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Review paper

A REVIEW ON RECOVERY OF REEs AND RADIOACTIVE MATERIALS FROM PHOSPHOGYPSUM

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Abstract

Different types of and huge amount of wastes, residue and by-products are generated in worldwide. These wastes could be considered as flotation tails, concentrate, end-of-life products, phosphogypsum (PG), bauxite residue (red mud), mine tailings, metallurgical slags and industrial process residues from thermal treatment facilities. These kinds of different wastes may become inherently complex, heterogeneous and contain different kinds of metals, rare earth elements (REEs), radioactive elements and impurities. Recovery of these wastes, which are harmful to the environment and those with economic benefits, is very important in terms of both sustainability and protecting the environment and obtaining economic benefits. Therefore it could increase resource efficiency in the sense of a sustainable circular economy. In this paper, it was evaluated reviews studies about radionuclides contents of PGs, typical REE contents and recovery efficiencies with different experimental conditions.

Keywords: *rare earth elements, radioactive elements, recovery, phosphogypsum*

1. INTRODUCTION

So many research has recently been conducted on the end-of-life products containing high concentrations of REEs, such as lamps or magnets, there is less attention has been paid to industrial landfilled stocks [1] such as PG. However, PG seems contain lower REE concentrations but have huge volume and considered a promising source of REES and also contains waste is of environmental concern due to the high content of metals, metalloids and radionuclides [1] and also various impurities such as residual acid (P2O5), fluorine compound [2-4]. In this regard, PG considered as a significantly value added component for both environmentally and techno-economic side due to REEs and radioactive elements content.

Natural gypsum contains small amount of impurities, but PG is accompanied by many impurities that come from the phosphate ore or formed by production process. Therefore, PG is not readily available to be unless the imprurities and radioactivities are reduced to the required accepted limits [5]. Two major disadvantages of PG were identified as its high content of both toxic elements and radioactivity and the negative effect of impurities on product quality [6].

The main environmental concern associated with PG in connection to radioactive contamination is the presence of the naturally occurring radionuclides, the ^{238}U decay series daughter products ^{226}Ra, ^{210}Pb and ^{210}Po. ^{226}Ra is considered to be the major source of radioactivity in PG and it is chemically analogous to calcium [7].

Table1 shows typical radionuclides composition of phosphogypsums.

Table 1 - Typical radionuclides composition of phosphogypsums

Source	^{235}U	^{238}U	^{226}Ra	^{228}Ra	^{232}Th	^{40}K	^{210}Pb	^{210}Po	Unit	References
Barreiro, Portugal	18.5	142	735				776			8
Egypt		164	482			72	418		Bq/kg	9
Bangladesh (fresh)			337				45	50	Bq/kg	7
Bangladesh (old)			295				39	45	Bq/kg	7
Bandırma, Turkey		9	22		1	11			Bq/kg	10
Poland			72.8-80.5			<20			Bq/kg	11
Spain		100	785				827		Bq/kg	12

The growth in global demand for the rare earth elements from 2020 to 2025 will lead to the opening of new mines or the search for an alternative source [13]. In this sense, PG emerges as an important resource. REEs normally contained in the phosphate rocks about 0.03 to 1.0 wt% [14] and PG has also relatively low REE content (~0.45%), however it seen as an anthropogenic source of REE and it has no costs for mining and disintegration of a natural raw material and recovery of valuable REEs and also radionuclides. Unlike metalloids and radionuclides, REEs show low mobility under environmental conditions [1]. Table 2 shows typical REEs composition of PGs.

Table 2 - Typical REEs composition of phosphogypsums

Source	Ca	P_2O_5	REE	Sr	Ce	La	Y	Nd	Unit	References
Russia	25	1.5	0.45	1.95	0.26	0.14	0.01	0.06	%	15
Tunisia			224.93		49.99	35.86	44.48	52.63	ppm	4
Poland					0.28-0.35	0.16-0.17	0.011-0.012	0.09	%	11

Recovery of REEs is challenging, because the elements are not found in pure form, they are in a complex form. Also, PG is usually obtained from phosphate rocks and solubility of REE-phosphates is low. Concentrated RRE minerals cannot be dissolved directly with water or mineral acids at ambient temperature. Only bastnasite mineral is partially dissolved in high concentration hydrochloric acid solution. In order to dissolve the elements in RRE minerals, it may be necessary to convert them into soluble and easily obtained forms [15]. Nitric acid and HCl could show more effective for leaching than H_2SO_4 for the recovery of REES, but H_2SO_4 leaching was still industrially preferred due to economical reasons [14, 16] such as availiability in the system already [4] and cheaper than nitric acid. Generally, leaching of REEs with sulfuric acid provides about 30-40% [17] efficiency. However, these leaching yield could be differing for different types of wastes and methods.

2. CONCLUSIONS

Phosphogypsum contains different kinds of metals, rare earth elements (REEs), radioactive elements and impurities. Recovery of these wastes, which are harmful to the environment and those with economic benefits is very important in terms of both sustainability and protecting the environment and obtaining economic benefits. For this reason, it is necessary to conduct a detailed literature research on the subject. In this paper, it was evaluated reviews studies about radionuclides contents of PGs, typical REE contents and recovery efficiencies with different experimental conditions.

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