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RARE EARTHS

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GOVERNMENT OF INDIA
MINISTRY OF MINES
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24 Rare Earths

Rare Earths are relatively plenty in earth's crust with cerium being the 25th most abundant element with a concentration of 68 ppm (similar to copper). However, because of their geo-chemical, rare earth elements are dispersed and not found in concentrated and economically exploitable forms. The few economically exploitable deposits are known as rare earth minerals.

Rare Earths are a group of 17 elements starting with lanthanum in the periodic table of elements and include scandium and yttrium. They are moderately abundant in earth's crust but not concentrated enough to make them economically exploitable. The REEs find key applications in defence, electronics, energy systems etc. For instance, magnets made from rare earths are many times more powerful than conventional ones. Along with energy critical elements (ECE) such as lithium which has become ubiquitous a battery material, REEs have emerged strategic elements essential for sustainable energy systems.

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).

Although these elements tend to occur together, the lanthanide elements are divided into two groups. The light elements are those with atomic numbers 57 to 63 (La, Ce, Pr, Nd, Pm, Sm and Eu) and the heavy elements are those with atomic numbers 64 to 71 (Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu).

REE are characterised by high density, high melting point, high conductivity and high thermal conductance. A number of rare earth minerals contain thorium and uranium in variable amounts, but they do not constitute essential components in the composition of the minerals.

The principal sources of REE are bastnaesite (a fluorocarbonate which occurs in carbonatites and related igneous rocks), xenotime (yttrium phosphate) commonly found in mineral sand deposits, loparite which occurs in alkaline igneous rocks and monazite (a phosphate). The rare earths occur in many other minerals and are recoverable as by-products from phosphate rock and from spent uranium leaching. In India, monazite is the principal source of rare earths and thorium.

RESERVES/RESOURCES

The mineral monazite is a prescribed substance as per the Notification under the Atomic Energy Act, 1962. AMD has been carrying out its resource evaluation for over six decades. It occurs in association with other heavy minerals such as ilmenite, rutile, zircon, etc. in concentrations of 0.4 – 4.3% of total heavies in the beach and inland placer deposits of the country.

The resource estimates of monazite in the beach and inland placer deposits have been enhanced from 11.935 million tonnes in 2012 to 12.47 million tonnes in 2016. The statewise resources are given in Table-1.

EXPLORATION & DEVELOPMENT

The exploration and development details, if any, are given in the review on "Exploration & Development" in "General Reviews".

Table – 1: Resources of Monazite

(In million tonnes)

State	Resources*
All India	**12.47**
Andhra Pradesh	3.69
Gujarat	0.003
Jharkhand	0.21
Kerala	1.84
Maharashtra	0.004
Odisha	3.06
Tamil Nadu	2.46
West Bengal	1.20

Source: *Department of Atomic Energy, Mumbai.*

** Inclusive of indicated, inferred and speculative categories.*

PRODUCTION AND PRICES

Indian Rare Earth Limited (IREL), a Mini Ratna Company is a Government of India Undertaking under the Department of Atomic Energy (DAE) and KMML, a Kerala State Government Undertaking, are actively engaged in mining and processing of beach sand minerals from placer deposits. IREL produced 2,265 tonnes rare earths in 2016-17. The domestic prices of rare earths in India during 2015-16 to 2017-18 are given in Table- 2.

MINING AND PROCESSING

Mining of beach sand is being carried out by IREL and KMML. The installed capacity of monazite (96% pure) separation plant of IREL at Manavalakurichi is 6,000 tpy while that of KMML at Chavara is 240 tpy. Details regarding mining and processing, etc., are provided in the Review on 'Ilmenite and Rutile'.

INDUSTRY

IREL has a plant at Udyogamandal, Aluva, located in Ernakulam district, Kerala, wherein the monazite obtained from Manavalakurichi is chemically treated to separate rare earths in its composite chloride form and thorium as hydroxide upgrade. Ground monazite is digested with caustic soda lye to produce trisodium phosphate (TSP) and mixed hydroxide slurry. This slurry is used for production of diverse rare earth compounds. Elaborate solvent extraction and ion exchange facilities were built to produce individual RE oxides, like oxides of Y, Ce, Nd, Pr and La of specific purities. India is the second largest supplier of yttrium in the world and the maximum production is reported from this plant in Kerala. Uranium values present in monazite which are recovered in the form of nuclear grade ammonium diuranate (ADU) are vital supplement to the indigenous supply of uranium. Thorium is separated in its pure oxalate form. A part of it is taken to OSCOM for further processing by solvent extraction to produce thorium nitrate. A small part of the purified thorium nitrate is converted to nuclear grade thorium oxide powder for supply to Bhabha Atomic Research Centre (BARC) and Nuclear Fuel Complex (NFC) for developing thorium based fuel for nuclear reactors. IREL has built a large stockpile of impure thorium hydroxide upgrade associated with rare earths and unreacted materials.

IREL has also entered into Memorandum of Understanding (MoU) with BARC, DMRL and International Advanced Research Center for powder metallurgy & New material (ARCI) for development of rare earth permanent magnet rings. DMRL has the necessary technology for production of rare earth magnets. BARC has developed the technology for manufacturing of RE Phosphors. However, these technologies are yet to see commercial application. Japan and India have reached at a basic agreement to jointly develop rare earths, used in the production of several high-tech goods from weapons to cellphones. IREL has also set up a Monazite Processing Plant (MoPP) at Odisha to produce about 11,000 tonnes of Rare Earth Chloride and associated products and High Pure Rare Earths (HPRE) plant at Rare Earth Division, Aluva to produce separated Rare Earth Oxide/carbonates. The company is also in the process of facilitation, setting up of industry in value chain of minerals produced other than expanding its existing capacity in near future. IREL has inhouse R&D division at Kollam, Kerala to support mineral and chemical operation and Corporate Office at Mumbai, Maharashtra.

The production of rare earth compounds from monazite at Udyogamandal plant is furnished in Table - 3.

Table – 2: Domestic Prices of Rare Earths 2015-16 to 2017-18

(In ` per kg)

Year	Grade	Price	Remarks
2015-16	RE chloride	180	Ex-works, packed
	RE fluoride (lumps)	450	Ex-works, packed
	Dicarbonate - Wet	150	Ex-works, packed
	Difluoride	285	Ex-works, packed
	Cerium hydrate -Dry	500	Ex-works, packed
	Cerium oxide B	550	Ex-works, packed
	Neo oxide - 95%	3420	Ex-works, packed
	Neo oxide - 99%	3800	Ex-works, packed
2016-17	Not Available		
2017-18	Not Available		

Source: *Department of Atomic Energy, Mumbai.*

Table – 3: Production of Rare Earth Compounds (IREL)

(In tonnes)

Product	Specification	Installed capacity (tpy)	Production		
			2014-15	2015-16	2016-17
RE chloride	REO 45% min. CeO_2/REO 45% min.	11,200	–	956	2265
RE fluoride	TO>78%, F>26% CeO_2/TO>45%	114	-	–	-
RE oxide	–	–	–	–	-
Cerium hydrate	Total REO>80% (dry) (30% for wet) CeO_2>68%, CeO_2/Total REO >85%	–	–	–	-
Cerium oxide	Grade C: CeO_2 99.00% min. Grade D: CeO_2 99.95% min. CeO_2 99.99% min.				
ADU	Nuclear Grade	28	27	33	28
Yttrium oxide	–	–	–	–	

***Source**: Indian Rare Earths Ltd*

***Note**: The plant has stopped production since 2004. Hence, installed capacity is redundant for products other than RE chloride and ADU.*

ADU: Ammonium diuranate. RE: Rare Earths.

POLICY

The recent amendment to Atomic Mineral Concession Rules (AMCR) 2016 stipulates reserving all Beach Sand Mines (BSM) deposits containing more than 0.75 per cent monazite in the Total Heavy Minerals (THM) for Government-owned corporations. As per the Foreign Trade Policy, 2015-2020 and the effective policy on export and import, the import of ores and concentrates of rare earth metals (under HS Code 25309040) and of rare earth oxides including rutile sand (HS Code 26140031) are permitted 'freely'.

As Per Gazette Notification No 26/2015-2020 dated 21.08.2018, the export of rare earth compounds classified as Beach Sand Minerals (BSM), namely [Ilmenite, Rutile, Leucoxene(Titanium bearing mineral), Zircon, Garnet, Sillimanite and Monazite (Uranium and Thorium)], shall be regulated in terms of Sl No 98A of Chapter 26 Schedule 2 of ITC(HS) Classification.

Other minerals under code 2617 are freely exportable, except those which have been notified as prescribed substances and controlled under Atomic Energy Act 1962.

Export of Beach Sand Minerals have been brought under STE and shall be canalized through Indian Rare Earths Limited (IREL). Beach sand minerals, permitted anywhere in the export policy, will now be regulated in terms of policy under at Sl No 98A of Chapter 26 of Schedule 2 Export Policy.

USES & CONSUMPTION

Rare earth materials are utilised in a wide range of critical products enabling many emerging green energy technologies, high tech applications and defence systems such as hybrid cars, plug-in-hybrid electric-vehicles (PHEVs), the latest generation of efficient windpower turbines, computer disc drives, missile guidance systems, etc. The lanthanide elements as a group have magnetic, chemical and spectroscopic properties that have led to their application in wide range of end-uses. Cerium finds application in polishing of glass items like lenses and display screens of cathode-ray tubes, liquid-crystal displays and plasma-display panels, in petrol and diesel fuels as fuel additive and along with lanthanum for replacement of cadmium in red pigments. Mixed salts of the cerium group of elements, other than fluorides are used in medicine, non-irritating antiseptic dressings, waterproofing agents and fungicides in textile manufacture. The principal uses of commercially pure cerium compounds that are in the form of nitrate is in the manufacture of incandescent gas mantles and cerium compounds as oxide. It also finds usage as a polishing agent of glass. Cerium compounds are also used in ceramic and glass as colouring pigments and also as catalysts in chemical industry.

Department of Atomic Energy (DAE), has accorded in principal approval for futuristic proposal of IREL towards setting up of rare earth theme park which inter alia includes setting up of pilot plants in the value chain of rare earths, skill-cum-enterpreneur development center. This will be a first of its kind theme park in the country.

To produce samarium-cobalt (Sm-Co) magnet for meeting national objectives, a Special Purpose Vehicle (SPV) has been formed. Production of Sm-Co metal and Magnet is based on technologies developed by BARC, Mumbai & DMRL, Hyderabad. Activities for firming up the investment, plant location etc., is under progress.

Supply of Nuclear Grade Ammonium di uranate (NGADU) from new source i.e. the newly commissioned monazite processing plant at OSCOM, Odisha has commenced.

Approval has been received for entering into production sharing contract viz. concessions and profits sharing option with land owner having surface rights within IREL mining lease area with a view to mitigate the difficulties in sourcing land for new material of the southern operating units of IREL.

Subsequent to identification and development of conditions for dissolution of Rare Earths (REE) from fly ash generated at lignite coal fired thermal power plant at Neyveli, Tamil Nadu, studies were taken up to understand the overall process efficiency and precipitate dissolved rare earths in purified form.

Cerium, lanthanum and neodymium are used as glass additives in optical lenses and display screens, as catalysts in automobiles to reduce sulphur di-oxide emission, in multilayer capacitors and along with yttrium in magnesium, aluminium and hydrogen storage alloys. Mischmetal which is an alloy of cerium with small amounts of other rare earth metals is used in lighter flints, for desulphurisation in steel and foundry, and with lanthanum alloys, in batteries and hydrogen storage systems meant for electronics and hybrid cars. Cerium oxide is used in glass polishing industries.

Lanthanum oxide and neodymium compounds are used in special glass manufacture. Lanthanum finds application in X-ray films as phosphorous; yttrium in advanced ceramics like nitrides, Y-stabilised ceramics, etc., and gadolinium in magnet alloys. Yttrium, europium and terbium are used as phosphorous in displays of computers, TV, etc. and with lanthanum, cerium & gadolinium as phosphorous in fluorescent and halogen lamps. Neodymium, samarium, dysprosium, praseodymium and terbium have application as high intensity magnets in electronics, electric motors and audio equipment. Lanthanum, erbium and ytterbium have application in fibre optics and lasers. Lanthanum and yttrium find application in solid oxide fuel cells. Scandium is used mainly in aluminium alloys for sporting goods. Scandium in minor amounts is used in semiconductors and special lighting, including halogen bulbs. Mixed rare earth products are used as catalysts in petroleum refining and fluid cracking. Neodymium is used in welding in heavy industries and also in MRI scanners. Praseodymium is not a primary element for any specific use, but finds use as a substitute for neodymium in magnets.

Samarium is used essentially for the Sm-Co magnets. Europium is a primary component of phosphorus and is responsible for white light in compact fluoroscent lamps when used with terbium compounds.

Erbium used as fibre optic and has emerged in the nineties as a remarkable tool for communication technology through which high quality rapid data in tight pulses can be transferred in speed unthinkable in the past.

The main application for neodymium-iron-boron (Nd-Fe-B) magnets are in automobiles for anti-lock brakes, and in computer hard disk drives, videos, CD-ROMs used in many small-size electronic consumer products, such as, digital cameras, where major advantage is their small sizes. Nickel metal hydride (Ni MH) batteries, containing mischmetal, a mixture of rare earth compounds, are used mainly in portable electronic equipment, such as, laptops, camcorders and mobile phones. Though, the market for batteries for portable electronic equipment is growing strongly, the Ni MH batteries are increasingly replaced by lithium-ion batteries.

Monazite contains about 25.28% P_2O_5 which can be recovered as a by-product for manufacture of fertilizers and production of elemental phosphorus or its salts. Besides, rare earths, thorium is recovered

Table – 4 : Consumption of Rare Earths, 2015-16 to 2017-18 (By Industries)

(In tonnes)

Industry	2015-16	2016-17	2017-18
All Industries	**63.80**	**1867.90**	-
Rare Earth Compounds Producers	31.90	1862.0	-
Paints Driers/Pigments	-	-	-
Cinema Arc Carbon	-	-	-
TV Colour picture tube	0.9	1.0	-
Glass/Optical polishing	0.09	1.0	-
Glassware decolouring	3.9	0.4	-
R&D and others	27.01	3.0	-

Source: *Department of Atomic Energy, Mumbai.*
Industry-wise consumption of minerals in India, IREL.

from monazite. It is a source of atomic energy. An important use of thorium is for addition to tungsten in minute quantity (about 0.75%) to increase the ductility of tungsten wire and thus to facilitate its drawing into filaments used in electric lamps. Metallic thorium is also used in photoelectric cells and X-ray tubes and in certain alloys. Thorium is used as catalytic agent for various processes. Amongst thorium salts, thorium nitrate is used largely in the manufacture of incandescent gas mantles. Mesothorium, the chief radioactive element recovered as a by-product in the chemical treatment of monazite, is marketed usually in the form of its bromide and used in self-luminous paints or enamels. Mesothorium is also used in the treatment of certain types of cancer and skin diseases.

The total consumption of rare earths during 2015-16 to 2017-18 is furnished in Table-4. The reported consumption during 2017-18 is not available. Rare Earth Compounds producer was the main consumer accounting for about 99.68% of the total consumption followed by Glassware which is negligible.

WORLD REVIEW

The total world reserves are estimated at 120 million tonnes of rare earth oxides (REO) of which China alone accounts for 44 million tonnes (37%) followed by Brazil and Vietnam (18% each) and Russia (10%) (Table- 5).

China holds the leading position among producers of rare earth oxides with 140 thousand tonnes. The other major producers are Australia, Russia, Malaysia and Vietnam (Table-6). Concentrates/partially processed intermediate products are further processed at many locations in Europe, USA, Japan and China.

In China, the principal production centres of rare earths are located at Baotou, Inner Mongolia and in Jiangxi & Sichuan provinces. At Baotou, bastnaesite is recovered as a by-product of iron ore mining while

Table – 5 : World Reserves of Rare Earths (By Principal Countries)

(In '000 tonnes of REO equivalent content)

Country	Reserves
World: Total (rounded off)	**120,000**
Australia	3400
Brazil	22000
China	44000
India	6900
Malaysia	30
Russia	12000
Vietnam	22000
USA	1400
Other countries	4400

Source: *Mineral Commodity Summaries, 2019, USGS.*

Table – 6 : World Production of Rare Earths Oxide (By Principal Countries)

(In tonnes)

Country	2015	2016	2017
Australia	8799	12631	16003
China(e)(a)	140000	140000	140000
Malaysia	365	1221	196
Russia	2312	3063	2500
USA	3540	-	-
India(b)	956	1000e	1000e
Vietnam(e)	250	220	100

Source: *World Mineral Production, 2013-2017, BGS.*
a :- Includes production from iron ore extraction, bastnaesite concentrates and ion adsorption clays.
b :-Year ending 31st March following that stated.
e:- Estimated

in Sichuan and in Gansu, bastnaesite occurs as primary mineral. In Jiangxi, Guangdong, Hunan and Jiangsu provinces, the ion adsorption clays are the source of the greater proportion of world yttrium production.

The Russian rare earths industry is based on loparite, a titanium-tantalum niobate mined from Lovozero massif in the Murmansk region. Rare earth minerals have been recovered as by-products from titanium-bearing heavy sands, particularly in Australia and from tin dredging in Malaysia.

FUTURE OUTLOOK

Indian Rare Earth Limited is in the process of setting up a Monazite Processing Plant (MOPP) at its OSCOM unit in Odisha. Initially, the plant will have capacity to process 10,000 tpa of Monazite and produce 11,000 tpa of Rare Earths Chloride i.e. equivalent to 5000 tpa of Rare Earths Oxide (REO) that represents about 3-4% of World demand of 1.25 - 1.5 lakh tonnes. Incidentally, only about 500 tpa is imported for domestic consumption of which over 90% is Cerium Oxide. The plant will also produce Rare Elements which are essentila for India's nuclear energy programme. Technology for separating the RE into their pure forms along with producing REM has been developed by BARC, Mumbai. Defence Metallurgical Research Laboratory (DMRL), Hyderabad has developed the process know-how to produce permanent rare earths magnets based on samarium cobalt & neodymium-iron-boron compositions. BARC has also developed the technology for manufacuring RE-phosphors. However, these technologies are yet to see commercial applications and India imports almost all its domestic requirement of consumer/ industrial electronics items, display panels, permanent magnet DC motors used in wind mills and tri-band phosphors used in CFL lamps containing the rare earths. The global shortage of petro-fuels and the spiralling cost of importing them with costly foreign exchange puts a tremendous indirect pressure on the national policy makers and manufacturers alike to support largely the case for electric vehicles. This brightens the prospects of the REE sector in India, provided the gap in the scale, experience and resource utilisation is strategically made up by Public and Private endeavours.