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Beneficiation of Eskişehir Beylikova Bastnasite Ore and Rare Earth Elements Recovery

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Abstract: Unique magnetic, optical and electrical properties of rare earth elements (REEs) have become essential in modern high technology. Considering this necessity of technology, efficient management and utilization of rare earth resources is of great importance. Even though there are more than 250 rare earth minerals in around the world, the number of minerals that can be economically processed, not exceeding three. Among these minerals, bastnaesite, has a significant impact on scientific advancement and social progress.

This project aims to contribute to the establishment of a sustainable supply chain for REE in Turkey and Europe by conducting research and development activities to leverage the utilization of REEs found in our country.

The primary objective of this project is to extract rare earth oxides from complex ore in the Eskişehir Beylikova region, which holds the largest reserve potential discovered in our country, and to refine these metal oxides to produce metals that can be used in magnet manufacturing. The project encompasses five main work packages during three years: Project management, ore enrichment, solvent extraction based purification, utilization of REOs and metals in additive material and magnet production.

Keywords: Bastnasite, Rare Earth Elements (REE), Ore Benefication, Hydrometallurgy.

1. Introduction

Rare earth elements (REEs) including the 15 lanthanides plus yttrium and scandium have been recognized as critical commodities by various international agencies and national governments due to their crucial roles in clean energy, high-tech and national defense industries and their inclusion in high-strength permanent magnets, as catalysts in petroleum refining processes and as additives in metal and glass, highlighting their significance in technological advancements [1][2].

As it is depicted in Table 1, particular rare earth elements are required for each of these applications (lanthanides are not universally interchangeable). It is clear that Maintaining a consistent supply of these elements presents significant issues due to the resulting disparities in demand for each REE in addition to the above-mentioned variances in their abundance in the Earth's crust [3]. For instance, producers of terbium (Tb) and neodymium (Nd), which are among the least abundant REEs, will face greater challences in terms of REE supply compared to producers of petroleum refining catalysts, who require lanthanum (La) and cerium (Ce), two orders of magnitude more abundant REEs [4].

Table 1. Rare earth element requirements by application [5]*.

Application	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Y	Other
Magnets			**23.4**	**69.4**			**2**	**0.2**	**5**		
Battery alloys	**50**	**33.4**	**3.3**	**10**	**3.3**						
Metal alloys	26	52	5.5	16.5							
Auto catalysts	5	90	2	3							
Petroleum refining	90	10									
Polishing compounds	31.5	65	3.5								
Glass additives	24	66	1	3						2	4
Phosphors	8.5	11				4.9	1.8	4.6		69.2	
Ceramics	17	12	6	12						53	
Other	19	39	4	15	2		1			19	

**Percentages are estimates of the total REE content required in a given application.*

The only REE bearing minerals extracted on a commercial scale are bastnäsite, monazite, and xenotime. Separation techniques such as flotation, gravity, magnetic and electrostatic separation are widely used in the beneficiation of rare earth minerals and the ores are the primary resources that are considered for this purpose [6][4].

Hydrometallurgical methods play a significant role in the processing of bastnazite ore and the extraction of REEs, following the pre-enrichment step. The leaching process has a significant importance, as leaching effectiveness is the key factor influencing the entire process.

Within the scope of the project, subsequent to the extraction of rare earth oxides from complex bastnazite ore in the Eskişehir Beylikova region, the largest reserve whose potential has been discovered in our country, metals are produced by metal oxide refining process to produce permanent magnets. The bastnasite ore obtained from the mining undergoes beneficiation process that is followed by a chemical beneficiation step to obtain pure metal.

2. Result and Discussion

As China accounts for 88% of global rare earths production, other countries are exploring strategies to decrease their dependence on China by extracting rare earths from primary and secondary sources. Various methods including ore beneficiation processes, leaching and solvent extraction, are used in this quest. Figure 1 provides a brief overview of the methods used for the beneficiation and purification of rare earth ores.

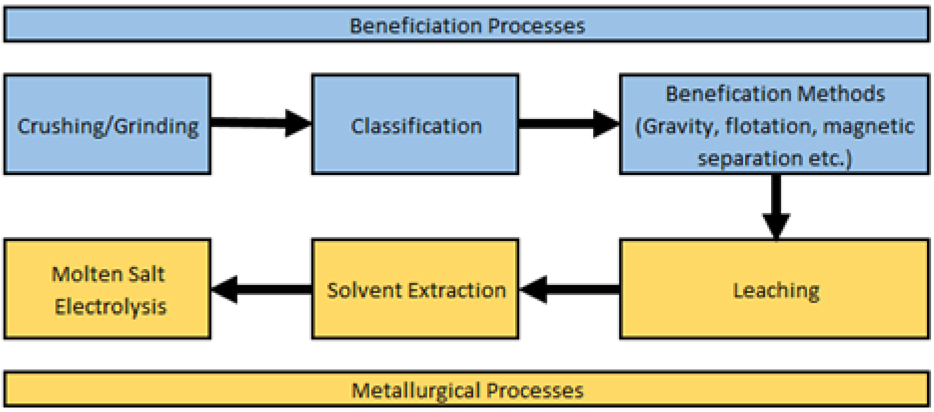

Figure 1. Overview of Rare Earth Element (REE) Production Techniques

This study involves, beneficiation and leaching investigations on rare earth ore found in Eskisehir-Beylikova. The ore consists of %40,80 CaF_2, %35,35 $BaSO_4$, %2,01 Ce, %1,50 La, %0,39 Nd and %0,10 Th and reserve is estimated to be 694 million tons. Atalay et al. suggested that rare earth minerals are accumulated in finer size fractions (-5 microns) and proposed attrition scrubbing method for ore benefication [7]. Basturkcu et al., performed MLA analysis on the -38 and +38 micron fractions of the attrition scrubbing product in order to examine the effect of attrition scrubbing in detail and compared these results with MLA analysis on the -38 and +38 micron fractions of the ore [8]. As a result of this study, rare earth yields in the -38 micron fraction of the attrition scrubbing product reached 70%. In this work, two approaches are used: during the primary sample preparation; the ore was fractionated, and crushed with a crusher prior to the attrition scrubbing. The attrition scrubbing products were sieved with a 45 micron sieve and the -45 micron fraction was obtained as the product, as the flow chart is given in Figure2. The behavior of the ore in different fractions have also been analyzed in the primary approach. The highest rare earth grade (Table 2) was obtained in the product at -45 microns after attrition scrubbing of the -3+0.075 mm fraction obtained from the -3 mm fraction of the ore and the leaching investigations have been performed using this product.

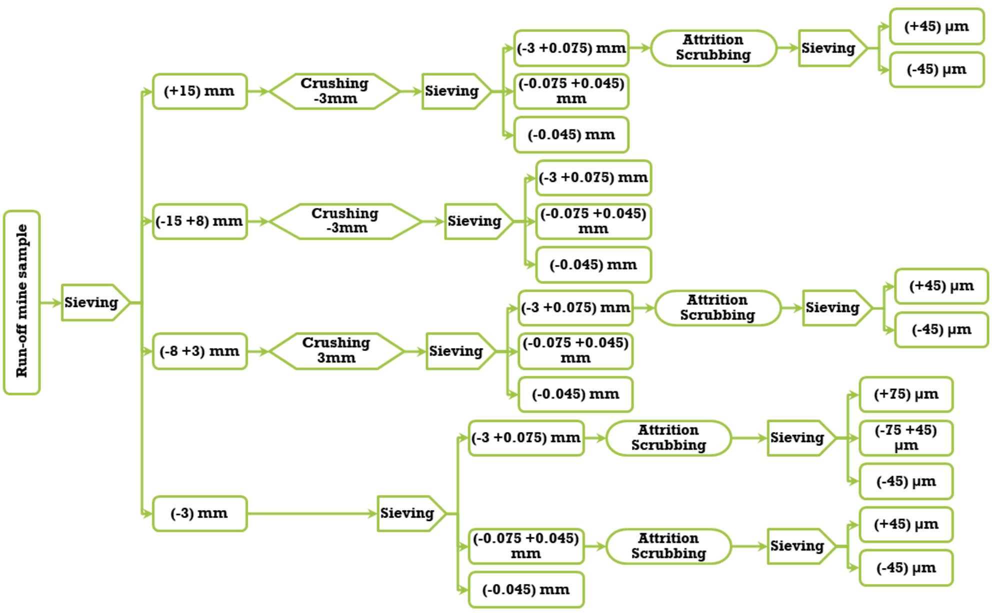

Figure 2. Preparation flowsheet of sample 1

The second sample was prepared by finely grinding the ore to -150 microns, followed by a flotation test as depicted in Figure 3.

Table 2. Major rare earth contents of the prepared samples

	La (ppm)	Ce (ppm)	Nd (ppm)	Pr (ppm)	U (ppm)	Th (ppm)
Sample 1	26.627,00	24.679,00	4.290,00	2.022,00	257,00	446,00
Sample 2	50.526,72	59.596,40	3.473,59	8.404,22	370,01	1.251,57

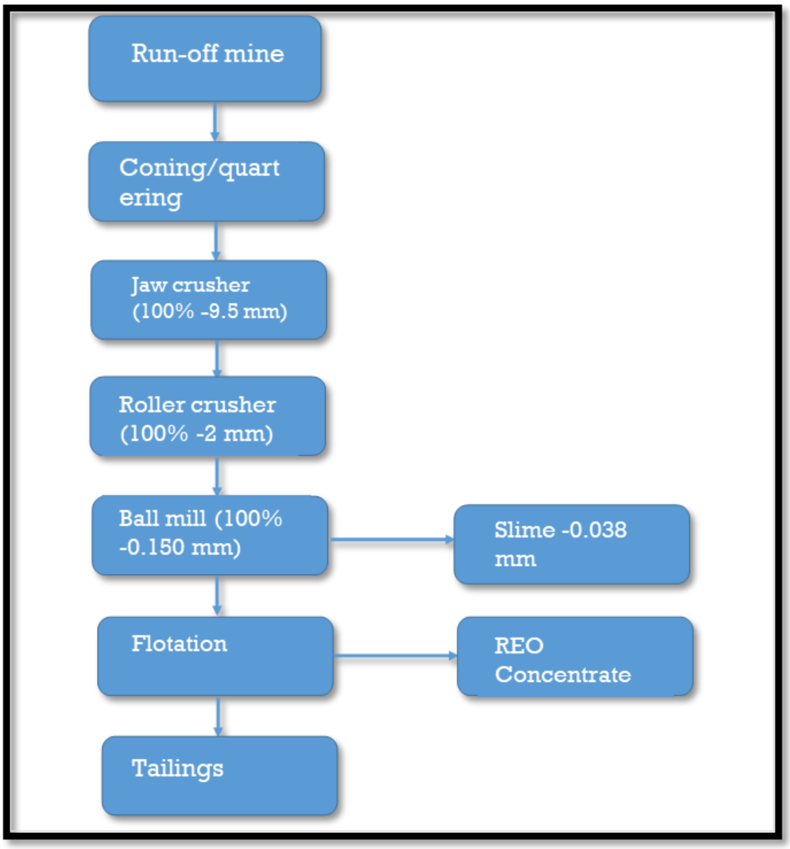

Figure 3. Preparation flowsheet of sample 2

Results in Table 2 shows that 7% REO content is achieved by simple attrition scrubbing and sieving and 18% REO content is achieved with grinding, sieving and flotation. Also its noticable that, REO content reaches up to 13% when grinding and sieving is applied.

Leaching tests were performed for both of the samples prepared by two different approach and chemical beneficiation process of the enriched Eskisehir Beylikova bastnazite complex ore involved acid leaching followed by solvent extraction method. The effect of different parameters such as K/S ratio, solution temperature, reaction time, oxidizing agent additives on the leaching efficiency was investigated in details. ICP (OES) and XRF analyses were utilized to characterize rare earth element oxides in this study.

3. Conclusion

The bastnazite ore sourced from the Eskisehir, Beylikova region was characterised in order to asses the ore structure beforehand. Subsequently, physical beneficiation was utilized to increase the ore content from approximately 3% to 13%. Following the physical beneficiation, chemical purification procedures were used to further enhance and purify the REEs.

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