Indian Minerals Yearbook 2016

(Part- III : Mineral Reviews)

55th Edition

RARE EARTHS

(ADVANCE RELEASE)

GOVERNMENT OF INDIA
MINISTRY OF MINES
INDIAN BUREAU OF MINES

Indira Bhavan, Civil Lines,
NAGPUR – 440 001

PHONE/FAX NO. (0712) 2565471
PBX : (0712) 2562649, 2560544, 2560648
E-MAIL : cme@ibm.gov.in
Website: www.ibm.gov.in

January, 2018

43 Rare Earths

The rare earth group contains 17 elements starting with lanthanum in the periodic table of elements and including scandium and yttrium. They are moderately abundant in earth's crust but not concentrated enough to make them economically exploitable. 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 they 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 11.935 million tonnes in 2016. The statewise resources are given in Table- 1.

Table – 1: Resources of Monazite

(In million tonnes)

State	Resources*
All India	**11.935**
Andhra Pradesh	3.72
Gujarat	0.003
Jharkhand	0.22
Kerala	1.90
Maharashtra	0.002
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, 2015-16

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							
Kurnool	Chetlamallapuram	1:12500	105	-	-	-	Reconnaissance stage investigation (G-4) was carried out to delineate potential areas for REE. Analytical results for the samples submitted are awaited. However, EPMA and SEM studies have indicated the presence of Rare Metal having Nb and Ta. The rare metal bearing phases identified are columbite and tantalite seen enclosed mostly within K-feldspar followed by Na-feldspar. Some REE (Eu, Nd) bearing grains are also seen within the feldspar.
Bihar		-	-	-	-	-	Reconnaissance stage investigation (G-4) for REE was carried out at southern margin of Bihar Mica Belt. Structurally, the area is highly disturbed. Several bands and lenses of aplitic granite and pegmatite have been mapped. Based on the available results 2 blocks viz Heth Chandan and Belhariya Blocks have been indentified for detailed investigations.
Banka & Jamui	Chandan area						
Chattisgarh Balodabazar District	Latwa and Rasera area	-	100	-	-	104	Reconnaissance stage investigation (G-4) was carried out to evaluate potentiality of REE in Latwa & Rasera areas. A total 104 unit cell samples pertaining to the composite samples showing anomalous REE values were analysed.
Gujarat							
Chhota Udepur	Ambadungar	-	13	-	-	-	LSM was carried out in Ambadungar-Saidiwasan area. 426 samples on 100 x 100 gridpattern was collected. The analytical results of grid sample show encouraging values. LREE in brecciated carbonate ranges from 500 to 11000 ppm.
Haryana Mahendragarh	Antri Biharipur	-	-	-	-	-	Reconnaissance stage investigation (G-4) for REE was carried out in Golwa-Gangutana Formation. REE bearing fluorite occurs in magnetite quartzite and quartz-biotite schist as inter-banded lenses and disseminated patches. The REE mineralization follows the contact between quartz-biotite schist and magnetitic quartzite and continue up to 1 km length and 5m width. A total 30 sample show total REE content 2000-4500 ppm.
Jharkhand Ranchi	Mahespur-Kamta Nawatoli-Jaratoli Guridih area	1:12500	-	-	-	100	Reconnaissance stage investigation (G-4) for REE was carried out to assess the REE & RM potentiality. Out 79 BRS, 13 samples received shows high concentration of REE. Apart from this, 50 soil samples and 28 petrological samples were collected. However, the total REE values of 40 soil sample received so far, ranges from 158 to 1428 ppm. Other results are still awaited.

Contd..

Agency/ State/ District	Location Area/ Block	Mapping		Drilling		Sampling (No.)	Remarks Reserves/Resources estimated
		Scale	Area (sq km)	No. of boreholes	Meterage drilled		
Maharashtra							
Nagpur	-	1:2000	1	-	-	165	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. A total 100 BRS, 40 PS and 25 PTS samples collected and submitted to respective laboratories. Out of 100 BRS, 5 samples received with high concentration of REE.
	Ghuksi area	1:12500	50	-	-	44	Reconnaissance stage investigation (G-4) for REE and RM mineralisation was carried out in Ghuksi Granite in Parseoni area. REE bearing mineral phases like monazite, xenotime, allanite and zircon have been recorded in petro-mineralogical studies. Analytical results of 18 bedrock sample (out of 44 BRS submitted) revealed that the highest concentration of REE is 6180 ppm.
Meghalaya							
Jaintia Hills & Ri-Bhoi	Bhoilymbong	-	50	-	-	-	Reconnaissance stage investigation (G-4) for REE was carried out to assess the REE enrichment shown by megacrystic hornblende biotite as well as two mica leucogranite. The REE results of the samples are awaited.
Karnataka							
Gulbarga	Wanadurg Area	1:12500	100	-	-	173	A detailed mapping was carried out along with trenching and pitting across the trend of quartz veins. Along with mapping, 61 BRS and 50 stream sediment samples were collected. These samples along with 62 trench samples were sent to Chemical laboratory, Hyderabad for ICPMS analysis of REE. 24 BRS for thin section study and 14 for petrochemical analysis were sent to NCEGR Division for analysis. The results are awaited.
Raichur	Mincheri Block Lingasugur Taluka	1:2000	0.5	10	967.50	390	Exploration for REE bearing zone in Mincheri Block was carried out with an objective to delineate REE mineralisation. The host rock of REE mineralisation is quartz vein. The analytical results of 302 samples out of 390 are still awaited. Encouraging results of LREE are expected from the core samples

Contd.

Concld.

Agency/ State/ District	Location Area/ Block	Mapping		Drilling		Sampling (No.)	Remarks Reserves/Resources estimated
		Scale	Area (sq km)	No. of boreholes	Meterage drilled		
Odisha							
Deogarh	Kankadakhol	-	-	-	-	250	In Odisha, REE investigation was taken up in the northern part of Eastern Ghat Granulite terrain adjecent to Singhbhum Craton. A total 250 samples have been generated during FS from bed rock, trenches, soil and stream sediments for chemical analysis. Results are available for RM(34 samples) and (38 XRF) samples. The result shows Li values ranges from <5 - 61 ppm. Cs < 10 ppm and Rb values ranging from 27 - 271 ppm; Zr values ranging from 165 - 591 ppm; Nb value ranges from 21 - 90 ppm; Rb values ranging from 73 - 232 ppm & Y values ranging from 9 - 32 ppm.
Rajasthan Jhunjhunu	Gothara	1:2000	0.6	9	-	42	A G-4 stage investigation for REE was carried out in Gothara granite of Khetri fold belt to explore REE potential. In Gothra Granite Central Block, 9 vertical Boreholes were drilled up to a depth of 50-60 m. Analytical results of core samples are awaited.
Uttar Pradesh							
Sonebhadra	Muirpur-Mahuaria area	-	-	-	-	42	A G - 4 stage investigation for REE was carried out in Dudhia Granitoid Complex around Muirpur-Mahuaria area. The analytical results of 3 trench samples out of 44 samples show very high values of total REE ranging from 964 ppm to 4538 ppm.

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 956 tonnes rare earths. The prices of rare earths in India during 2013-14 to 2015-16 are given in Tables- 3.

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. 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 & supply to Japan about 14% of its rare earths needs. 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 in house 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 - 4.

Table – 3: Domestic Prices of Rare Earths 2013-14 to 2015-16

(In ₹'per kg)

Year	Grade	Price	Remarks
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
	Neo oxide - 95%	3420	Ex-works, packed
	Neo Oxide - 99%	3800	Ex-works, packed
2014-15	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
2015-16	Not Available		

Source: *Department of Atomic Energy, Mumbai.*

POLICY

The recent ammendment 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'. 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.

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

(In tonnes)

Product	Specification	Installed capacity (tpy)	Production		
			2013-14	2014-15	2015-16
RE chloride	REO 45% min. CeO_2/REO 45% min.	–	–	–	–
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	26.5	26.20	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.

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 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 are 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 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. Neodymium is used in welding in heavy industries and also in MRI scanniners. 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 transfered 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. 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 2013-14 to 2015-16 was estimated at 31.18 tonnes, 30.49 tonnes and 31.90 tonnes, respectively. Research and Development was the main consumer accounting for about 85% of the total consumption followed by Glassware (12%) in 2015-16 (Table- 5).

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 followed by Brazil and Vietnam (18% each) (Table- 6).

China holds the leading position among producers of rare earth with 140 thousand tonnes. The other major producers are Australia, USA, Russia, Malaysia and Vietnam (Table-7). 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 – 6 : World Reserves of Rare Earths (By Principal Countries)

(In '000 tonnes of REO content)

Country	Reserves
World: Total(rounded)	**120000**
Australia	3400
Brazil	22000
Canada	830
China	44000
Greenland	1500
India	6900
Malaysia	30
Malawi	136
Russia	18000
South Africa	860
Vietnam	22000
USA	1400

Source: Mineral Commodity Summaries, 2017

Table – 5 : Consumption of Rare Earths, 2013-14 to 2015-16 (By Industries)

(In tonnes)

Industry	2013-14	2014-15	2015-16
All Industries	**31.18**	**30.49**	**31.9**
Paints Driers/Pigments	-	-	-
Cinema Arc Carbon	-	-	-
TV Colour picture tube	0.93	1.59	0.9
Glass/Optical polishing	0.09	0.09	0.09
Glassware decolouring	3.9	2.25	3.9
R&D and others	26.26	26.56	27.01

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

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

(In tonnes)

Country	2013	2014	2015
Australia	970	3965	8799
China(e)(#)	95000	140000	140000
Malaysia	229	292	365
Russia(e)	1443	2134	2312
USA	3300	3240	2460e
Vietnam (e)	100	100	100

Source: *World Mineral Production, 2011-2015.*
 # Includes production from iron ore extraction, bestnaesite concentrates and ion absorption clays.

FUTURE OUTLOOK

China is the world leader in rare earth oxide supply comprising 90% of the global market. The demand for rare earths is centered around countries which manufacture high tech goods and components like automotive catalyst systems, fluorescent lighting tubes and display panel. 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.