A Study to Determine the REE Potential of Waste and Wastewater Originating from Turkey for the Future

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Abstract

Rare Earth Elements (REEs) are a group of 17 elements that consist of lanthanides, Yttrium, and Scandium; these elements are also known as vitamins of the modern industry. REEs were one of the critical elements listed in recent strategic reports by the European Union Commission and the United States Department of Energy; it is considered crucial to recover REEs from various sources like natural resources, wastes, and wastewater. This study aims to determine the REE potential of different types of waste and wastewater located in Turkey.

Introduction

Rare Earth Elements (REEs) are an elemental group including yttrium and scandium in addition to lanthanides and have similar chemical properties to each other. While there is a significantly growing demand in the modern industry, these REEs are becoming increasingly more crucial for a low-carbon and green economy. In other words, because of the increasing necessity for wind turbines, hybrid and electrical vehicles, fluorescent lights, demand and prices of the REEs have risen significantly. Some REEs are defined as critical REEs and are stated to be difficult to obtain. These critical REEs are Neodymium (Nd), Europium (Eu), Terbium (Tb), Dysprosium (Dy) and Yttrium (Y) (US DOE 2011, Seredin 2010). During the next 25 years, demands of Dysprosium and Neodymium are expected to increase by 2600% and 700% respectively (Alonso et al., 2012; Khanna et al., 2018).

In parallel with the potential increase of resource scarcity and the acceleration of sustainability studies, the development of the circular economy model has been getting more attention in the last decade. The main idea of the circular economy is to carry out the “take, make and dispose of” prevalent economic development model with the adoption of a “closing the loop” production model (Ghisellini et al., 2016, Geissdoerfer et al., 2017). However, less than 1% of the REEs used can be recovered nowadays. It is known that recovery processes have a smaller environmental effect and are more energy-efficient when the material recovery is compared with the extraction of raw ore (Reck ve Graedel, 2012). However, the problem is whether the recovery of metals provides economic benefits compared to the removal of raw metals (Favot and Massarutto, 2019).

To summarize, it is inevitable to identify REE potentials in many sources such as end-of-life products/secondary sources, industrial wastes and wastewater, both to meet the increasing demand and to ensure REE independence and sustainability of the country, which is one of the objectives of the circular economy. The main purpose of this study is to reveal the REE potential of various wastes, wastewaters and natural sources originating from Turkey.

Material and Method

Definition of Waste and Wastewater Samples

Nine different types of wastes and wastewater were collected from different regions from Turkey to determine the REE potentials. The first waste was provided from an advanced biological domestic wastewater treatment in İstanbul. To understand the fate and transport mechanism of the REEs in the environment and investigate the REE potential of sludge cake was selected. Waste slime of one of the boron mining plant facilities was obtained from Central Anatolia Region as a second waste type. The third waste is a kind of fly ash generated as a result of hazardous waste incineration located in the Marmara Region. The fourth and fifth samples are fine and coarse fly ashes respectively were taken from a thermal power plant in Marmara Region. The sixth waste was provided from a sludge processing unit of the domestic solid waste landfill site located on the European side of İstanbul. The seventh waste sample was obtained from the sediment of the Golden Horn estuary, as it is between the Black and Marmara Seas, it can be an innovative source for REEs. The eighth and ninth samples are wastewater from two different points of Turkey. The facility where the eighth sample was taken generates wastewater as a result of boron mining and is collected into a dam. This facility is located in the Central Anatolia Region. For the ninth sample, the leachate generated in a hazardous waste storage area in the Marmara Region was selected.

Acid-Leaching and Characterization

Solid samples were dried under 105°C during one night and ground before characterization. X-ray fluorescence (XRF) (Bruker S8 Tiger, USA) analysis was performed to determine the major oxide content of samples. A microwave-assisted (Berghof, Speedwave) acid digestion procedure was carried out under 180°C for 25 min to prepare the acidic leaches before the determination of REE content using inductively coupled plasma (ICP-MS, Perkin Elmer). 0.1 g dry sample, 6 mL HCl (37%, Merck), 2 mL HNO_3 (65%, Merck) and 1 mL HF (40%, Merck) were added into polytetrafluoroethylene tubes. Samples were stocked to 50 mL with distilled de-ionized water.

Results and Discussion

Table 1: REEs concentration of samples.

Wastewater treatment sludge cake (ppm)		Waste slime from boron mining (ppm)		Fly ash of hazardous waste incineration plant (ppm)	
Ce	49,85	Ce	46,29	La	30,82
La	24,79	La	22,90	Gd	29,21
Nd	19,97	Y	20,92	Ce	12,73
Y	14,84	Nd	19,12	Sm	10,03
Pr	5,49	Pr	5,09	Eu	6,79
Sm	3,98	Sm	4,01	Y	5,66
Gd	3,69	Gd	3,73	Nd	3,58
Dy	2,74	Dy	3,52	Pr	0,95
Er	1,58	Er	2,22	Yb	0,63
Yb	1,44	Yb	2,17	Dy	0,57
Eu	0,96	Ho	0,69	Er	0,31
Tb	0,54	Tb	0,61	Tb	0,12
Ho	0,52	Eu	0,61	Lu	0,10
Lu	0,21	Lu	0,32	Ho	0,10
Tm	0,21	Tm	0,31	Tm	0,04
Total REE	130,80	Total REE	132,53	Total REE	101,65

REE concentrations of three different solid samples were listed in Table 1. Total REE concentrations were determined between 100-130 ppm for these waste samples. While fly ash samples have higher REE potential, different kinds of waste samples can be a good alternative for the future generation to recover REEs.

Acknowledgement

This study was financially supported by The Scientific and Technological Research Council of Turkey (TUBITAK) (Project no:117Y357) and Istanbul Technical University (ITU) Scientific Research Project (Project ID: 41893). The authors would like to thank Geochemistry Research Laboratory for XRF analysis.

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