67 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 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 57 through 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 its occurrence with other rare earth elements is also found in a number of minerals.

Rare earths 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 five 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 estimation for the areas explored by AMD up to 2006 is almost complete. The resource estimates of monazite in the beach and inland placer deposits have been enhanced from 10.21 million tonnes in 2005 to 10.70 million tonnes in 2009. The statewise resources are given in Table - 1.

Table – 1 : Resources of Monazite

(In million tonnes)

State	Resources*
All India	**10.70**
Andhra Pradesh	3.74
Bihar	0.22
Kerala	1.51
Odisha	1.85
Tamil Nadu	2.16
West Bengal	1.22

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

EXPLORATION & DEVELOPMENT

AMD carried out exploration in Gujarat, Odisha, Kerala and Tamil Nadu. Directorate of Geology, Odisha, has carried out exploration in beach sands along the Puri Coast to assess the heavy-mineral contents like ilmenite, rutile, zircon, monazite, etc. Details of exploration carried out by AMD, State Directorate, etc., are provided in the Review on 'Ilmenite and Rutile', Chapter 46.

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 earth chlorides, in 2009-10 against 4,500 tpy installed capacity. The production and prices of rare earths in India during 2007-08 to 2009-10 are given in Tables - 2 and 3, respectively.

Table – 2 : Production and Value of Rare Earths*
2007-08 to 2009-10

Year	Quantity** (tonnes)	Value (Rs. lakh)
2007-08	35	65
2008-09	22	27
2009-10	16	48

Source: *Department of Atomic Energy, Mumbai.*
* *Produced by IREL.*
***Mainly Rare Earths fluoride, cerium oxide & cerium hydrate from conversion of Rare Earths chloride.*

Table – 3 : Domestic Prices of Rare Earths 2007-08 to 2009-10

(In Rs. per kg)

Year	Grade	Price	Remarks
2007-08	RE chloride	50	Ex-works, packed
&	RE fluoride	135	Ex-works, packed
2008-09	RE carbobate	72	Ex-works, packed
	Cerium oxide A	145	Ex-works, packed
	Cerium oxide B	300	Ex-works, packed
2009-10	RE chloride	60	Ex-works, packed
	RE fluoride	160	Ex-works, packed
	RE carbobate	72	Ex-works, packed
	Cerium oxide A	145	Ex-works, packed
	Cerium oxide B	360	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, Alwaye, 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 is setting up a 10,000 tpy monazite processing plant (MoPP) and the project is likely to be commissioned by 2012. IREL has entered into an agreement with Toyoto Corporation, Japan for supplying of over 50% of Rare Earth 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. A thorium plant is in operation since 1992 at OSCOM to produce 240 tpy mantle grade thorium nitrate.

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		
			2007-08	2008-09	2009-10
RE Chloride	REO 45% min. CeO_2/REO 45% min.	–	–	–	–
RE Fluoride	TO>78%, F>26% Ce/TO>45%	114	30.250	20.000	NA
RE Oxide	–	–	–	–	–
Cerium Hydrate	Total REO>80% (30% for wet) CeO_2>68%, CeO_2/Total REO >85%	–	5.633	2.000	NA
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	25.877	32.686	33.000
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 and 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 earth phosphates, 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, find use 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 phosphors; yttrium in advanced ceramics like nitrides, Y-stabilised ceramics, etc., and gadolinium in magnet alloys. Yttrium, europium and terbium are used as phosphors in displays of computers, TV, etc. and with lanthanum, cerium & gadolinium as phosphors 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 as solid oxide fuel cells. Scandium is used mainly in aluminium alloys for sporting goods. Scandium in minor amounts is used in semiconductors and speciality lighting including halogen bulbs. Mixed rare earth products find use 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 2009-10 was estimated at 118 tonnes. Paints Driers/Pigments Industry was the main consumer accounting for about 78% of the total consumption followed by Cinema Arc Carbon Industry (21%) (Table-5).

Table – 5 : Consumption* of Rare Earths 2007-08 to 2009-10 (By Industries)

(In tonnes)

Industry	2007-08	2008-09	2009-10
All Industries	**221**	**158**	**118**
Paints Driers/Pigments	118	85	92
Cinema Arc Carbon	94	66	25
TV Colour picture tube	–	–	1
Glass/Optical polishing	2	2	–
Glassware decolouring	2	–	–
R&D and others	5	5	–

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

FOREIGN TRADE

In 2009-10, IREL exported 2 tonnes monazite valued at Rs. 4.37 lakh to Japan compared to five tonnes of monazite valued at Rs. 10.51 lakh in the previous year.

WORLD REVIEW

The total world reserves are estimated at 99 million tonnes of rare-earth oxides (REO) of which China alone accounts for 36 million tonnes followed by CIS, USA, Australia and India (Table - 6).

China holds the leading position among producers of rare earths followed by Brazil, Malaysia & India (Table-7). Rare earths are also produced in Russia, 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 Mangolia 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 earth 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)	**99000**
Australia	5400
Brazil	48
China	36000
Commonwealth of Independent States	19000
India*	3100
Malaysia	30
USA	13000
Other countries	22000

Source: *Mineral Commodity Summaries, 2010.*
** As per Department of Atomic Energy, Mumbai, the total resources of monazite, a source of rare earths, are estimated at 10.70 million tonnes.*

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

(In tonnes)

Country	2007	2008	2009
Brazil (Monazite)	760	540	650
China #	120000(e)	125000(e)	120000
India (Monazite)@	35	20	20(e)
Malaysia (Monazite)	440	150	20

Source: *World Mineral Production, 2005-2009.*
 # Includes production from iron ore extraction, bestnasite concentrates and ion absorption clays.
@ As per Department of Atomic Energy, Mumbai, the total production of rare earths in 2007-08, 2008-09 and 2009-10 was 35 tonnes, 22 tonnes and 16 tonnes, respectively.

FUTURE OUTLOOK

Demand for rare earths is centered around countries which manufacture 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 controls the entire global supply and its export limits, mine restructuring and other policies are responsible for determining prices of rare earths which are almost manifold since 2009 due to panic buying globally.