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Recovery and Recycling Sources of Rare Earth Elements in India and its Subcontinent - A Review

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Abstract: ***Rare earth has been of considerable and wide interest due to its manifold applications but they are depleting gradually. Under the sustainable development goals it is necessary to look for the new Primary and secondary sources of energy and the recycling techniques to have sufficient reserves of rare earth in Indian subcontinent .This will reduce our dependence on China for import and makes us economically better globally. The idea of the paper is to highlight the present scenario and to unfold the availability of secondary sources in water beds of India. This will be a major breakthrough in the economy of our country.***

Keywords: Rare earth elements, Secondary resources, Monazite, Hydrometallurgical, Indian Rare Earth Ltd.

1. Introduction

Rare earth elements are real treasuresthey are important for high end electrical components and its devices worldwide. Its production has been less in India and most in China which makes us dependable on China for it. This explains need of the exploration of various resources of rare earth elements in India (Table 1).Various memorandum of understanding (MOU's) had been signed by the government enterprise body with many giant leaders in the same field. Even from its production from primary resources it had contributed less than 50 tonnes of yearly production of rare earth oxides in 2010 (British geological survey; 2011). Since, then output gets increased but in comparison to other countries we are still short of huge demand to be accomplished (Indian rare earth Ltd; 2015). It arises the need and the requirement to understand the past 10 years trend and availability in the field of rare earth with respect to Indian subcontinent. Focus had been given to 3 types of sustainable development goals of rare earth in context to Indian subcontinent they are: economy and population inflation , the exhausting resources and the automation required .In response to the gaps in knowledge the paper elucidate the value of review of related literature with respect to its sustainable development goals .It aims to highlight the major usage and availability of resources as secondary sources in water beds of Indian subcontinent due to shortage of primary resources. The literature data aims to bring the better connection of environment friendly development with the rare earth which will be a major step towards the green and clean energy thus contributes in the better economy of India.

2. Methodology

The literature reviewed extensively to understand the economic and industrial development of rare earth with respect to Indian-subcontinent as per Indian rare earth limited (Indian rare earth Ltd; 2015). The unavailability and the un fulfilment of rare earth demand globally brings our focus on secondary resources due to lack of reserves. Henceforth, literature has been broadly classified and calls for the urgent exploration of water bodies in Indian sub-continent region through hydrometallurgical process for recovery of rare earth (Negrea et al.; 2018). From the reviewed literature the key topics were drawn out with due respect to availability of resources and this has been used toidentify the core areas to broaden the area of research.

3. Results

The review of literature defines the step taken in the field of rare earth since 2011 till now. It has classified thepresent scenario with respect to developmental goals in three broad categories till now.

A) Economy and population inflation: With growing increase in population of Indian subcontinent the demand of energy sources has arisen. Non-renewable sources like rare earth utilised more due to the population inflation. The rare earth metals are 17 elements having 15 lanthanides along with scandium and yattrium. Rare earth is classified into three types such as heavy, light and middle rare earth materials. Major application of rare earth is in the field of magnets, batteries, metallurgy, catalyst, polishing, phosphorus (Directorate general enterprise and industry; 2014) (Liu et al.; 2005) (Pyrzynska et al.; 2016). Out of this majority is in the field of magnet and catalyst (ERECON.; 2014). Out of the above monazite type minerals are majorly explored in India since year 2011 (Indian rare earth Ltd.; 2015). But monazite type minerals are basically found most only in Orissa region of Indian subcontinent (Table 2). Various memory of understanding (MOU's) are signed with Indian government by many countries including Japan to avoid interdependence of countries over major producer China. India in Orissa has elaborated the total amount of 1065 reserves till now including ilmenite, sillimanite, Garnet, Zircon, Rutile, Monazite projected by chairperson Indian rare earth Ltd (Indian rare earth Ltd; 2015). Out of all the worldwide companies for the extraction of rare earth India proposed to feed the capacity of 5000 reserves which we are short of till date. So presently this accounts for just 1% of total global reserve contribution in field of Rare Earth, it makes India highly dependable upon China which accounts to 59.3% of global reserves (Indian rare earth Ltd.; 2015).So , to safeguard and to reduce the dependency we have to find out the more of secondary sources in Indian subcontinent which will be our major step towards the growing economy .Indian rare earth Ltd 2015 in agreement with professor of Indian institute of management (IIM) Dr S. Chandrashekar who has done extensive research in Rare Earth projected that if India wanted to become an Industrial power it needs to have handle on whole rare earth ecosystem from raw material to finished products (Economic times; 2014).

B) Exhausting resources: Natural resources are the things that we get from the mother Earth.These are of two broad categories as per their extinction.

1) Renewable energy source: It means the "new one "can make it again. These types of resources can be grown again and again so they are easy to get. For example, trees can be grown again and again.

2) Non-renewable sources: These type of resources gets finished when they are majorly used as they are limited in amount they cannot be re-grown. So, we are more concerned about them as we need to preserve them to our best means. Likewise, fossil fuels, coal, gas and rare earth materials cannot be regrown.

So, we need to look for primary as well as secondary resources for the procurement of growing demand of rare earth globally in context to Indian subcontinent. Looking in to the development of secondary sources found and challenges encountered below we can decide what can be done further.

a) Recovery of rare earth from e-waste as a secondary source primarily

Secondary sources recycling for rare earth elements has restricted its reuse ability asvery less quantity gets recovered (Binnemans et al.; 2013). But various examples of rare earth recovery from end of life products like fluorescent lamps, magnets, batteries and mobile phones have been produced .Many of the studies report 99% of re-usable rare earth elements (Ruiz-Mercado et al.; 2017) (Yang et al.; 2015) (Abrahami et al.; 2015). Many experimental data have proven good data in recovery and recycling techniques with respect to industrial content but overall they are still at the beginning of the Era (Lister et al.; 2014). Some main types of recycling products from e-waste are as follows.

1) Permanent magnets: Permanent magnets become electronic waste which is shredded and melted down for recycling of other metals .During this process rare earth elements present in the waste whichwere oxidised and becomes part of the smelter slag in this process (Binnemans et al.2013) .Hitachi Ltd recovered the rare earth from the hard drive waste and separated them . (Schuler et al.; 2011) reported the re-use of permanent magnet in medical magnetic resonance imaging.

2) Batteries: In March 2013 Honda motor's-started recovering rare earth elements from batteries which are collected and dismantled in the powder form. This gets separated into different fractions containing rare earth and the rare earth are dissolved in acid to produce rare earth oxides these are then treated by the molten state electrolysis to produce rare earth in metal form (Honda Motor Co. Ltd; 2013).

3) Lamp phosphors: (Rhodia et al.; 2012) he started the process recycle in which there were elements from old phosphors in France (Tsamis et al.; 2015). The phosphors are sent to a facility where powders are suspended in water solution and treated chemically and dried. Thus, waste water and gases are treated further to produce rare earth elements (Solvay; 2014).

4) Miscellaneous: (Schuler et al.; 2011) identified the recycling of small amount of rare earth from yattrium that to mainly from laser crystals and synthetic garnets. Different methods were employed for separation of rare earth for recycling purpose but they encountered some major challenges.

b) Challenges encountered:

There was the presence of contaminants in the feedstock usually as electronic waste comprise of complex composition so extensive pre-treatment was required to extract rare earth efficiently (Tsamis et al.; 2015). (Schuler et al.; 2011) also proclaimed that there was not sufficient waste due to certain norms in regulation authority and moreover the used in items were exported to developing countries so that available feedstock for the countries of technical infrastructure could be reduced. Most of the recycling methods through electronic waste demands large power and chemicals. Thus, lethal effects of acid instead end up into chemical waste as a pollutant in water. So, still we are in short of rare earth till today.

3.) Automation required: With respect to Indian subcontinent thereis the limited production of rare earth metals asby-product of uranium and thorium extraction are using caustic soda method so it becomes life threatening.

Indian rare earth having production facilities mainly in southern India and Orissa producing 99.9% of rare earth compounds by multistage solvent extraction and fractional precipitation and high purity oxides. But the problem encountered is basically the storage of thorium and processing of containers titanium metal production without any hindrance as projected by (Indian rare Earth Ltd ; 2015).

4. Discussions

Going through the recurrent literature we can understand a stage in terms of rare earth production there is requirement of other resources to be acknowledged to fulfil the due lag of production till date. There are few recovering methodologies which are also source of rare earth from Indian water bodies and its aqueous system (Singh et al.; 2001)

Broadly rare earth removal technologies are hydrometallurgical and Para metallurgical techniques (Yoon et al.; 2014) (Zhang et al.; 2013). The recovery of rare earth depends on the concentration of valuable metals, the composition of the solution and the process of the target metals (Tolba et al.; 2017).

While hydrometallurgical techniques used are absorption, ionexchange, chemicalprecipitation, electrocoagulation, floatation, reverse osmosis, membrane filtration, nano-filtration, membrane electrolysis which are available for extraction of metals from the waste streams etc (Zhang et al.; 2013) (Fu et al.; 2011) (Marder et al.; 2004). These techniques will also be employed for industrial scale production and resource settings for further use. So, the eco-friendly design demands the Indian society to proclaim the rare earth production to be enhanced as this is extremely important. But apart from evaluating the new resources the prime fascia factor to be considered here is the environmental load which it puts on the ecosystem. Thus, it could be analysed that new techniques process, governance, flexible system is required. To put a greater number of environmental rare earth operations with due impact on environment must be modelledto ensure that how much degree of certainty we can gather from the end use so that it can outweigh the production side effects (Mc lellan et al.; 2014)

5. Conclusion

From the above review of literature problems encountered and demand for the urgent consideration for the production of rare earth must be simplified as follows:

- More number of innumerable numbers of primary and secondary sources to be considered as prime most important in India.
- Development and fulfilment of required mentioned technology by Indian rare earth Ltd at the topmost priority.
- Suggesting the best techniques with reference to Indian context for the removal and the extraction from Indian aqua systems.
- Availability and expansion must be gathered and accumulated considering the broad environmental impact over the ecosystem.
- End of product must add its contribution to the aim of sustainable green and clean energy output.

6. Acknowledgement

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Table 1: Data Furnished By Indian Rare Earth Limited

Select RE projects outside China

S.no	Company	Country	Proposed REO Capacity
1	Lynas Corp	Malaysia	22,000
2	Molycorp Minerals	USA	20,000
3	Indian Rare Earths Limited	India	5,000
4	Great Western Minerals	South Africa	2,500
5	Alkane Resources	Australia	2,600
6	Vietnamese Gov/Toyata Tsusho/Sojitz	Vietnam	3000 – 5,000
7	Arafura Resources	Australia	20,000
8	Avalon Rare Metals	Canada	5,000
9	Kazatomprom/Sumitomo	Kazakhstan	15,000
10	Stans Energy	Kyrgyzstan	2,000
11	Minerals and Energy	Greenland	43,700
12	Rare Element Resources	USA	-
13	Resources	Canada	-
14	Quest Rare Metals	Canada	-
15	Ucore Uranium	USA	-
16	US Rare Earths	USA	-
17	Matamec Explorations	Canada	
18	Etruscan Resources	Namibia	-
19	Montero Mining	Tanzania	-
20	Tasman Metals	Sweden & Finland	
21	Neo Material Technologies/ Mitsubishi	Brazil	-

Table 2: Data Furnished by Indian Rare Earth Limited

Major Minerals of RE of Commercial importance

Minerals	Chemical formula	Countries of origin	Remark
Carbonate			
Bastnaesite	(Ce,La) FCO_3	USA, China & Australia	Processing relatively simpler than Monazite. It has larger content of Europium compared to Monazite. In China it is associated with iron ore mining.
Phosphate			
Monazite	(Ce,La,Th & U) PO_4	Australia, India, Malaysia, Brazil, Thailand & Korea	RE content more or less uniform around 60% and minerals available in placer beach sand resources. The ore contains Th & Uranium which are radioactive
Xenotime	YPO_4	Malaysia, India, China	Yttrium major constituent. In Malaysia production is associated with Tin mining
Apatite	$(CaRE)_5[(PSi)O_4]_3(O,F)$	CIS, South Africa	Occurs in Copper, Tin, Phosphate mining
Ion exchange clay	Weathered apatite & xenotime ore concentrated in the soil in ionic form	China	Unique deposits found only in southern China. Though lowest in rare earth contents easiest to concentrate from the ore. Rich source of Y, Eu, Tb & Dy