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RARE EARTHS

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GOVERNMENT OF INDIA
MINISTRY OF MINES
INDIAN BUREAU OF MINES

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43 Rare Earths

The rare earth group contains 17 elements, namely, scandium (Sc), yttrium (Y) and lanthanides (15 elements in the periodic table with atomic numbers from 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, they tend to occur together, the 15 lanthanide elements are divided into two groups - light & heavy elements. The light elements are those with atomic numbers from 57 to 63 (La, Ce, Pr, Nd, Pm, Sm and Eu) and the heavy elements are those with atomic numbers from 64 to 71 (Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu). Generally, the light rare earth elements are more common and more easily extracted than the heavies. In spite of its low atomic weight, yttrium has properties more similar to the heavy lanthanides and is included with this group. Scandium, besides occurring with other rare earth elements is also found in a number of minerals.

Rare Earth Elements (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 thorium and uranium do not constitute essential components in the composition of the minerals.

The principal sources of rare earth elements 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.

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 10.70 million tonnes in 2009 to 11.93 million tonnes in 2014. The statewise resources are given in Table- 1.

Table – 1 : Resources of Monazite

(In million tonnes)

State	Resources*
All India	**11.93**
Andhra Pradesh	3.72
Jharkhand	0.22
Kerala	1.90
Odisha	2.41
Tamil Nadu	2.46
West Bengal	1.22

Source: *Department of Atomic Energy, Mumbai.*
** Inclusive of indicated, inferred and speculative categories.*

EXPLORATION & DEVELOPMENT

Details of exploration carried out for Rare Earth by GSI are given in Table - 2.

Table – 2 : Details of Exploration Activities for Rare Earths, 2014-15

Agency/ State/ District	Location Area/ Block	Mapping		Drilling		Sampling (No.)	Remarks Reserves/Resources estimated
		Scale	Area (sq km)	No. of boreholes	Meterage drilled		
GSI							
Andhra Pradesh	Chetlamallapuram	-	-	-	-	-	Reconnaissance stage investigation (G-4) was carried out to delineate potential areas for REE and seven major pegmatitic bodies were mapped. Trenching in the west of Chetlamallapuram helped in identification of zoned pegmatite body. Around Bastipudu zoned pegmatite intrudes the leucogranite as horizontal sheets containing tourmaline.
Bihar	Banka & Jamui Chandan area	-	-	-	-	59	Reconnaissance stage investigation (G-4) for REE was carried out. Several bands and lenses of aplitic granite and pegmatite have been mapped. Aplite has been analysed 86.86 to 500.10 ppm.
Chattisgarh Gariabandh District	Gobra-Pendra area	-	-	-	-	4	Reconnaissance stage investigation (G-4) for REE was carried out to evaluate potentiality of REE in Gobra-Pendra area. The area exposes coarse grained granite, porphyritic granite. The REE analysed for 4 samples.
Jharkhand Ranchi	Mahespur-Kamta Nawatoli-Jaratoli Guridih area	-	-	-	-	-	Reconnaissance stage investigation (G-4) for REE was carried out to assess the REE & RM potentiality. Pegmatite of the area are mixed with zoned type and have been recorded mostly around Chamghati, Rajadera south of Nawagarh and Baijnathtata.
Maharashtra Nagpur	Deolapar area	-	-	-	-	100	Reconnaissance stage investigation (G-4) for REE/Rm was carried out and several mappable pegmatite bodies have been located within the rocks of Sausar Group and Tirodi Biotite Gneiss. In some complex pegmatites, K-feldspar, beryl, tourmaline and mica commonly occur in larger crustals than associated minerals. Out of 100 samples analysed results of 5 samples received with high concentration of REE.
Karnataka	Tamankal/ Raidurg/ Gogalgatti	-	100	-	-	-	A total of 100 sq. km was mapped along with detailed mapping of 0.5 sq km in the area exposed with different variety of younger granites (closepet granite) which were intruded into the PGC. In Tamankal and Raidurg area, LSM of 100 sq km and DM of 0.559 Sq km were completed for REE investigation and a 68 m wide and 27-30 m length pegmatite-vein was observed in the area with suspected REE. In the area around Gogalgatti a 20-25 m wide &1.7 km length quartz reef was observed with suspected REE characteristic unit.

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Tamil Nadu	Sukkampatti/ Chinnatambipalayam/ Ayyampalayam	1:1000	0.55	-	-	-	In Tamil Nadu, REE investigation was taken up covering Sukkampatti(LREE ranges from 299.97 ppm to a maximum 1203.57 ppm and HREE ranging with minimum of 10.58 ppm to maximum 83.40 ppm, Chinnatambipalayam LREE - 205.36 to 1359.59 ppm with HREE - 25.19 to 85.44 ppm, Pallathur LREE - 359 to 1459.70 ppm with HREE 1.67 to 107.34 ppm, Sembakavundanpudur-Surampatti contact zone LREE - 505.36 to 778.51 ppm with HREE - 36.62 to 76.77 ppm, Seviturangampatti LREE - 240.10 to 1168.40 ppm and HREE - 35.19 to 117.90 ppm and Tannipandal LREE - 262.14 to 3282.23 ppm and HREE - 34.59 to 131.70 ppm have yeilded relatively high values for REE in chemical analysis.
Rajasthan Jhunjhunu	Gothara	-	-	-	-	42	A (G-4) stage investigation of REE was carried out in Gothara granite of Khetri fold belt to explore REE potential. A total 421 no. of samples collected on 50x20 m interval out of which 7 samples yielded REE > 2500 ppm & 25 samples yielded REE > 1000 ppm 106 sample yielded REE > 500 ppm.
Barmer	Siwana	1:12,500	-	-	-	31	In Siwana area, Siwana granite & rhyolite bears promising locale for REE mineralization. All the 16 samples, shows REE > 0.1% ; 6 samples of granite show REE > 0.3% with highest value 3978 ppm. All the 15 rhyolite samples show REE > 0.1% . In Perna Biosalpur area, 7 samples out of 55 samples show REE > 500 ppm 3 samples show REE > 0.1%.
Sirohi	-	1:10000	104	-	-	314	A (G-4) stage investigation of REE in alkaline and carbonatitic plugs and associated dyke rocks was carried out in Sirohi district. Total 58 nos. of bed rocks samples collected. 9 samples have been analysed noteworthy a namolous REE concentration. One sample of carbonatite dyke have analysed 7% total REE with other samples analysing 300 ppm, 800 ppm, 1% & 2% total REE.
Bhilwara	Bhagwanpur	1:10000	50	-	-	302	A (G-4) stage investigation for REE and RM elements in Bhagwanpur area in Bhilwara districts. A total of 86 nos. of bed rock samples collected from pegmatite bodies and gneissic rocks are not showing encouraging result of REE & RM. However, only one sample from gneissic rock has assayed over 1000 ppm of total REE.
Pali	Perva Bisalpur	-	-	-	-	-	The maximum value recorded is 0.025 mR/hr against a background value of 0.015 mR/hr. An instance of REE bearing phase - bastanasite is observed in granite.

PRODUCTION AND PRICES

IREL, a Government of India Undertaking and KMML, a Kerala State Government Undertaking, are actively engaged in mining and processing of beach sand minerals from placer deposits. IREL produced 16 tonnes rare earths, viz, RE fluoride, cerium oxide, cerium hydrate from conversion of Rare Earths chlorides in 2009-10. The prices of rare earths in India during 2012-13 to 2014-15 are given in Table- 3. Production by Indian Rare Earth Ltd was reported Nil during 2010-11 to 2014-15.

Table – 3 : Domestic Prices of Rare Earths 2012-13 to 2014-15

(In ₹per kg)

Year	Grade	Price	Remarks
2012-13	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
2013-14	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
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	Neo oxide - 95%	3420	Ex-works, packed
	Neo oxide - 99%	3800	Ex-works, packed

Source: *Department of Atomic Energy, Mumbai.*

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 Reaserch 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. 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 & supply to Japan about 14% of its rare earths needs. IREL has entered into an agreement with Toyoto Tshusho Corporation, Japan for supplying of over 50% of Rare Earths chloride that shall be produced at MoPP. The plant will have provision for expanding its capacity of processing monazite from 10,000 tpy to 20,000 tpy in the future. The company is also in the process of setting up plant facilities at RE Division, Aluva, to take up processing of RE chloride produced at MoPP, OSCOM to produce High Pure Rare Earths. A thorium plant is in operation since 1992 at OSCOM to produce 240 tpy mantle grade thorium nitrate. IREL & Toyota Tsusho Corporation will complete a plant in Odisha state to extract rare earths from uranium residue and was to start production of minerals in 2012.

The production of rare earth compounds from monazite at Udyogamandal plant is furnished in Table - 4.

Table – 4 : Production of Rare Earth Compounds (IREL)

(In tonnes)

Product	Specification	Installed capacity (tpy)	Production		
			2012-13	2013-14	2014-15
RE chloride	REO 45% min. CeO_2/REO 45% min.	–	–	–	–
RE fluoride	TO>78%, F>26% CeO_2/TO>45%	114	15.6	–	
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	32.0	32.0	
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 fluoride and ADU.*

ADU: Ammonium diuranate. RE: Rare Earths.

POLICY

Exploitation of beach sand minerals and participation of private sector with or without foreign companies is subject to conditions stipulated in the Beach Sand Mineral Policy notified by the Government of India in October, 1998. As per the Foreign Trade Policy, 2009-2014 and the effective policy on export and import, the import of ores and concentrates of rare earth metals (under code No. 25309040) and of Rare Earth oxides including rutile sand (code No. 26140031) are permitted freely. Rare earth compounds are freely exportable, but Rare Earths phosphates (Monazite), which contain uranium and thorium are prescribed substances and controlled under Atomic Energy Act, 1962.

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.

Cerium, lanthanum and neodymium are used as glass additives in optical lenses and display screens, as catalysts in automobiles, 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.

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 finds 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.

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. The market for batteries for portable electronic equipment though 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 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 in 2012-13 to 2014-15 was estimated at 25.52 tonnes, 30.98 tonnes and 30.49 tonnes, respectively. Research and Development was the main consumer accounting for about 87% of the total consumption followed by Glassware (7%) in 2014-15 (Table- 5).

WORLD REVIEW

The total world reserves are estimated at 130 million tonnes of rare earth oxides (REO) of which China alone accounts for 55 million tonnes followed by Brazil (Table- 6).

China holds the leading position among producers of rare earths, while USA, Russia & Australia produce monazite (Table-7). Rare earths are also produced in Kazakhstan, Kyrgyzstan and Thailand. 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 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.

Table – 5 : Consumption* of Rare Earths, 2012-13 to 2014-15
(By Industries)

(In tonnes)

Industry	2012-13	2013-14	2014-15
All Industries	**25.52**	**30.98**	**30.49**
Paints Driers/Pigments	-	-	-
Cinema Arc Carbon	-	-	-
TV Colour picture tube	0.19	0.93	1.59
Glass/Optical polishing	0.43	0.09	0.09
Glassware decolouring	1.87	3.9	2.25
R&D and others	23.03	26.06	26.56

Source: *Department of Atomic Energy, Mumbai.*
** Consumption relates to sales figures of IREL.*

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

(In '000 tonnes of REO content)

Country	Reserves
World: Total(rounded)	**130000**
Australia	3200
Brazil	22000
China	55000
India*	3100
Malaysia	30
USA	1800
Other countries	41000

Source: *Mineral Commodity Summaries, 2016.*

* *As per Department of Atomic Energy, Mumbai, the total resources of monazite, a source of rare earths, are estimated at 11.93 million tonnes.*

Table – 7 : World Production of Rare Earths (By Principal Countries)

(In tonnes)

Country	2012	2013	2014
Australia	3200	2000	2500
Brazil(e)	206	0	0
China#(e)	100000	95000	95000
Malaysia	114	229	221
Russia(e)	2131	1443	2134
USA	1800	3300	4200(e)

Source: *World Mineral Production, 2010-2014.*

\# *Includes production from iron ore extraction, bestnaesite concentrates and ion absorption clays.*

FUTURE OUTLOOK

Demand for rare earths is centered around countries which manufacture high tech goods and components like automotive catalyst systems, fluorescent lighting tubes and display panels. The demand, therefore, is expected to emanate mainly from Europe, USA, Japan, China and Republic of Korea. China dominates the entire global supply. Mine restructuring and other policies are responsible for determining prices of rare earths which are almost manifold since 2009 due to panic buying globally.