualities in the dependence on the changes in the level of treatment techniques as well as on the feed quality to mineral processing plant was gradually deposited. Thus, from a viewpoint of barite content, the settling pit may be divided into three layers (Jančura and Čechová, 2001):

1) Bottom layer, so called "old settling pit", formed during the first stage of silting-up in the border of original dams (1963 – 1974);

2) Middle layer, which was formed by the silting-up the "old settling pit" after capacity increase (1975 – 1984);

3) Upper layer, so called "low grade cover" characteristic by the decreased content of utility components as a result of an improvement of technological parameters of the magnetic separation and flotation (1985 – recent).

A total amount of material, its volume density, content of components and their part by weight and percentage in individual layers were determined. The results are introduced in Tab. 1.

Statistical average annual values of barite content monitored during the years of 1963 – 2000 show significant differences, which result in various content of barite in individual layers. For instance the difference between the bottom and middle layer is of 5.39 %, and between the bottom and upper layer it attains 9.77 %. Similarly, the distribution of iron and copper in the settling pit is very variable, too. So from the viewpoints of the content and spatial distribution of the utility components in the settling

pit it can be regarded as a non-uniform body. Further detailed prospecting, using suitable wells density will enable the cost-effective utilization of the material from the settling pit.

The reserves of the barite ore in the Rudňany deposit will be mined out during several years (Karoli et al., 2008). But the production of the barite concentrate can continuously carry on after solving and designing technology for the processing of the flotation sands from the settling pit. Owing to verification, the behaviour of flotation sands during their processing, the laboratory analyses and experiments on their upgrading were performed (Kovaničová et al., 2001).

Mineralogical and chemical analyses of flotation sands

Microscopic study was carried out with the aim to determine a grade of the mineral liberation. Thus, 95 – 100 % of barite, siderite, quartz and slates in the grain size class under 0.5 mm are liberated. The liberation grade of sulphides was investigated in more details. So in a grain size class of 0.16 – 0.50 mm the liberation is of 80 – 90 %, in a class of 0.09 – 0.16 mm it runs of 95 – 100 % and finally in a class of 0 – 0.09 mm it attains almost 100 %. The obtained results point to the fact that mineral components of the flotation sands are sufficiently liberated and therefore no further grinding is needed.

The chemical composition of sands as a dependence on a grain size was studied. The results of the grain size and chemical analyses as well as the recoveries of observed components into the grain size classes are presented in Tab. 2.

An upgrading of sands using classifying techniques is impossible because no significant concentration of any component in a grain size class was observed. On the other side a portion of grain size classes under 0.5 mm, i.e. the classes with sufficiently liberated minerals attains of 97.33 %. On the basis of this fact a successful application of separation method may be expected.

Results of separation and discussion

Owing to the chemical and mineral composition of sands, the physical and physical-chemical properties of dominant minerals an obtaining of siderite and barite concentrates as well as tailings, containing quartz and slates applicable as building material may be considered. Firstly, the magnetic separation was applied with the aim to prepare the siderite concentrate in a magnetic product. Secondly, a non-magnetic product was subjected to flotation to obtain the barite concentrate in a floating product and quartz-bearing tailings in a cell one. The results of laboratory experiments on magnetic separation and flotation are introduced in Tabs. 3 and 4, respectively.

The application of the magnetic separation resulted in almost twofold enhancement of the iron content in the magnetic product in comparison with the feed quality. Similarly, the recovery of iron into magnetic product and on the other side the recoveries of SiO_2 and $BaSO_4$ into a non-magnetic product achieved appropriate values.

Tab. 3
Average parameters of magnetic separation – laboratory experiment

product	mass yield [%]	content [%] Fe	SiO_2	$BaSO_4$	recovery [%] Fe	SiO_2	$BaSO_4$
magnetic	44.40	27.90	18.28	1.59	83.47	20.48	8.68
non-magnetic	55.60	4.41	56.68	13.35	16.53	79.52	91.32
feed	100.00	14.84	39.63	8.13	100.00	100.00	100.00

Tab. 4
Average parameters of flotation – laboratory experiment

product	mass yield [%]	content [%] Fe	SiO_2	$BaSO_4$	recovery [%] Fe	SiO_2	$BaSO_4$
concentrate	12.04	0.76	1.57	91.30	2.07	0.34	82.34
tailings	87.96	4.91	64.22	2.68	97.93	99.66	17.66
feed	100.00	4.41	56.68	13.35	100.00	100.00	100.00

Tab. 5
Average parameters of flotation – full-scale experiment

product	mass yield [%]	content [%] Fe	SiO_2	$BaSO_4$	recovery [%] Fe	SiO_2	$BaSO_4$
concentrate	25.52	0.64	0.71	96.99	4.66	0.36	91.61
tailings	74.48	3.73	67.02	3.05	95.34	99.64	8.39
feed	100.00	3.50	50.10	27.02	100.00	100.00	100.00

As to flotation test a relatively high-grade barite concentrate has been obtained. The content of $BaSO_4$ in floating product was almost by sevenfold higher compared to feed. A high recovery of barite into floating product at small mass yield was also attained.

So, independently on laboratory tests a full-scale experiment on flotation of non-magnetic product was performed. It is needed to mention that a fed sample of non-magnetic product was of higher quality than one fed during the laboratory test. This fact resulted in better quality of floating product as it is presented in Tab. 5.

On the basis of laboratory and full-scale experiments a wasteless technology was proposed. The flowsheet of processing technology is introduced in Fig. 1. The flowsheet covers the obtaining of all utility components but it must be stated that at given time and prices some products are not marketable.

Conclusion

The laboratory magnetic separation and flotation tests and the full-scale flotation experiments applied in the processing of flotation sands from the Rudňany settling pit showed that it is possible to produce siderite and high-grade barite concentrate as well as the quartzy sands utilizable in the building industry.

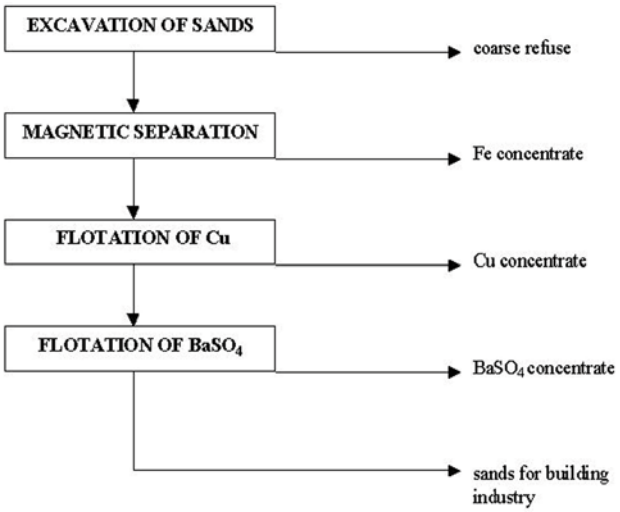

Fig. 1. Processing technology flowsheet.

Recently, the obtaining of high-grade barite concentrate and sands for building industry is a foreground task. The iron and copper-bearing sulphide concentrates are not saleable now. But a necessity of their winning arises from the requirements for commercial quality of barite concentrate and sands for building industry to avoid a contamination of the final products above all by sulphides.

The realization of flotation sands processing from the settling pit will results in:

– Upgrading onto industrially utilizable products;

– Improvement in utilization effectiveness of engineering facilities;

– Offering of job opportunities in the region by continuing of present productive activity;

– Reduction of ecological loading in the Rudňany village surrounding.

Acknowledgements. This work has been supported by the Slovak Scientific Grant Agency for the VEGA projects No. 2/0087/08. This contribution is the result of the project implementation of the Research excellence centre on earth sources, extraction and treatment supported by the Research & Development Operational Programme funded by the ERDF.

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Rukopis doručený 22. 6. 2010
Rukopis akceptovaný red. radou 7. 9. 2010
Revidovaná verzia doručená 19. 10. 2010