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ZIRCON

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GOVERNMENT OF INDIA
MINISTRY OF MINES
INDIAN BUREAU OF MINES

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29 Zircon

Zirconium is the twentieth most abundant element in the Earth's crust and occurs in a variety of rock types and geological environment but most often in the form of zircon ($ZrSiO_4$) found usually as a constituent in heavy mineral sand assemblages, which include ilmenite, rutile, leucoxene, monazite and garnet in varying proportions. Zircon sand and baddeleyite (an oxide-ZrO_2) are used via their salts to extract zirconium and hafnium. Normally, all zirconium compounds contain between 1.4% and 3% hafnium. Zircon is very stable at high temperature and has excellent thermal shock resistance, low thermal conductivity and chemical inertness. It finds use chiefly in industries like ceramic, refractory, abrasive, foundry, chemical and speciality alloys. Gem variety of zircon is used in jewellery. Ministry of Mines vide notification No. S.O. 2356(E) dated 11.7.2016 inserted entry 12 beach sand minerals (which includes zircon) in Part B of the First Schedule to the MMDR Act,1957.

Table – 1: Resources of Zircon

(In million tonnes)

State	Resources#
Total	**33.71**
Andhra Pradesh	11.94
Bihar/Jharkhand	0.08
Gujarat	0.01
Kerala	7.83
Maharashtra	0.01
Odisha	3.25
Tamil Nadu	10.20
West Bengal	0.39

Source:*Department of Atomic Energy,Mumbai*

 # :Inclusive of indicated, inferred and speculative categories.

RESERVES/RESOURCES

Zircon occurs in close association with other heavy minerals such as ilmenite, rutile and monazite in beach sands, along the coastal tracts of the country. Its concentration in the deposits is about 0.6-18.7% of the total heavy minerals. Indian zircons analyse 63-66% ZrO_2. AMD has carried out reconnaissance investigation in parts of Gujarat, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Kerala, Odisha and West Bengal during 2008-14. The resource estimation in these areas have been carried out up to 2016. The resources of zircon are placed at 33.71 million tonnes as per Department of Atomic Energy (DAE). The statewise break-up of the resources is given in Table-1.

EXPLORATION & DEVELOPMENT

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

PRODUCTION AND PRICES

Production of zircon decreased to 13,951 tonnes in 2017-18 from 30,351 tonnes in the preceding year. The production of zircon is given in Table-2. Prices of zircon as furnished by IREL, KMML and V. V. Minerals are given in Table- 3.

Table – 2: Production of Zircon

2015-16 to 2017-18

(In tonnes)

Year	Production of Zircon*
2015-16	18437
2016-17	30351
2017-18	13951

**Indian Rare Earths Ltd reported production of zircon at 10,785 tonnes, 12,804 tonnes and 9,107 tonnes during 2015-16, 2016-17 and 2017-18, respectively.*

Table – 3: Prices of Zircon, 2015-16 to 2017-18

(` per tonne)

Period	Grade	Price	Remarks
IREL			
2015-16	Q	63800	Ex-works, bagged
	MK	63800	Ex-works, bagged
	OR	57000	Ex-works, bagged
2016-17	Q	63500	Ex-works, bagged
	MK	63500	Ex-works, bagged
	OR	60800	Ex-works, bagged
2017-18	NA	NA	
KMML			
2015-16	Zircon Gr.I	73000	-
	Zircon Gr.II	67333	-
	Zircon Gr.III	62800	-
2016-17	Zircon Gr.I	75583	-
	Zircon Gr.II	70250	-
	Zircon Gr.III	66250	-
2017-18	Zircon Gr.I	85170	-
	Zircon Gr.II	80170	-
	Zircon Gr.III	76170	-
V.V. Mineral			
2015-16	NA	34565	-
2016-17	NA	35416	-
2017-18	NA	NA	-

Source: *Department of Atomic Energy, Mumbai.*

MINING AND PROCESSING

Indian Rare Earths Ltd (IREL), a Government of India Undertaking, KMML, a Kerala State Government Undertaking and V.V. Mineral, a Private Sector company are engaged actively in mining and processing of beach sands in India. Zircon is recovered by these companies as a co-product of mining/dredging of heavy mineral sands which include ilmenite, rutile, leucoxene, monazite, sillimanite and garnet. Beach sand deposits containing these minerals are obtained from coastal tracts of Manavalakurichi in Tamil Nadu, Chavara in Kerala and Gopalpur in Odisha. As such, no deposit is being worked exclusively for zircon alone. For details regarding mining and processing, etc., review on 'Ilmenite and Rutile' may be referred. Plantwise capacity and production of zircon during 2015-16 to 2017-18 are given in Table- 4.

INDUSTRY

IREL has set up a dry grinding mill at Chavara, Kerala to produce Zirflour for its application in the ceramic industry. A wet grinding mill was also set up at Chavara to produce micro-zir for its specialised application as opacifier. Besides, IREL established a small chemical plant at Manavalakurichi, Tamil Nadu to produce zircon frit, zirconium chloride, etc., primarily for making supply of zircon frit to Department of Atomic Energy's Nuclear Fuel Complex (NFC), Hyderabad. A pilot plant (3.5 tpy capacity) was set up at Orissa Sand Complex (OSCOM) to produce a whole range of zirconia stabilised with CaO, MgO and rare earths.

The NFC manufactures and supplies fuel bundles for Pressurised Heavy Water Reactors (PHWRs) and Boiling Water Reactors (BWRs) of NPCIL. Highest ever production of PHWR fuel bundles, Zirconium Oxide, Zirconium sponge and Niobium metal was achieved during the period. The NFC, Hyderabad has different types of production facilities which include the zirconium oxide plant for processing of zircon to pure zirconium oxide and zirconium sponge plant for conversion of zirconium oxide to pure sponge metal and Zirconium Complex (ZC) at Pazhayakayal, near Thoothukudi, Tamil Nadu. NFC Hyderabad produced 625 tonnes, 651 tonnes and 165 tonnes of zirconium oxide during 2015-16, 2016-17 and 2017-18, respectively. ZC, Pazhayakayal, produced 502 tonnes, 503 tonnes and 351 tonnes of ZrO_2 in 2015-16, 2016-17 and 2017-18, respectively. Besides, the Zircaloy Fabrication Plant produces various zirconium alloy tubings and sheet, rod and wire products. The plant also has facilities for reclamation of zircaloy mill-scrap. Zircon sand is processed through caustic fusion, dissolution, solvent extraction (to remove hafnium), precipitation and calcination to obtain zirconium oxide. The pure oxide is then subjected to high temperature chlorination, reactive metal reduction and vacuum distillation to obtain homogeneous zirconium sponge. The sponge is briquetted with alloying ingredients and melted in vacuum to produce zircaloy ingots. The alloy ingots are extruded to convert into seamless tubes, sheets and bars. The total installed capacity and production of zirconium oxide and zirconium sponge plants at NFC and ZC are furnished in Table-5.

Besides, Bhalla Chemical Works Pvt. Ltd operates three plants; two of which are located in Gurgaon, Haryana to manufacture zirconium derivatives (ZrO_2), based on imported zircon ore (capacity 10,000 tpy) and zirconium silicate opacifiers (capacity 5,000 tpy). The third plant of the company in Rajasthan manufactures zirconium oxychloride crystals and special zirconias (capacity 10,000 tpy).

Table – 4: Plantwise Capacity and Production of Zircon ore, 2015-16 to 2017-18

(In tonnes)

Company	Location	Specification	Installed capacity (tpy)	Production		
				2015-16	2016-17	2017-18
Total			**57000**	**18437**	**30351**	**13951**
Indian Rare	Manavalakurichi,	65% ZrO_2+HfO_2(min)	10000		2606	-
Earths Ltd	Kanyakumari distt., Tamil Nadu			10785		
	Chavara, Kollam distt., Kerala	65% ZrO_2+HfO_2(min)	17500	-	4502	2649
	Orissa Sand Complex, Ganjam distt., Odisha	64.25% ZrO_2(min)	5000	-	5696	6458
Kerala Minerals & Metals Ltd	Chavara, Kollam distt., Kerala	Zircon Gr.I 64.0% (min) Zircon Gr.II 62% (min)	6500	5346	4784	4844
V. V. Mineral	Keeraikaranthattu, Tirunelveli distt.,Tisaiyanvilai, Tamil Nadu	66% min (ZrO_2+HfO_2)	18000 (654,000 - of heavy minerals)	2306	12763	-

Source: *Respective Producers and Department of Atomic Energy, Mumbai.*

Note: *During the financial year 2017-18 MK plant was not operating from January 2017 because of non availability of environment clearances (EC)*

Table – 5 : Production at Zirconium Oxide and Sponge Plants of DAE at NFC and ZC 2015-16 to 2017-18

(In tonnes)

Plant/Location	Installed capacity (tpy)	Production		
		2015-16	2016-17	2017-18
Zirconium Oxide Plant, NFC, Hyderabad	600/750	625	651	165
Zirconium Sponge Plant, NFC, Hyderabad	400	-	-	-
Zirconium Oxide Plant, ZC, Pazhayakayal	500	502	503	351
Zirconium Sponge Plant, ZC, Pazhayakayal	250	-	-	-

Source: *Department of Atomic Energy, Mumbai.*

USES & CONSUMPTION

Zircon's exceptional qualities of hardness and durability make it a must-use for the manufacture of ceramics and refractory tiles and also for a range of other high-tech applications such as armour plating on military aircraft, heat shield in space shuttles potentially as solid oxide fuel cells in hydrogen powered vehicles and in many industrial and chemical applications. Owing to its chemical inertness, very low heat conductivity, high specific gravity, low expansion, good resistance to abrasion, high melting point and no shrinkage on being heated up to 1750^{0}C, zircon is found to be an outstanding refractory material. Zircon finds its application in ceramics, zirconia, chemicals, refractory and foundry & castings which accounts for zircon's total world estimated consumption. Zirconia and Zirconium chemicals can be used for a variety of uses. Yttria-stablised zirconia (YSZ) is used in the manufacture of oxygen sensors that control combustion in automobile engines and furnaces. In Foundry Industry, zircon is used as facing for foundry moulds as it increases the resistance to metal penetration and accords a uniform finish to castings. Zircon sand is preferred to silica sand because of its uniform size, higher melting point, low thermal expansion and resistance to molten metal, acidic chemicals, slag, etc. Zircon containing 64% ZrO_2 is used generally for foundry applications. In Ceramic Industry, finely ground high-grade zircon and zirconium dioxide are used as opacifier in melts for vitreous enamelling and as pigment in ceramic glazes. Zirconium oxide is considered as a potential ceramic material for high temperature applications like engine components. Usually, zircon containing 65% ZrO_2 is preferred in ceramics. The toughened zirconia finds its use in ceramic coatings in jet aircraft engines and in other applications where strength and high temperature oxidation resistance are important. Zirconia ceramics are also used in automobile sensors for the microprocessor control of engines. In Chemical Industry, its property of high resistance to corrosion is used where dry chlorine, hydrochloric acid and caustic alkalies are involved. Abrasive and grinding wheels made from zircon sands are used for polishing optical glasses. Zircon powder is used as a medium in waterjet cutting machines.

Zirconium and zirconium powders are used in ammunition, primers, detonation caps, flashlight mixtures, radio tubes and in various heating elements. Hafnium-free zirconium metal is used as cladding material in atomic reactors due to its low absorbing cross section for thermal neutron. Green, blue, indigo, red,orange coloured zircon is used as a natural gemstone and also processed to produce cubic zirconia - a synthetic gemstone resembling diamond. Zircon compounds have a very low toxicity and are not perceived as a potential environmental hazard. They are even said to have some medicinal properties and are now increasingly preferred in the manufacture of food products and pharmaceuticals too. It is also widely used in television and computer screens, resistance to corrosion and erosion makes ziron products ideal for use in the Chemical Industry and in desalination plants. Zircon flour is manufactured by milling zircon sand. It is used in ceramic frits, foundry mould coatings,ceramic shells for investment casting, refractories, friction products, insulating fibres and glass. Zircon opacifier are used in refractories and friction products. Zirconium metal, or sponge is used mainly in the Nuclear Industry with a requirement for minimum content of hafnium.

Consumption of zircon/zirflour decreased to 17,400 tonnes in 2017-18 from 29,000 tonnes in 2016-17. Consumption of zircon/zirflour during the year 2015-16 to 2017-18 is furnished in Table- 6. Refractory industry was a major consumer of Zircon/Zirflour accounting for 56% consumption in 2017-18, followed by Ceramic Industry (41%).

Table – 6: Estimated Consumption * of Zircon Zirflour
2015-16 to 2017-18
(By Industries)

(In tonnes)

Industry	2015-16	2016-17	2017-18
All Industries	**29800**	**29000***	**17400**
Ceramic	15700	19100	7200
Refractory	10300	8300	9700
Others (Alloy steel,iron & steel, Chemical, foundry & paint)	3800	1600	500

Figures rounded off.

** Includes actual reported consumtion and/or estimates made wherever required. Due to paucity of data, coverage may not be complete.*

POLICY

Zircon was earlier classified as a 'prescribed substance', as per notifications issued under Atomic Energy Act, 1962. From the revised list notified vide S. O. No. 61(E), dated 20.1.2006, zircon has been deleted, subject to the condition that the mineral shall remain a prescribed substance till the policy on exploration of beach sand minerals notified on 6.10.1998, is adopted/ revised/modified by Ministry of Mines or till 1.1.2007, whichever occurs earlier and shall cease to be so thereafter. Recently, vide notification No.S.O.2356(E) dated 11.07.2016, zircon covered under beach sand minerals and being inserted after entry 11 of Part B of the First Schedule to the MMDR Act, 1957. As per the Foreign Trade Policy, 2015-20, the export and import of zirconium ores and concentrates under ITC (HS) Code 26151000 are freely allowed.

WORLD REVIEW

World reserves of zirconium are placed at 73 million tonnes in terms of ZrO_2. The world's largest reserves are with Australia (58%), South Africa (19.17%). The world production of zirconium minerals was estimated at 1.38 million tonnes in 2017. Australia, South Africa, Mozambique, Senegal and Kenya are the principal producers of zirconium minerals (Tables- 7 & 8).

Table – 7: World Reserves of Zirconium
(By Principal Countries)

(In '000 tonnes of ZrO_2)

Country	Reserves
World: Total (rounded)	**73000**
Australia	42000
China	500
Mozambique	1800
South Africa	14000
USA	500
Other countries	14200

Source: *Mineral Commodity Summaries,USGS 2019.*

Table – 8 : World Production of Zirconium Minerals
(By Principal Countries)

(In tonnes)

Country	2015	2016	2017
World: Total	**1328000**	**1396000**	**1385000**
Australia[e] (c)	607836	620136	535933
South Africa[e]	390000	400000	460000
Mozambique	51800	68200	74000
Senegal	45248	52627	61563
USA[e]	50000	50000[e]	30000[e]
Kenya	25951	34977	35293
China[e]	33500	33500	33500
Indonesia[e] (b)	31000	35000	27000
Ukraine[e]	25000	25000	25000
Brazil[e] (a)	25000	25000	25000
Madagascar	11879	9200	21000
Other countries	30600	42493	56767

Source: *World Mineral Production, BGS.,2013-17.*
Note: *(a) Including caldasite rock containing zircon & baddeleyite.*
(b) Conservative BGS estimates, based on exports.
(c) Years ended 30 June of that stated.
In this table the term Zirconium minerals is understood to mean zirum, unless otherwise stated

To give a generalised view of the development in various countries, the country-wise description is sourced from latest available publication of Minerals Yearbook 'USGS' -2015 is furnished below.

Australia

Iluka Resources produced 351,000 tonnes of zircon from its operations in Australia, an increase of 6% compared with that of 2014. Production was 297,000 tonnes from its operations in the Eucla Basin, South Australia, and the Perth Basin, Western Australia, and 54,000 tonnes from its operations in the Murray Basin.

MZI Resources Ltd completed construction of its Keysbrook project and began mining heavy-mineral concentrates in October. By year end, Keysbrook had produced 1,775 tonnes of zircon and had shipped 1,000 tonnes to China.

In New South Wales, Alkane Resources Ltd continued to develop its Dubbo Zirconia project and planned to produce hafnium, niobium, rare-earth, tantalum and zirconium products. Based on recoveries developed from the demonstration pilot plant, 25,200 tonnes per year of combined output was expected, including zirconium carbonate (equivalent to 16,300 t/yr of ZrO_2) and more than 200 t/yr of hafnium oxide. Ore reserves were sufficient to support a 35-year mine life. Alkane received State and Federal environmental approvals in 2015 and was expecting to begin construction in 2016 with production to begin in 2018.

China

China imported 1.05 tonnes of zircon concentrates in 2015, an increase of 30% from that of 2014, but the average value decreased by 10% to $752 per tonne.

By the end of 2015, major zirconium metal producers were reportedly operating at reduced capacity due to overcapacity issues. Other producers had stopped producing zirconium sponge and were liquidating existing stock. The Shanghai Hafeng New Materials Science and Technology Co., Ltd applied for a national patent based on a new zirconium and hafnium separation technology. Shanghai Hafeng also announced the planned construction of a new operation with an annual capacity of 200,000 t/yr of zirconium and 3,000 t/yr of hafnium, to be built in Jiangsu. No timetable was given for start of construction.

Kenya

Base Resources Ltd reported that it produced 26,000 tonnes of zircon from its Kwale operation in 2015, the first full year of production. The production target for 2016 was 27,000 to 30,000 tonnes of zircon.

Mozambique

Kenmare Resources plc produced 51,800 tonnes of zircon at its Moma Mine in 2015, an increase of 2% from that of 2014.

Senegal

Mineral Deposits Ltd reported that it produced 45,200 tonnes of zircon at its Grande Cote project in 2015, the first full year production. The company planned to increase zircon production in 2016. At full production levels, Mineral Deposits expected to produce 85,000 t/yr of zircon over a 25-year mine life.

South Africa

Tronox Ltd expected to begin operations at its Fairbreeze Mine in 2016. During a 12-year mine life, the Fairbreeze Mine was expected to produce 60,000 t/yr of zircon.

Mineral commodities Ltd reported that it produced 44,489 tonnes of zircon-rutile concentrate, grading 72.88% zircon and 13.44% rutile, at their Tormin Mine in 2015, an increase of 4% form that of 2014.

FOREIGN TRADE

Exports

Exports of zirconium ores and concentrates drastically decreased to 308 tonnes in 2017-18 from 1693 tonnes in the previous year. Exports were mostly to UAE (59%) & Bangladesh (39%). Exports of zirconium and scrap sharply decreased to 7 tonnes in 2017-18 as against 11 tonnes in 2016-17. Exports were mostly to Canada (57%) & Germany (28%) (Tables-9 & 10).

Imports

Imports of zirconium ores and concentrates increased to 83,781 tonnes in 2017-18 from 73,932 tonnes in the previous year. Main suppliers were Australia (64%) and South Africa (23%). Imports of zirconium and scrap reduce to 22 tonnes in 2017-18 as against 27 tonnes in 2016-17. Imports were mainly from China (41%), Germany (23%), Italy & Malaysia (9%) each (Tables-11 & 12).

Table – 9: Exports of Zirconium Ores & Conc.
(By Countries)

Country	2016-17		2017-18	
	Qty (t)	Value (``'000)	Qty (t)	Value (``'000)
All Countries	**1693**	**95182**	**308**	**31130**
UAE	4	250	181	18448
Bangladesh	5	405	120	11838
Oman	18	1609	5	613
Kenya	-	-	1	136
Israel	-	-	1	95
Belgium	154	9216	-	-
UK	26	1669	-	-
Netherlands	280	16924	-	-
China	448	17889	-	-
France	++	33	-	-
Other countries	758	47187	-	-

Table – 10: Exports of Zirconium & Scrap
(By Countries)

Country	2016-17		2017-18	
	Qty (t)	Value (``'000)	Qty (t)	Value (``'000)
All Countries	**11**	**6661**	**7**	**33359**
Germany	-	-	2	26349
USA	++	2569	++	2746
Canada	2	1919	4	2378
Israel	-	-	++	391
Ethiopia	1	580	++	311
Australia	++	142	++	298
Tanzania	-	-	++	259
Poland	-	-	++	115
Italy	++	283	1	113
Turkey	-	-	++	111
Other countries	8	1168	++	288

Table – 11: Imports of Zirconium Ores & Conc.
(By Countries)

Country	2016-17		2017-18	
	Qty (t)	Value (``'000)	Qty (t)	Value (``'000)
All Countries	**73932**	**4569039**	**83781**	**6202746**
Australia	49174	3073405	53791	4031215
South Africa	14261	868582	19615	1380560
Senegal	2142	127992	4191	289247
Indonesia	1506	95215	3025	251511
Ukraine	2272	133584	1590	95906
USA	319	45907	294	53552
Kenya	2346	133465	-	-
Sri Lanka	1375	41059	525	45530
Malaysia	154	9243	364	26935
Austria	-	-	156	11430
Spain	36	2852	86	734
Other countries	2693	171200	144	9486

Table – 12: Imports of Zirconium & Scrap
(By Countries)

Country	2016-17		2017-18	
	Qty (t)	Value (``'000)	Qty (t)	Value (``'000)
All Countries	**27**	**51750**	**22**	**65331**
Germany	5	15357	5	21344
China	16	20146	9	17764
Italy	1	6677	2	7104
Malaysia	1	2668	2	3994
Austria	-	-	1	3911
France	++	450	1	3283
Ukraine	-	-	1	2960
USA	2	4355	++	2190
Singapore	++	116	++	1163
Unspecified	-	-	1	692
Other countries	2	1981	++	926

FUTURE OUTLOOK

The development of digital printing of ceramic tile pattern has the potential to increase demand since higher zircon content of the base tile is required to impart greater aesthitic appeal and optimise the cost of the digital printing process.

TZ Minerals International Pty Ltd, a major industry analyst of the zircon and Titanium Mineral Sands Industry, expected global zircon demand to increase by 3% to 4% per year from 2015 to 2020.

In the IREL's Annual Report, 2016-17 it was mentioned that the way Chinese Industry copes with the regulations is likely to impact the demand - supply dynamics of two major products produced by IREL viz. Ilmenite and Zircon.