Indian Minerals Yearbook 2020

(Part- III : MINERAL REVIEWS)

59th Edition

ILMENITE AND RUTILE

(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

October, 2021

15 Ilmenite & Rutile

India is endowed with large resources of heavy minerals which occur mainly along coastal stretches of the country and also in inland placers. Heavy mineral sands comprise a group of seven minerals, viz, ilmenite, leucoxene (brown ilmenite), rutile, zircon, sillimanite, garnet and monazite. Ilmenite ($FeO.TiO_2$) and rutile (TiO_2) are the two chief minerals of titanium. Titanium dioxide occurs in polymorphic forms as rutile, anatase (octahedrite) and brookite. Though brookite is not found on a large-scale in nature, it is an alteration product of other titanium minerals. Leucoxene is an alteration product of ilmenite and is usually found associated with ilmenite.

RESERVES/RESOURCES

Ilmenite and rutile along with other heavy minerals are important constituents of beach sand deposits found right from Saurashtra coast (Gujarat) in the west to Digha coast, West Bengal in the east. These minerals are concentrated in five well-defined zones:

* Over a stretch of 22 km between Neendakara and Kayamkulam, Kollam district, Kerala (known as 'Chavara' deposit after the main mining centre).
* Over a stretch of 6 km from the mouth of River Valliyar to Colachal, Manavalakurichi and little beyond in Kanyakumari district, Tamil Nadu (known as MK deposit).
* On Chatrapur coast stretching to about 18 km between Rushikulya river mouth and Gopalpur lighthouse with an average width of 1.4 km in Ganjam district, Odisha (known as 'OSCOM' deposit after IREL's Orissa Sands Complex).
* Brahmagiri deposit stretches for 30 km from Girala nala to Village Bhabunia with an average width of 1.91 km in Puri district, Odisha.
* Bhavanapadu coast between Nilarevu and Sandipeta with 25 km length and 700 m average width in Srikakulam district, Andhra Pradesh.

The AMD of the Department of Atomic Energy has been carrying out exploration of these mineral deposits. Of the total, coastal length of 5,921 km spread in Odisha, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Maharashtra, Goa, Gujarat and West Bengal about 451 km, 1,873 km, and 112 km have been covered by detailed exploration, general exploration and preliminary exploration respectively. A coastal length of 2,272 km have not been covered due to various reasons viz., mangrove, port activity etc., leaving an unexplored coastal length of 1,214 km. The distribution of area coverage (sq km) in different geological domains are Beach & Dune (1845), Inland Sand Body (180), Terrace sediments (368), River Channel (32), Inland alluvium (646) and Lake & Sea Beds (38). The ilmenite resource estimation for the areas explored up to March, 2020 has been completed and the resources are up from 629.57 million tonnes (including leucoxene) in the year 2016 to 687.57 million tonnes in the year 2020. The resources include Measured, Indicated and Inferred categories. Though, the latest state-wise / deposit-wise details are not available, the state-wise/ deposit-wise details as received from DAE vide letter dated 26.07.2018 are furnished in Tables-1 & 1A.

EXPLORATION & DEVELOPMENT

The exploration and development details, if any, are covered in the Review on "Exploration and Development" under "General Reviews".

PRODUCTION AND PRICES

Ilmenite

The production of ilmenite was 351 thousand tonnes in 2019-20 increased by 20% as compared to that in the preceding year. Odisha was the leading producer of ilmenite during the year under review, contrubuting 69% of the total production followed by Kerala (21%) and Tamil Nadu (10%).

Table – 1 : Ilmenite Reserves, Resources/Deposits in India

State/Deposit	Ilmenite reserves (In million tonnes)
Andhra Pradesh	
1. Bhavanapadu	10.18
2. Kakinada (Phase I-VIII)	13.81
3. Kalingapatnam	7.03
4. Narasapur	2.92
5. Nizampatnam	19.26
6. Srikurman (South)	8.60
7. Visakhapatnam (Bhimunipatnam)	2.88
8. Amalapuram (Phase I-IV)	4.72
9. Pandurangapuram-Voderevu (Bapatla-Chirala coast)	10.38
10. Vetapalem Coast (Chirala coast)	5.31
Kerala	
1. Chavara Barrier beach	13.17
2. Chavara Eastern Extension (Phase-I)	17.02
3. Chavara Eastern Extension (Phase-II)	49.26
4. Trikkunnapuzha-Thotapally Beach & Eastern Extension	9.50
5. Alapuzha-Kochi	5.88
Maharashtra	
Ratnagiri	3.68
Munge-Achra-Malvan	1.12
Vijayadura-Mithbav	0.70
Gujarat	
Moti Daman-Umbrat coast	2.77
Odisha	
1. Brahmagiri (Phase I-V and NW extension)	86.04
2. Chatrapur	26.72
3. Gopalpur	6.42
Tamil Nadu	
1. Kudiraimozhi	22.86
2. Ovari-Periyatalai-Manapadu (Teri)	24.01
3. Sattankulam Teris	41.26
4. Cuddalore-Pudupattuchavadi (beach sand)	4.67
5. Vayakallur (beach sand)	4.52
6. Manavalakurichi (beach sand)	3.07
7. Midalam	1.64

Source: *As per letter received from Department of Atomic Energy, Mumbai dated 26/07/2018*

Table – 1 A : Reserves/Resources of Ilmenite and Rutile

(In million tonnes)

State	Total in situ #
Ilmenite* : Total	**629.57**
Andhra Pradesh	156.17
Jharkhand	0.73
Gujarat	2.77
Kerala	144.02
Maharashtra	5.50
Odisha	150.62
Tamil Nadu	167.70
West Bengal	2.06
Rutile : Total	**33.95**
Andhra Pradesh	10.55
Jharkhand	0.01
Gujarat	0.02
Kerala	8.74
Maharashtra	0.01
Odisha	6.58
Tamil Nadu	7.85
West Bengal	0.19

Source: *As per letter received from Department of Atomic Energy, Mumbai dated 26/07/2018. The resources of beach sand minerals (BSM) viz. Ilmenite, Rutile, Zircon, Garnet, leucoxene, monazite and Sillimanite were last updated in the year 2016 by AMD.* *# Inclusive of Indicated, Inferred and Speculative categories.* ** Including leucoxene.*

Rutile

The production of rutile at 13 thousand tonnes in 2019-20 increased by 4% as compared to that in the previous year. Kerala was the leading producer of rutile accounting for 66% of the total production followed by Odisha (25%) and Tamil Nadu (9%).

Production and prices of ilmenite and rutile are furnished in Tables -2 to 4.

Table – 2 : Production of Ilmenite and Rutile (By States)

(In tonnes)

State	2017-18	2018-19	2019-20* (P)
ILMENITE			
India : Total	**284667**	**292226**	**350535**
Odisha	184657	191492	241009
Kerala	100010	74834	75593
Tamil Nadu	-	25900	33933
RUTILE			
India : Total	**11829**	**12593**	**13102**
Kerala	3969	8384	8669
Odisha	7860	3270	3257
Tamil Nadu	-	939	1176

Table – 3 : Prices of Rutile 2017-18 to 2019-20

(₹ per tonne)

Year	Grade	Price	Remarks
IREL			
2017-18**	Q	60748	Ex-works, Bagged
	MK	-	Ex-works, Bagged
	OR	61070	Ex-works, Bagged
2018-19	Q	76995	Ex-works, Bagged
	MK	79627	Ex-works, Bagged
	OR	76798	Ex-works, Bagged
2019-20	Q	92138	Ex-works, Bagged
	MK	93052	Ex-works, Bagged
	OR	92788	Ex-works, Bagged
KMML			
2017-18	-	52083	Average
2018-19	-	66916	Average
2019-20	-	NA	-
V.V. Mineral			
2017-18	-	NA	Average
2018-19	-	NA	-
2019-20	-	-	-

Source: *Department of Atomic Energy, Mumbai*
Note*: Q: Quilon; MK: Manavalakurichi; OR: Odisha*
***During the financial year 2017-18 MK unit not despatches any material due to non- availability of transport permit.*

Table – 4: Prices of Ilmenite 2017-18 to 2019-20

(₹ per tonne)

Period	Grade	Price	Remarks
IREL			
2017-18**			
	Q*	11922	Ex-works, loose
	MK*	-	Ex-works, loose
	OR*	11618	Ex-works, loose
2018-19			
	Q*	12978	Ex-works, loose
	MK*	12667	Ex-works, loose
	OR*	12512	Ex-works, loose
2019-20			
	Q*	14618	Ex-works, loose
	MK*	14235	Ex-works, loose
	OR*	13167	Ex-works, loose
KMML			
2017-18		NA	
2018-19		NA	
2019-20		NA	
V.V. Mineral			
2017-18	-	-	-
2018-19	-	-	-
2019-20	-	-	-
BMC			
2017-18		NA	
2018-19		NA	
2019-20		NA	
DCW Ltd			
2017-18	-	8423	
2018-19	-	14489	
2019-20	-	15265	

Source: *Department of Atomic Energy, Mumbai.*
Note*: Q: Quilon; MK: Manavalakurichi; OR: Odisha*
Ilmenite is usually sold on NAW (naked at works) basis from all production center
**: Regular Price*

MINING & PROCESSING

A notification dated 27.07.2019, was issued for reseving the prospecting and mining rights of offshore minerals under Offshore Areas Minerals (Development and Regulation) Act, 2002 exclusively to Government and Government owned companies for curbing illegal miing of atomic minerals by private parties. Mining and processing of beach sand is carried out by the IREL, a Government of India Undertaking and KMML, a Kerala State Government Undertaking. Exploitation work of beach sand deposits located at Chavara in Kerala, Gopalpur in Odisha and Manavalakurichi in Tamil Nadu by IREL is under progress.

At IREL, Chavara, Beach Sand was collected over a stretch of 22 km between Neendakara and Kayamkulam in Kerala and was transported to plant site. The unit has adopted wet mining operations involving use of two Dredge and Wet Concentrator (DWC) of 100 tph capacity each to exploit the inland deposits away from the beaches. Chavara ilmenite is the richest in TiO_2 content (75.8% TiO_2) and has great demand in India and abroad for manufacture of pigments.

At Manavalakurichi, the deposit is spread over 300 hectares at Thuthoor-Ezudesam villages, Vilavancode tehsil, district Kanyakumari, Tamil Nadu. All the raw sand required for the mineral separation plant to operate to its full capacity is collected from nearby beaches. Deposits are also exploited by DWC of 100 tph capacity. Manavalakurichi is next to Chavara in terms of TiO_2 content which is more than 55%.

The sand deposits of OSCOM at Chatrapur in district Ganjam extend along the coast of Bay of Bengal with an average width of 1.4 km and average depth of 7.5 m. Mining operations involve suction dredging to 6 m depth below water level on a much larger scale (500 tph) augmented by a smaller sized (100 tph) supplementary. The ilmenite from OSCOM is inferior in grade in terms of TiO_2 content (50%) in comparison to Chavara and Manavalakurichi. The Synthetic Rutile Plant of OSCOM is presently not working. As a result, the majority of OSCOM ilmenite produced of late is routed to the international market as feedstock for production of both slag grade and anatase grade pigment.

In dry mining, beach washings laden with 40-70% Heavy Minerals (HM) are collected through front-end loaders and bulldozers for further concentration to 90% HM at land-based concentrators. Though dry mining is very simple and economic, there is considerable opposition by local people for this form of mining for reasons that removal of sand would expose the land area to sea erosion. Therefore, collection of beach washings has reduced significantly in recent past.

As an alternate approach, IREL has adopted wet mining involving dredging and wet concentration (DWC) from inland areas away from the beach lines. In this mode, an artificial pond is created, the sand bed is cut and the slurry is pumped to spiral concentrator for removal of quartz. Manavalakurichi was the first plant to install a DWC (100 tph) followed by one (500 tph) at OSCOM and two (each 100 tph) at Chavara. The concentrate (90% HM) of beach washing plant from DWC is further upgraded to 97% HM grade at a Concentrate Upgradation Plant (CUP) before sending it to Mineral Separation Plant (MSP).

Execution of Supplimentary Mining Lease deed for OSCOM Mines till a period up to the year 2047 has been completed under the provision of AMCR 2016. Communication on precious area of the Bramhagiri Mineral Sands Deposit in Puri District under AMCR 2016 is in the final stages of issuance by Government of Odisha.

After much persuasion, the precise area communication over an extent of 855 ha out of the identified area of 1,817 ha in Kanyakumari district is also expected to be issued by Government of Tamil Nadu. The Government is showing keen interest in exploiting the resources through a joint venture between IREL and TAMIN, a State PSU. This initiative would be a breather for MK operations as the mineable land within the mining leasehold areas are on the verge of exhaustion. Further, it will also pave way for formation of a new subsidiary of IREL in the same line as that of IREL and IDCOL.

KMML collects seasonal accretions of heavy mineral sand from the beach front. The pit so formed gets filled by fresh accretions of heavy mineral sand. The mineral sand is collected using bulldozers and wheel loaders and transported in tippers to Mineral Separation Plant.

The mineral separation plants use variety of equipment, such as, gravity concentrators, high tension electrostatic separators and magnetic separators. Making use of difference in physical properties like electrical conductivity, magnetic susceptibility and difference in specific gravity, etc., individual minerals like ilmenite, rutile, zircon, sillimanite and garnet are separated. The mined beach sands are pre-concentrated and dried after sieving (30-mesh) to separate the heavies from rejects. The heavy minerals are passed through electrostatic separators where conducting minerals – ilmenite and rutile – are separated from other non-conducting minerals. Ilmenite and rutile are further subjected to low-intensity magnetic separators where magnetic fraction - ilmenite is separated from rutile. Similarly, non-conducting fractions are subjected to high-intensity magnetic separators where weak magnetic fraction (monazite and garnet) is separated from non-magnetic fraction (zircon and sillimanite). The fractions are further processed on wind tables to separate garnet from monazite and sillimanite from zircon.

Installed capacity and production of ilmenite, rutile and other associated heavy minerals by various separation plants are furnished in Table-5.

Table – 5 : Installed Capacity & Production of Ilmenite, Rutile and Other Heavy Minerals, 2017-18 to 2019-20

(In tonnes)

Company/ Location	Mineral/ Product	Installed capacity (tpy)	Production		
			2017-18	2018-19	2019-20
Indian Rare Earths Ltd					
Manavalakurichi,#	Ilmenite	90000	-	25745	320485
Distt Kanyakumari,	Rutile	3500	-	938	11674
Tamil Nadu.	Zircon	10000	-	2190	11490
	Sillimanite	8778	-	-	26052
	Monazite	6000	-	-	69748
	Garnet	10000	-	7425	5034
Chavara,	Ilmenite	200000	43253	48694	
Distt Kollam,	Rutile	11400	1515	1723	
Kerala.	Zircon	17500	2649	3072	
	Rare Earths	4500*	-	-	
	Sillimanite	10000	6826	7953	
Orissa Sands Complex,	Ilmenite	220000	184657	191492	
Distt Ganjam,	Rutile	7400	7860	8384	
Odisha.	Zircon	5000	5696	6694	
	Sillimanite	13000	16698	17930	
	Garnet	20000	34170	31332	
Kerala Minerals & Metals Ltd					
Chavara,	Ilmenite	61600	56757	26140	30009
Distt Kollam.	Rutile	4400	2454	1548	1428
Kerala.	Zircon	6500	4844	4762	4110
	Sillimanite	3600	701	271	1329
V.V. Mineral					
Distt Thoothukudi,	Ilmenite	450000	-	-	
Tamil Nadu.	Rutile	12000	-	-	NA
	Zircon	18000	-	-	
	Zircon-sillimanite	24000	-	-	
Beach Minerals Co. Pvt. Ltd					
Kuttam, Distt Tirunelveli, Tamil Nadu.	Ilmenite	150000	-	-	
V.V. Titanium Pigments Pvt. Ltd Distt Thoothukudi Tamil Nadu.	Titanium Dioxide	18000	13801	11902	9419

Source: *Department of Atomic Energy, Mumbai and IREL.*

** In terms of rare earths chloride. '-' Not Available # During the year 2017-18, Manavalkurichi Plant was non-operating from Jan 2017 because of non-availability of environmental clearence (EC). V.V.Mineral mine is not in operation since 2017-18*

INDUSTRY

For manufacturing titanium dioxide pigment, ilmenite is first treated chemically to obtain upgraded ilmenite, commonly called as synthetic rutile. There are two major pigment production processes, namely, chloride process and sulphate process depending on different operating characteristics and feedstock requirements. Plants employing chloride process consume high TiO_2 content feedstocks like synthetic rutile and chloride slag. On the other hand, plants employing the sulphate process use lower-grade ilmenite and sulphate slags.

Ilmenite obtained from Mineral Separation Plant (MSP) is chemically treated to remove impurities, such as, iron to obtain synthetic rutile (90% TiO_2) in Synthetic Rutile Plant (SRP). Indian SRP are based on reduction roasting followed by acid leaching with or without generation of hydrochloric acid. Plants of IREL (OSCOM) and KMML depend on acid regeneration from the leach liquor while those of Cochin Minerals & Rutile Ltd (CMRL) and DCW use fresh acid and recover ferric chloride from the leach liquor for its use in water purification.

At OSCOM plant of IREL, reduction-roasting of ilmenite with coal is followed by leaching with HCL to separate iron as soluble ferrous chloride. The leached ilmenite is calcined to yield synthetic rutile and the acidic leach liquor is treated in an acid regeneration plant to recover HCL for recycling with iron oxide as waste. The unit stopped production in 1997, as it was not viable economically. Against the Request for Proposal floated to set up titanium slag plant under Build-Own-Operate (BOO) model, a CPSE has shown keen interest and based on their request, the due date of submission has been extended. Considering the formidable investment and difficulties in sourcing technology in the field, the progress, though slow is in the right direction.

Environment Clearence for setting up nano titania/zirconia facilities have been received. However, in consideration of the stringent norms of Zero Effluent Discharge, work has been taken up to use alternate feed material to meet the stipulations. The KMML is manufacturing rutile grade titanium dioxide pigment by chloride route at its Sankaramangalam plant near Chavara in Kerala. The project for the production of one lakh tonnes of TiO_2 in a phased manner is under implementation. The Company also has plans to enhance pigment capacity to 60,000 tpy for which detailed project report is under preparation. In 2009, the Company had developed Nano Titanium Dioxide particles on laboratory scale and in July 2011, India's first commercial plant for synthesis of Nano titanium Dioxide was commissioned.

The DCW Ltd procures ilmenite from Manavalakurichi which is then roasted with coke fines to convert Fe_2O_3 into FeO. The reduced ore is leached with concentrated hydrochloric acid to remove oxides of iron and other metals. The leached ore is washed and calcined to get upgraded ilmenite which contains more than 95% TiO_2. The upgraded ilmenite is micronised to 2 microns by using high-pressure steam. This is marketed as Titox. The liquor from ilmenite leaching process contains fine TiO_2 particles and chlorides. The TiO_2 recovered by filtration & washing in filter process is marketed as Utox. The Company has plans to increase the plant capacity to 48,000 tpy and also to install facilities for the manufacture of ferrite grade iron oxide from the effluent of the ilmenite plant.

Cochin Minerals and Rutile Ltd (CMRL), which began production at its 10,000 tpy synthetic rutile plant in Kerala in 1990 as a 100% EOU, has gradually raised the production capacity to around 45,000 tpy since 2008-09 for exports. It also has ferric chloride & ferrous chloride plants having capacities of 24,000 tpy & 72,000 tpy, respectively.

The Travancore Titanium Products Ltd (TTPL), a Kerala State Government Undertaking, manufactures titanium dioxide pigment by sulphate process at its plant at Kochuveli, Thiruvananthapuram. Ilmenite is reacted with sulphuric acid in digesters and a porous cake is formed. The mass in the solid form is dissolved in dilute sulphuric acid to get titanium in solution as titanium oxysulphate along with other metallic ingredients in ilmenite as their sulphate. The liquor is reduced using scrap iron, when ferric iron gets completely reduced to the ferrous state. The liquor is clarified, concentrated and boiled to precipitate the titanium content as hydrated titania which is then filtered by vacuum filters and calcined. Sulphuric acid required for captive consumption is produced at site using elemental sulphur. Till recently, TTPL was the only unit producing anatase grade titanium dioxide pigment in India. TTPL has capacity to produce 17,000 tpy of titanium dioxide, and with plans to modernise and diversify in stages, the Company has chalked out targets to produce both anatase and rutile grades titanium dioxide pigment.

Tata Steel has proposed a project to produce 1,00,000 tonnes per year titanium dioxide from ilmenite mined from beach sands of Tirunelveli and Thoothukudi districts in southern Tamil Nadu.

Present domestic titanium metal production is negligible. KMML has setup a 500 tpy titanium sponge plant with Defence Metallurgical Research Laboratory (DMRL) technology and first batch of titanium was delivered in September 2011. The plant will be further expanded to 1,000 tpy. IREL is to setup a 10,000 tpy titanium sponge plant at OSCOM for which proposals have been invited on "build, operate and own" basis. IREL intends to set-up titanium slag plant based on ilmenite from OSCOM, Odisha and has signed an MoU with NALCO for this purpose. Depending upon feasibility, further value addition to TiO_2 pigment and titanium sponge will be taken up, subsequently. Titanium sponge is imported by Mishra Dhatu Nigam Ltd (MIDHANI) for further processing in the country.

The available data on plantwise installed capacities of synthetic rutile and TiO_2 pigment are furnished in Table-6.

USES

About 90% of the world's titanium mineral production is used in the manufacturing of white titanium dioxide pigment. The unique combination of superior properties of high refractive index, low specific gravity, high hiding power and opacity and non-toxicity enable titanium dioxide in its application in the manufacture of all types of white and pastle shades of paints, white-walled tyres, glazed papers, plastics, printed fabrics, flooring materials like linoleum, pharmaceuticals, soaps, face powders and other cosmetic products. Besides, its non-toxic nature facilitate its use in cosmetics, pharmaceuticals, and even in foodstuffs as well as in toothpastes. Titanium dioxide is used in the manufacture of many sunscreen lotions and creams because of its non-toxicity and ultraviolet absorption properties. Synthetic rutile is used for coating welding electrodes as flux component and for manufacture of titanium tetrachloride which in turn is used in making titanium sponge. Synthetic rutile is also used as ingredient of special abrasives. Titanium metal is a versatile material with exceptional characteristics. The lightness, strength and durability of the metal make it an essential metal for the Aerospace Industry. It is also used in desalination and power generation plants and corrosive chemical industries because of its inertness and resistance to corrosion and high thermal conductivity. Its non-reactive property makes titanium metal one of the few materials that can be used in the human body for orthopaedic use and in pacemakers.

Table –6 : Installed Capacity of Synthetic Rutile/Titanium dioxide Pigment,

(In tonnes)

Plant	Location	Specification	Installed capacity (tpy)
IREL	Orissa Sands Complex, Distt Ganjam, Odisha.	90.5% TiO_2 (min.)	100000 (Synthetic rutile)
KMML Kerala	Chavara, Distt Kollam,	92-93% TiO_2	55000 (Synthetic rutile) 60000 (TiO_2 - Chloride Process)
DCW Ltd	Sahupuram, Distt Thoothukudi, Tamil Nadu.	95% TiO_2	42000 (Synthetic rutile)
CMRL	Edayar, Distt Ernakulam, Kerala.	96.5% TiO_2	50000 (Synthetic rutile)
TTPL	Kochuveli, Distt Thiruvananthapuram, Kerala.	97.5% TiO_2	17000 (TiO_2-Sulphate Process)
VVTi Pigments Pvt. Ltd* (formerly Kilburn Chemicals)	Thoothukudi, Tamil Nadu.	98% TiO_2 (min.)	18000 (TiO_2- Sulphate Process)
Kolmark Chemicals Ltd	Kalyani, Distt Nadia, West Bengal.	NA	4800 (TiO_2- Sulphate Process)

Source: *Department of Atomic Energy, Mumbai and individual companies*

Note: *KMML captively consumes synthetic rutile while CMRL and DCW export synthetic rutile*

** Including Kilburn Chemicals*

CONSUMPTION

The ilmenite consumption is placed at 2,25,100 tonnes in 2019-20 which is lower as compared to the previous year. The bulk of ilmenite is consumed by the Chemical Industry (99 %). Moderate proportions are consumed by Welding Electrode Industry. The consumption of rutile in 2018-19 was 10,500 tonnes as compared to 9,700 tonnes in 2017-18. The entire consumption was reported from Electrode Industry since last two years (Table-7).

Table – 7 : Consumption* of Ilmenite and Rutile 2017-18 to 2019-20 (By Industries)

(In tonnes)

Industry	2017-18	2018-19 (R)	2019-20 (P)
Ilmenite			
All Industries	**295000 (36)**	**222900 (36)**	**164800 (26)**
Chemicals	294100	222000	163900
Electrode	800	800	900
Others (Ceramic, Ferroalloys)	100	100	-
Rutile			
All Industries	**9700**	**10500**	**NA**
Electrode	9700	10500	NA
Paint	-	-	NA

Figures rounded off
** Includes actual reported consumption and/or estimates made wherever required.Paucity of data, hence, the coverage may not be complete.*
():Number of plants reported/estimated.

POLICY

A notification dated 27.07.2019, was issued for reseving the prospecting and mining rights of offshore minerals under Offshore Areas Minerals (Development and Regulation) Act, 2002 exclusively to Government and Government owned companies for curbing illegal miing of atomic minerals by private parties. The Government of India had notified in October 1998, a policy on exploitation of beach sand minerals in the country, which inter alia allows participation of the Private Sector with or without foreign companies subject to conditions stipulated. This will encourage further exploitation of mineral deposits through a judicious mix of Public & Private Sector participation including foreign collaboration. The ceiling on FDI on mining of titanium minerals has been raised to 100 per cent.

Joint ventures with foreign participation were being pursued by IREL for production of value-added products, keeping in view the Beach Sand Mineral Policy of the Government.

The minerals, ilmenite and rutile, were grouped as 'prescribed substances' as per notifications issued under the Atomic Energy Act, 1962. However, as per the revised list of Prescribed Substances, Prescribed Equipment and Technology notified by Department of Atomic Energy vide S.O.No.61(E), dated 20.1.2006, the titanium ore minerals like ilmenite, rutile and leucoxene have been delisted as prescribed substances by the Department of Atomic Energy subject to the note as below:

"These minerals shall remain prescribed substances only till such time the policy on Exploration of Beach Sand Minerals notified vide Resolution No.8/1(1)/97-PSU/1422, dated 6.10.1998, is adopted/revised/modified by the Ministry of Mines or till 1.1.2007, whichever occurs earlier and shall cease to be so thereafter".

As per notification No 26/2015-2020, the export of Beach Sand Minerals have been brought under State Trading Enterprise (STE) and shall be canalised through Indian Rare Earths Limited (IREL). Beach Sand Minerals, permitted anywhere in the export policy under Sl. No. 98A of Chapter 26 of schedule 2 Export Policy.

As per Gazette Notification No : GSR.134 (E) dated 20.2.2019, the particulars of threshold values for atomic minerals in respect of Beach Sand Minerals (BSM) shall be regulated as Schedule A [Rule 2(1)(m) and Rule 36] (Table-7A).

SUBSTITUTES

There are no cost-effective substitutes for titanium dioxide pigments. Synthetic rutile made from ilmenite can be substituted for natural rutile. Nickel steels, stainless steels and some non-ferrous metal alloys can sometimes replace titanium alloys in industrial uses although at the expense of performance or economics. Tungsten carbide competes with titanium carbide for surface cutting machine tools. Titanium slag competes with ilmenite and rutile.

Environmental awareness indicates that titanium dioxide plants are likely to use chloride technology in future as it produces much less quantity of waste products. Synthetic rutile or slag (made from ilmenite) is likely to be used as feed in increasing amount. There is also a strong pressure to reduce the radioactive content of feedstocks because it affects the marketability of beach sand ilmenite. Titanium alloys could be replaced in aerospace applications by lithium-aluminium alloys or carbon-epoxy composites.

Table - 7 A : Particulars of Threshold Value for Atomic Minerals
[See Rule 2 (1)(m) and Rule 36]

Uranium-bearing tailings left over from ores after extraction of copper and gold, ilmenite and other titanium ores.	60 ppm U_3O_8 and/or 250 ppm ThO_2.
Zirconium-bearing minerals and ores including zircon.	All cases of zirconium-bearing minerals occurring in Beach Sand Minerals and other placer deposits in association with monazite are notified as above threshold (i.e. the threshold is 0.00% monazite in Total Heavy Minerals), irrespective of monazite grade. In other cases, zircon containing less than 2,000 ppm of Hafnium.
Beach Sand Minerals, i.e., economic heavy minerals found in the teri or beach sand, which include ilmenite, rutile, leucoxene, garnet, monazite, zircon and sillimanite.	All cases of Beach Sand Minerals and other placer deposits in association with monazite are notified as above threshold (i.e., the threshold is 0.00% monazite in Total Heavy Minerals), irrespective of monazite grade.

WORLD REVIEW

World resources of anatase, ilmenite and rutile are more than 2 billion tonnes. World reserves of ilmenite are estimated at 700 million tonnes in terms of TiO_2 content. Major reserves are in China with 230 million tonnes (33%) followed by Australia with 150 million tonnes (21%), India with 85 million tonnes (12%), Brazil with 43 million tonnes (6%), Norway with 37 million tonnes & South Africa with 35 million tonnes (5% each), Canada with 31 million tonnes & Mozambique with 26 million tonnes (4% each) and Madagascar with 23 million tonnes (3%). The world reserves of rutile are 46 million tonnes in terms of TiO_2 content. Major rutile reserves are located in Australia with 27 million tonnes (59%), followed by India with 7.4 million tonnes (16%), South Africa with 6.8 million tonnes (15%) and Ukraine with 2.5 million tonnes (5%).

World production of ilmenite and rutile concentrates was 12 million tonnes and 0.60 million tonnes, respectively, in 2019. China and Canada contributed 4.2 million tonnes (35%) and 2.1 million tonnes (17%) of ilmenite production, followed by Ukraine with 0.92 million tonnes (8%), Mozambique with 0.89 million tonnes & South Africa with 0.82 million tonnes (7% each), Norway with 0.63 million tonnes & Australia with 0.59 million tonnes (5% each) and Senegal with 0.49 million tonnes (4%).

Australia produced 0.16 million tonnes of rutile, contributing 26% of world rutile output, followed by Sierra Leone with 0.14 million tonnes (23%), South Africa with 0.11 million tonnes (18%), Ukrain with 0.094 million tonnes (16%) and Kenya with 0.086 million tonnes (14%). World reserves and production of ilmenite and rutile are furnished in Tables-8 to10.

Table – 8 : World Reserves of Ilmenite and Rutile (By Principal Countries)

(In '000 tonnes of contained TiO_2)

Country	Reserves	
	Ilmenite	Rutile
World: Total (Rounded)	**700000**	**46000**
China	230000	-
Australia[a]	150000	27000
India	85000	7400
Brazil	43000	-
Norway	37000	-
South Africa[d]	35000	6800
Canada[d]	31000	-
Mozambique	26000	890
Madagascar[d]	23000	-
Ukraine	5900	2500
USA[b][c]	2000	-
Kenya	440	740
Senegal	NA	NA
Sierra Leone	-	490
Vietnam	1600	-
Other countries	26000	400

Source: USGS, Mineral Commodity Summaries, 2021
a:Joint Ore Reserves Committee- compliant reserves for ilmenite and rutile were estimated to be 36 million and 8.2 million tonnes respectively
b:Rounded to nearest 1,00,000 tonnes to avoid disclosing company proprietary data
c:US rutile reserves data are included with ilmenite.
d: Mine production is primarily used to produce titaniferous slag

Table – 9 : World Production of Ilmenite (By Principal Countries)

(In '000 tonnes)

Country	2017	2018	2019
World: Total (Wt of Conc.)	**11900**	**12200**	**12000**
China	3830	4200	4200
Canada	2300	2000	2100
Ukraine*[(a)(b)]	500*	745	924
Mozambique	998	959	893
South Africa[(b)]	550*	765	820*
Norway*	630	630	630
Australia[(c)]	694	569	587
Australia[(c)]Leucoxene	57	69	47
Senegal	492	507	492
Senegal[(m)]Leucoxene	10	10	10
Madagascar	430	382	462
Kenya	491	463	352
Korea, Rep. of	223	213	296
Vietnam	225	235	271
India[(d)]	285	266	265*
Other countries	284	308	302

***Source**: BGS, World Mineral Production,2015-2019.*
**:Estimate*
a:Canada produces some ilmenite which is sold as such and not processed into slag, but tonnages are small
b:It is believed that the majority of this is processed in to slag
c:Years ended 30 June of that stated
d:Years ended 31 March following that stated
m:Including natural rutile

Metal

Commercial production of titanium metal involves the chlorination of titanium-containing mineral concentrates to produce titanium tetrachloride ($TiCl_4$), which is reduced with magnesium (Kroll process) or sodium (Hunter process) to produce a commercially pure form of titanium metal. The metal formed has a porous appearance and is referred to as sponge. Titanium ingot and slab are produced by melting titanium sponge or scrap or a combination of both, usually with various other alloying elements.

Pigment

Global TiO_2 pigment production capacity was estimated to be 5.7 million tonnes per year. TiO_2 pigment produced is categorised by crystal form as either anatase or rutile. Rutile pigment is less reactive with the binders in paint when exposed to sunlight than the anatase pigment and is preferred substance in outdoor paints. Anatase pigment has a bluer tone than rutile, is somewhat softer and is used mainly in indoor paints and in paper manufacturing. Depending on the manner in which it is produced and subsequently finished, TiO_2 pigment can exhibit a wide range of functional properties, including dispersion, durability, opacity and tinting.

Table – 10 : World Production of Rutile (By Principal Countries)

(In '000 tonnes)

Country	2017	2018	2019
World: Total (wt of conc)	**700**	**600**	**600**
Australia[(c)]	227	209	155
Sierra Leone	165	108	137
South Africa*	95	103	110
Ukraine*	90	107	94
Kenya	87	98	86
India[(d)]	12	11	11
Mozambique	9	8	8
Malaysia	5	5	6
Madagascar*	5	5	5
Sri Lanka	2	2	2

***Source :** BGS, World Mineral Production,2015-2019.*
c: Years ended 30 June of that stated.
d: Years ended 31 March following that stated
** : Estimated*

FOREIGN TRADE

Exports

Exports of titanium ores & conc. decreased drastically by 32% to 0.25 million tonnes during the current year from 0.36 million tonnes in the preceding year. Exports were mainly to China (35%), Japan (29%), Republic of Korea (18%), Belgium (16%) and Malaysia (1%). Out of the total exports in 2019-20, the contribution of ilmenite was 0.25 million tonnes, rutile 16 tonnes and others 8 tonnes.

Exports of titanium and alloys (including waste & scrap) were at 492 tonnes, registering an increase of 54% from 319 tonnes in the previous year. Exports were mainly to Russia (26%), USA (24%) and Republic of Korea (20%) and UK (3%). Exports of titanium oxide and dioxide (total) increased marginally by 4 % to 38,512 tonnes in 2019-20 from 37,089 tonnes in the preceding year. Out of the total exports in 2019-20, those of titanium dioxide were 6,235 tonnes (16%) and exports of titanium oxides (other than titanium dioxides) were 32,277 tonnes (84%) (Tables-11 to 18).

Imports

Imports of titanium ores & conc. increased drastically by 42% to 1,38,044 tonnes in 2019-20

from 97,307 tonnes in the preceding year. Imports were mainly from Mozambique (66%), Norway (11%), Australia (4%) and Sri Lanka, China & Thailand (3% each). Out of the total imports of titanium ores & conc. in 2019-20, those of ilmenite were 1,09,771 tonnes, rutile 20,590 tonnes and other titanium ores were 7,683 tonnes.

Imports of titanium and alloys (including waste & scrap) were 8,348 tonnes in 2019-20 as compared to 7,657 tonnes in the previous year. Imports were mainly from USA (29%), China (17%), Japan (13%) and Singapore (9%). Imports of titanium oxide and dioxide (total) were 16,591 tonnes in 2019-20 as compared to 14,649 tonnes in the preceding year. Imports were mainly from Republic of Korea (38%), China (33%), Netherland (11%) and Japan (5%). Bulk of these imports were of titanium dioxide (16,416 tonnes) and titanium oxides (other than titanium oxides) were 175 tonnes in 2019-20 (Tables - 19 to 26).

Table – 11 : Exports of Titanium Ores & Conc. (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**359974**	**6566846**	**246203**	**4995764**
Japan	77735	2075944	71337	2407794
China	163924	2264780	87300	1166713
Korea, Rep. of	44025	593918	44000	579319
Belgium	23078	513058	40000	525768
Malaysia	15122	494640	3484	311364
Bangladesh	20	1457	24	1041
UK	-	-	7	829
Brazil	-	-	7	812
Cyprus	13	1266	5	610
UAE	1	139	9	408
Other countries	36056	621644	31	1106

Figures rounded off

Table – 12 : Exports of Titanium Ores & Conc. (Ilmenite) (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**358027**	**6438829**	**246179**	**4992946**
Japan	77715	2074615	71337	2407794
China	162916	2209240	87300	1166713
Korea, Rep. of	44000	592301	44000	579319
Belgium	22902	499955	40000	525768
Malaysia	15122	494640	3484	311364
Bangladesh	6	232	24	1041
Kenya	2	37	14	323
Qatar	-	-	7	186
UAE	-	-	7	166
Taiwan	-	-	5	141
Other countries	35364	567810	1	131

Figures rounded off

Table – 13 : Exports of Titanium Ores & Conc. (Rutile) (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**1847**	**120257**	**16**	**2001**
UK	-	-	7	829
Cyprus	13	1266	5	610
Pakistan	44	3672	2	296
UAE	1	139	2	242
Egypt	11	882	++	23
Nepal	-	-	++	++
China	1008	55540	-	-
Iran	268	23271	-	-
Netherlands	196	13965	-	-
Belgium	78	5422	-	-
Other countries	228	16102	-	-

Figures rounded off

Table – 14 : Exports of Titanium Ores & Conc. (Others) (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**100**	**7759**	**8**	**817**
Brazil	-	-	7	812
Sri Lanka	-	-	1	5
Belgium	98	7681	-	-
Indonesia	1	51	-	-
Nepal	1	17	-	-
Malawi	1	11	-	-

Figures rounded off

Table – 15 : Exports of Titanium & Alloys (Incl. Waste & Scrap) (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**319**	**272937**	**492**	**546043**
Russia	-	-	128	204663
Korea, Rep. of	27	26477	99	86285
Israel	++	8860	1	44101
USA	109	110276	116	29685
Malaysia	22	8658	3	20262
France	2	19873	3	17284
Turkey	++	212	3	16499
Egypt	++	2051	3	14534
China	51	11564	11	14093
UK	59	15159	15	12934
Other countries	48	69807	110	85702

Figures rounded off

Table – 16 : Exports of Titanium Oxide & Dioxide : Total (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**37089**	**3255387**	**38512**	**3779067**
Japan	27277	1941610	30540	2612449
USA	2745	479320	2270	377398
Italy	1200	226773	1032	186369
Malaysia	868	53761	2268	181340
Spain	518	72809	420	73139
Egypt	147	37321	186	56134
Iran	19	5387	138	37777
Indonesia	323	52183	164	28718
UAE	156	29328	179	27687
Sri Lanka	159	28176	160	26764
Other countries	3677	328718	1155	171292

Figures rounded off

Table – 17 : Exports of Titanium Dioxide (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**7345**	**1274279**	**6235**	**1065354**
USA	2637	470891	2250	375637
Italy	1200	226773	1032	186369
Japan	1117	180384	1122	161844
Spain	518	72742	420	73139
Iran	19	5387	138	37777
Indonesia	322	51914	164	28471
UAE	156	29328	178	27619
Nepal	63	13722	123	24631
Sri Lanka	159	28107	121	20909
Egypt	100	14901	96	15661
Other countries	1053	180129	592	113297

Figures rounded off

Table – 18 : Exports of Titanium Oxide (Other than Titanium Dioxide) (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**29744**	**1981107**	**32277**	**2713713**
Japan	26160	1761227	29418	2450605
Malaysia	868	53761	2268	181335
Egypt	47	22420	90	40474
Brazil	481	28581	146	9673
Turkey	5	975	75	5968
Sri Lanka	++	69	39	5854
Canada	40	2327	100	5672
Mexico	++	6	20	3638
Tanzania	--	--	31	2228
USA	108	8429	20	1761
Other countries	2036	103313	70	6504

Figures rounded off

Table – 19 : Imports of Titanium Ores & Conc. : Total (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**97307**	**3013233**	**138044**	**3965291**
Mozambique	60162	1090697	91132	1614268
Australia	11529	317145	4844	422284
China	8918	638679	4155	350068
Sri Lanka	2123	132345	4781	330562
Thailand	3100	202242	3483	237874
Norway	-	-	15538	229440
South Africa	3248	219736	2212	199534
Ukraine	1787	143201	1680	155318
Senegal	1820	89171	1840	126597
Netherlands	2306	101817	2533	88994
Other countries	2314	78200	5845	210351

Figures rounded off

Table – 20 : Imports of Titanium Ores & Conc. (Ilmenite) (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**70275**	**1250833**	**109771**	**1963148**
Mozambique	60084	1083791	91132	1614268
Norway	-	-	15538	229440
Sri Lanka	630	16349	1294	94928
Malaysia	169	2219	1710	20130
Vietnam	-	-	25	1874
China	-	-	20	1063
Sierra Leone	-	-	26	727
Netherlands	-	-	26	711
Brazil	-	-	++	6
Australia	9338	147292	-	-
Other countries	54	1182	-	-

Figures rounded off

Table – 21 : Imports of Titanium Ores & Conc. (Rutile) (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**20825**	**1500945**	**20590**	**1689191**
Australia	1307	111142	4224	372804
China	7579	554128	3199	275463
Thailand	3100	202242	3483	237874
Sri Lanka	1493	115996	2435	220132
South Africa	3248	219736	2212	199534
Ukraine	1621	132576	1652	152615
Senegal	1140	54375	860	59021
Netherlands	837	75916	646	56191
Vietnam	-	-	341	26232
USA	++	18	234	18905
Other countries	500	34816	1303	70421

Figures rounded off

Table – 22 : Imports of Titanium Ores & Conc. (Others) (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**6207**	**261456**	**7683**	**312951**
China	1339	84552	936	73541
Senegal	680	34796	980	67577
Australia	884	58710	620	49481
Netherlands	1469	25902	1861	32092
Taiwan	-	-	120	25461
Belgium	1502	26709	1373	23487
Sri Lanka	-	-	1052	15502
Vietnam	24	1247	219	13919
USA	-	-	491	8604
Ukraine	112	9486	28	2703
Other countries	197	20054	3	584

Figures rounded off

Table – 23 : Imports of Titanium & Alloys (Incl. Waste & Scrap) (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**7657**	**7031699**	**8348**	**7448532**
China	1375	1811839	1445	2130089
USA	1987	1377465	2448	1479857
Japan	987	1077137	1051	1119975
UK	215	668770	239	569578
Germany	207	480465	226	526619
Italy	320	246403	365	304898
France	90	344083	76	264565
Russia	50	113154	61	237541
Singapore	632	174173	742	177512
Korea, Rep. of	542	154187	699	146524
Other countries	1252	584022	996	491374

Figures rounded off

Table – 24 : Imports of Titanium Oxide & Dioxide : Total (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**14649**	**2907346**	**16591**	**3164189**
Korea, Rep. of	4820	818335	6350	991895
China	5970	1017189	5521	928826
Netherlands	694	181920	1780	443328
Japan	668	208853	838	252812
Germany	475	126788	571	161576
Belgium	1109	285154	566	139462
Taiwan	40	9870	200	49685
Canada	160	52658	129	42684
USA	97	40289	151	41728
Mexico	20	4502	140	34833
Other countries	596	161787	344	77360

Figures rounded off

Table – 25 : Imports of Titanium Dioxide (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**14546**	**2868635**	**16416**	**3082534**
Korea, Rep. of	4820	818335	6350	991895
China	5887	1000489	5464	916752
Netherlands	694	181920	1780	443324
Japan	661	204003	773	218107
Germany	474	121786	570	148788
Belgium	1108	284812	526	130055
Taiwan	40	9870	200	49685
Canada	160	52658	129	42684
Mexico	20	4502	140	34833
USA	97	38954	141	33956
Other countries	585	151305	342	72456

Figures rounded off

Table – 26 : Imports of Titanium Oxide (Other than Titanium Dioxide) (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**104**	**38711**	**175**	**81655**
Japan	7	4850	65	34705
Germany	1	5002	1	12788
China	83	16700	57	12074
Belgium	1	342	40	9407
USA	++	1335	10	7772
France	9	5740	1	3558
UK	1	610	++	751
Italy	-	-	1	285
Switzerland	++	43	++	203
Poland	++	37	++	108
Other countries	2	4052	++	4

Figures rounded off

FUTURE OUTLOOK

As per Technology Vision Document 2035, the demand for titanium in India would be approximately 1,000 tonnes by 2035. The contribution to the demand would be from Space Sector (100 tonnes), General Engineering (50 tonnes), Atomic Energy (125 tonnes), Aeronautical (50 tonnes), Power Generation (150 tonnes), Petroleum Refinery (50 tonnes) and Chemical Industry (475 tonnes).

As per data available, the defence, atomic energy and space research which are critical sectors have been assigned targets to increase communication set-up, safeguard India's security with modern arms, ammunitions & control and to increase power generation by three-fold. For meeting these targets, Indian Engineering Industry will dependent on input materials like titanium sponge. Titanium sponge was not available in India till 2012, the first ever commercially indigenously made Ti-sponge was released as late as 2013 at KMML, Kerala, with the support of ISRO. However, with the successful commissioning of the titanium sponge plant, India has joined the elite club of seven countries capable of producing aerospace -grade titanium sponge. The plant has the basic infrastructure for increasing the capacity to 1,000 tpa in future with sponge to metal yield at 35%, the requirement of titanium sponge on a conservative estimate would be 2,500 tpa for India. The gap, therefore, will remain and would have to be meet by import. The plant capacity now will be just sufficient to serve Strategic Industry like the indigenous space & defence programmes.

Global demand growth for TiO_2 is expected to trend with the prospects of economic growth and production of paint, paper and plastics.

Aerospace, defence and industrial uses are expected to strongly influence the consumption of titanium metal in the near future.

The impetus by the Government for renewal energy and infrastructure, however, augers well for demand for steel and that for IREL's rutile which finds application in production of welding electrodes.