Rare Earths Mining and Applications in India

D. Singh
Formerly at CMD, IREL (India) Limited

A. Mishra
IREL (India) Limited
Prabhadevi, Mumbai-400028

Preamble

The Rare Earth Elements (REE) are a collection of 17 elements, namely, scandium, yttrium and lanthanides (15 elements in the periodic table with atomic numbers 57 to 71, namely, lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb) and lutetium (Lu). Though Scandium and Yttrium are not REE, they are called so, since they are extracted from similar deposits and exhibit properties similar to REE. They are characterized by high density, high melting point, high electrical and thermal conductivity, etc. and exhibit excellent catalytic, magnetic and optical characteristics.

The first time a "rare earth" mineral was discovered was in a mine in the village of Ytterby (a village near Stockholm) Sweden way back in the year 1787.They are considered "rare" because they are relatively scarce compared to more common elements like oxygen, silicon, and iron. Despite their name, they are not actually rare in terms of their abundance in the Earth's crust, but they are often dispersed widely and not typically found in concentrated form. However, with the exception of the highly unstable promethium, rare-earth elements are found modestly in the earth's crust with cerium being 25thmost abundant element at 68 parts per million.

REE do not occur as separate minerals amenable for easy mining and are widely distributed across the earth's surface. That is the reason, though found in many countries, they are exploited by only three to four countries globally.

1. Source

The sources of REE are bastnaesite (a fluorocarbonate which occurs in carbonatites and related igneous rocks), xenotime (yttrium phosphate), loparite which occurs in alkaline igneous rocks, monazite (a phosphate), etc. The REE occur in many other minerals and are recoverable as by-products such as from phosphate rock

1.1 Discovery of Rare Earths in India

A German chemist, Herr Schomberg discovered a few colored particles that were sticking to coconut fiber imported from India, in 1909. He identified the particles as Monazite, a precious mineral which came as a contaminant in the coir. It is believed that the bundles were smeared with mineral sand when the same was stacked in the shore for lighterage to ships.

On further investigation, the origin was traced to Manavalakurichi in the erstwhile Travancore state in the southern tip of India, which was an important trading point and was well known due to spices. This accidental discovery of RE minerals made the beach an area of scientific interest. Monazite was important as it was the source for Thorium, required for the manufacture of gas mantles.

Herr Schomberg established the first step of supply chain at Manavalakurichi (MK) in 1910. Subsequently, another source of Monazite was found in Chavara along the coastal stretch in the north. Post World War 1, the London Cosmopolitan Mineral Company took control of these resources. In 1920, Hopkins and Williams (H&W), yet another London based company took over the operations to extract Ilmenite, a titanium bearing mineral, found in association with Monazite. Between 1921 to 1930, a second company started operations in Chavara. The Travancore Minerals Company Ltd. (TMC) took over the assets of LCMC in 1930. A third company, F X Pereira & Sons (Trv) Pvt. Ltd., (presently Kerala Minerals and Metals Ltd.) also commenced its operations in Chavara in 1932.

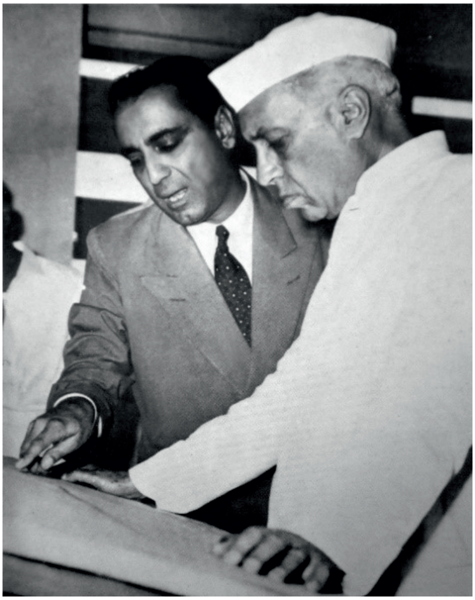
1.2 Start of Rare Earth Operations in India

The Government of India realized the strategic importance of mineral sands because of the presence of Monazite. The Atomic Energy Act was passed on 15thApril, 1948 and the Atomic Energy Commission was set up in the same year on 10thAugust under the chairmanship of Dr. Homi J. Bhabha. One of the first steps taken by the Commission was to stop the export of Monazite and set up a facility for processing the mineral for extraction of thorium and REE. IREL (India) Limited was incorporated on 18th August, 1950 under Indian Companies Act, 1913 jointly owned by the Government of India and the then Government of Travancore, Cochin with the objective of processing monazite for the production of thorium for future use in the atomic energy programme. In 1963, IREL (India) Limitedbecame a full-fledged Central Public Sector Undertaking.

As a first step, IREL established the Rare Earth Division (RED) at Udyogamandal to extract thorium and RE from Monazite based on technology sourced from erstwhile Societe de Produits Chimiques des Terres Rares, Paris, now Solvay. A team from France comprising of a few individuals even set base in India in the initial stages. There were initial problems in setting up of the plant such as delays in shipping of machinery from Europe and U.K., delay on the part of certain manufacturers in supplying machinery, difficulty in obtaining steel in India and frequent changes made by the consultants in drawings. However, the construction was completed by June 1952 and regular production commenced by sourcing the Monazite from the erstwhile private players.

View of RED, Aluva from the banks of river Periyar

The plant was dedicated to the nation by the late Prime Minister Pandit Jawaharlal Nehru on December 24, 1952 in the presence of Dr. Homi J. Bhabha. Calling this factory a symbol and promise for the future, “Profit earning”, he said, “was only secondary as against the greater role IREL had to play”.



Dr. Homi Bhabha explaining the flow sheet of Monazite Processing Plant to the then Hon'ble Prime Minister of India

The Department of Atomic Energy came into being on 3rd August, 1954 which was kept under the direct charge of the Prime Minister. IREL was entrusted by the DAE to set up a Thorium plant at Trombay for the production of thorium nitrate to be used by the gas mantle sector. It was a matter of pride that the plant commissioned in 1955, was one of the largest in the world, meeting the requirements of the vast gas mantle industry in India as well as abroad.

Ilmenite, Rutile and Zircon along with Monazite occurred together in the mineral assemblage and they could not be differentiated before separation. The Atomic Energy Act 1948 was repealed and new act was passed in the year 1962 wherein, the minerals associated with Monazite were brought into the category of atomic minerals.

2. Expansion of business

Since sourcing of Monazite for the strategic operations was inconsistent, it was necessary to take over their operations. IREL was made a full-fledged central government undertaking in 1963, under the administrative control of the Department of Atomic Energy.

Travancore Minerals Ltd. went into voluntary liquidation on 27th January 1965. IREL took over the two companies i.e. Hopkins & Williams and Travancore Minerals Limited engaged in mining and processing of mineralsands in the southern part of the country and established two mineral divisions at Chavara in Kerala and at Manavalakuruchi in Tamil Nadu. This would ensure that the minerals sand industry would be operated in a modern and more efficient manner with a view to extracting other valuable minerals constituents viz. Zircon, Monazite, Rutile and Sillimanite with Ilmenite. The acquisition of the mineral sand industry would ensure an adequate and uninterrupted supply of Monazite for the extraction of thorium and REE.

Collection of beach washings

Subsequently, a third mining and mineral processing plant was established in Orissa Sand Complex (OSCOM) at Chatrapur in Odisha to meet the increasing requirement of monazite. The plant started operations in the year 1986.

Modern Mining Methods deployed by IREL

3. Sale of Rare Earths Concentrate

Initially, the RE produced as a by-product during the processing of Monazite was not able to find full market which led to issues concerning its disposal. In early days, part of the RE chloride was sold through Societe de Produits Chimiques des Terres Rares, Paris, in the European market. However, due to poor evacuation, the location of the plant near the sea and limited availability of land parcel posed additional challenges with respect to its disposal. The sales could not be increased despite substantial reduction in selling price. On numerous occasions, tons of Rare Earths Chlorides had to be written off as unfit for sale due to deterioration as a result of long storage.

In the 1960s, the Japanese initiated inhouse research to learn how best RE could be utilized. M/s. Wako Bussan Co. Ltd., Japan, was added as a selling agent for RE Chloride (RECL) to Japan which resulted in increased sales and disposal of most of the accumulated stocks.

To meet the increased demand for RECL, processing was stepped up to more than 1500 tons of Monazite per year. IREL had now established itself in Japan on a firm footing with increased demand continuing from Europe. In order to meet the increased demands from Japan and Europe, steps to increase the production were taken up and during 1961-62when the processing at Alwaye was stepped up to about 1800 MT of Monazite per year and subsequently to 3000 MT of Monazite per year. For the first time, orders were also booked in America. In due course of time, the plant capacity was again increased to process 4200 MT of Monazite per year.

As a part of value addition initiatives, IREL set up a 10 tons per month plant, at Alwaye for the manufacture of RE Fluoride to meet the demand of the Carbon Arc Industry through in-house design which was able to meet the entire domestic requirement. The company also entered into production and sales of RE Oxide, RE Fluoride and RE Hydrate to different destinations globally.

The RE market slowly started picking up and its applications found numerous uses in the Western world for niche products. RE were normally used as concentrate form as mixed RECL. IREL RECL had a global footprint and was instrumental in developing a variety of applications of individual REE through sustained research efforts.

Although REwas produced in the country, their consumption within the country never exceeded 10% of the production. The rest 90% was always exported to USA, Europe and Japan. With a view to creating an awareness within the country on the potential of RE and to generate an interest amongst researchers and the industrial community to take up research and production based on RE, the company organized a symposium on “Rare Earths – Applications and Technology” in 1986.

4. Modernization and Value Chain initiatives

4.1 Closure of Rare Earths production in Kerala

Due to continuous operations of Monazite processing at RED, Aluva and consequent storage of radioactive Thorium Oxalate residue for use in the 3rd stage Atomic Power Programme, the regulatory wing, the Atomic Energy Regulatory Board (AERB) observed that radioactive levels were approaching the benchmark leveland they did not grant permission for further operations.

Due to statutory and regulatory conditions,the beginning of the new century witnessed closure of Monazite processing operations in RED, Aluva on the recommendations of the statutory body, AERB.

4.2 Rare Earth Extraction Plant

To meet the obligations of Government of India, IREL took up the challenge to set up a new Rare Earth Extraction Plant(REEP) in the OSCOM premises at Odisha and retrofit the operations at RED, Aluva for refining the RE concentrate from REEP to produce separated High Pure Rare Earths (HPRE). The new REEP plant in Odisha was set up with a capacity to process 10,000 tons per year of Monazite.

The process of setting up new REEP at Odisha with increased capacity had its own regulatory challenges. Since no other plant was working in the sector, the expertise in upscaling of equipment construction brought with it, its own constraints. Even though the plant was ready, teething troubles were encountered initially for scaling up the operations. Factors included the use of very old technology of the 1940’s, limited availability of engineering companies in India to take up RE specific work, improper selection of the material of construction by the consultants, etc.

Rare Earth Extraction Plant, Odisha

To add value to the mixed RECL produced from Monazite processing operations, the operations of IREL in RED, Aluva were modified based on in-house R&D to set up a plant to produce refinedHPRE. The REEP plant in OSCOM, Odisha started commercial operations in 2016 while production of refined RE started in the year 2017. With this, India came into the global arena for having the capabilities and capacity to produce refined REs.

An agreement was signed with M/s Toyotsu Rare Earths India Limited, an Indian subsidiary of Toyota Tsusho Corporation, Japan post cabinet approval culminating from G-to-G understanding between the respective Governments. The agreement helped in understanding and improving the qualitative aspects of RECL which are acceptable on an international level. The pilot plants for Dysprosium (Dy) and Gadolinium (Gd) were also established and dedicated to the nation. Similarly, facilities were established to produce high purity (6N) Neodymium (Nd) and Yttrium (Yt). All the above high pure separated RE had strategic applications.

5. New Initiatives

5.1 Facility for production of Rare Earth Permanent Magnet (Samarium-Cobalt):

After establishing the above plants, concerted efforts were made in the value addition side to set up the Rare Earth Permanent Magnet Plant (Sm-Co based) at Vizag based on technology developed by BARC/DMRL for use by Defence and Atomic Energy sectors.

Rare Earth Permanent Magnet Plant being dedicated to the Nation

The facility was dedicated to the nation by Hon’ble Prime Minister of India, Shri Narendra Modi on the occasion of the 25th anniversary of ‘National Technology Day’ on 11.05.2023. With this started the first time production of Rare Earth Permanent Magnets in the Country.

Rare Earth Permanent Magnet Plant, Andhra Pradesh

5.2 Rare Earth &Titanium Theme Park:

With a view to increasingthe production and consumption of RE within the Country, a RE and Titanium Theme Park was established at Bhopal in Madhya Pradesh in line with the Solar, plastic parks, etc. set up elsewhere in the Country.


Rare Earth & Titanium Theme Park

The objective of the theme park is to set up industrial facilities by carrying out industrial engineering to upscale the scientific principles proven by BARC in laboratory scale so as to encourage entrepreneurs to gain hands on experience in the use of these technologies and set up commercial operations. It also includes skill development to develop the skill sets of the workmen of the future.

The theme park will house plants to produce Neodymium, Cerium and Lanthanum Metals, recycling of RE from end-of-life magnets, RE phosphors, etc. Plants for production of Cerium and Lanthanum metalsare already operationalized resulting in the first time production of RE metals in the Country. Further, the plant for recovery of Rare Earths from end-of-life magnets is also operationalized. Other plants are under erection and will be commissioned shortly.

5.3 Expansion Plan

The global commitments towards clean energyand net zero emissions by 2070 depend on RE. Considering the upcoming requirement of RE, IREL with the support of DAE has recently obtained Letter of Intent (LoI) over three deposits including one for its first subsidiary IREL IDCOL Limited. Further, IREL has constituted a JV company named 'IREL TAMIN Limited' to harness the deposits in Tamil Nadu. All the above projects will result in increased production of Monazite leading to its processing and meeting the requirement of RE.

5.4 The Challenges in RE Sector in India

The source of RE in the country is Mineral Sands, which occur to the tune of only 0.056-0.058%, while that in China is to the order of 6%. Further Chinese deposits are associated with iron, copper and gold making the operations cost effective, whereas Indian source is locked up with radioactivity making the extraction process long drawn and expensive. In addition, the source of REE being radioactive in nature, poses additional challenges in terms of disposal of radioactive waste and environmental sustainability.

Another important issue is that the Indian source primarily contains five elements called Light REE (LREE) out of 17 elements and does not contain majority of Heavy REE (HREE), which are important for strategic sectors. Further, in Indian deposits, 2/3rd constitute Cerium and Lanthanum, which are otherwise abundantly available in earth crust and are of least economic value among REE. Among LREE, it has been seen that only Neodymium and Praseodymium, have gained importance since the beginning of the 21stcentury due to their usage in high power permanent magnets.

5.5 Long Gestation Periods

Production of RE is a very long drawn process starting from exploration to license for mining, obtaining statutory clearances, operationalization of the leases, carrying out mining, concentration, mineral processing, monazite upgradation, cracking of monazite to produce RE concentrate in the form of RECL and subsequently its refining to produce separated HPRE.

Towards the value side, production of HPRE is followed by metal extraction & alloy and product unlike other metals. All these stages require long gestation periods coupled with a need of partnering the segments in inter-disciplinary field to make a useful product. Hence, along drawn vision with an expanse of 10 to 30 years' time horizon is needed with continuity to generate momentum in the sector. It is a sector, which would never give instant returns and needs investment in terms of man and machinery.

Though IREL was ready with the upstream side immediately after independence on account of its association with radioactivity and provides radioactive free HPRE, the private sector has not shown particular interest in establishing the downstream industry for which there is meager market for RE inthe Country.

In India, a major source of REE is Monazite which is a prescribed substance containing U and Th meant for the atomic energy programme in the country. The prima-facie mandate of IREL has been to extract such radioactive elements (U & Th) for appropriate use in DAE and provide REEs in liberated (from radioactivity) and marketable form to industry for commercial applications.

REEs are therefore kept under the open category free from license regime or any restriction. It has been expected as in any other commercial product that the private sector would play a significant role thereafter for manufacturing of products. However, this has not happened in India which may be due to certain inherent economic constraints namely low profits, consumption in selective global pockets, lack of a domestic market, long gestation period, non-availability of industry scalable technology and lack of instant returns.

India witnessed production of RE sector since independence. The primary need however then was to cater to the requirements of the atomic energy programme. More so, in comparison to technological excellence for which REEs are known; basic amenities to meet the requirements of the society at large became the priority. REE are known to find use in niche products, and opting the use of these products was far from reality at that point of time.

In spite of all the above factors, India is known for having complex processing technology for RE, however India does not have a comprehensive end to end value chain of REE beyond oxides. As such capabilities of India may not be available in public domain as like any other country owing to radioactive resources of REE. Such a situation creates a perception in the minds of people that despite having reasonable resources in the country, India does not have a place in the global Rare Earth industry eco system as of today, which is far from the truth.

6. Conclusion

India has developed capabilities in terms of extraction and refining of RE and the products of IREL are globally acclaimed. Further, recently India has established its capabilities in the production of RE Permanent Magnets (for the strategic needs of the country) and is gradually moving towards RE metals, RE recycling, etc.

Since it is inter-disciplinary sector, the need of the day is to carry out focused R&D to develop scalable technologies to produce products using RE. Further, there is a need for policy interventions to incentivize the private sector to set up industries for the production of RE Permanent Magnets for the commercial sector, auto catalysts, and other products using RE as a performance enhancing material. IREL on its part is geared up to provide radioactive free refined RE to the industries as and when they start their operations.