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1. INTRODUCTION
HISTORICAL BACKGROUND

India is bestowed with its mineral deposits especially with a coastline of 6000 km. Heavy mineral deposits of Manavalakurichi in the state of Travancore (now Tamilnadu) was discovered by Schomberg, a German chemist in 1909 which was proved richer and economical compared to rest of the world.

Interestingly, Mineral sands then mined from rich seasonal Beach washings for only one mineral i.e. Monazite, which produce incandescence by infusing the paraffin mantle in a solution of thorium and cerium compounds, lost its worth due to arrival of filament lamp.

World War I gave the British an opportunity to seize the German-sponsored company and Schomberg was arrested and sent to Madras. The interest of monazite importers was ceased after 1920. First shipment of ilmenite from India was effected in 1922 and production expanded in 1940 contributing nearly 80% of the world production which is almost 300,000 tonnes. The Atomic Energy Commission was commissioned in 1948 by Govt. of India. Indian Rare Earths Limited was incorporated as a private company as a joint venture with the then Government of Travancore, Cochin in 1950 under the Indian Companies Act, 1913. IREL became a full-fledged Govt. undertaking under DAE in 1963. OSCOM was set up during 1972, construction had been started in 1975 and mining had been started in 1984. Accordingly IREL took over the assets of the closed mineral Operation Companies at Chavara and Manavalakurichi. Manavalakurichi plant come into the operation in 1968 and the Chavara plant in 1970. After a gap of 20 years, Accordingly IREL commissioned its largest Division called Odisha sand Complex (OSCOM) at Chatrapur, Odisha. Today IREL operates these four units and products/sells six heavy minerals namely ilmenite, rutile, zircon, monazite, sillimanite, and granite as well as various value added product.

Main objective of IREL is to emerge as a leading international player in the area of mining and separation of beach sand deposits to produce minerals as well as process value added products. It has mineral processing plants at Tamilnadu, Kerala, and Odisha, Rare Earths division at Kerala and Research center at Kollam, Kerala. Its corporate offices are in Mumbai, Maharashtra.

DISTRIBUTION OF HEAVY MINERALS IN INDIAN BEACH SAND DEPOSITS:

India is gifted with valuable resources of beach sand minerals. Indian coast-line along Kerala, Tamil Nadu, Odisha, and Andhra Pradesh where significant deposits of different minerals are available is presented below. The important economic minerals are such as -
Ilmenite (Fe₂O₃ TiO₂)
Rutile (TiO₂)
Monazite (Ce,La,Y,Th)PO₄ Garnet
Sillimanite (Al₂O₃·SiO₂) Zircon (ZrO₂·SiO₂)

Varying in size, concentration and grade ranging from 5% to 45%. So far estimated Indian resources of placer minerals are (Mir Azam Ali et al., 2001).

- 348 million tons (mt) of ilmenite
- 107 mt of garnet
- 21 mt of zircon
- 18 mt of rutile
- 130 mt of sillimanite

According to Rajamanickam et al. (2004), of the total global inferred reserves of 1775 million tonnes of placer minerals, India is bestowed with a reserve of:

1. 278 million tons of ilmenite
2. 13 million tons of rutile
3. 18 million tons of zircon
4. 07 million tons of monazite
5. 86 million tons of granite
6. 84 million tons of sillimanite

FACTORS CONTROLLING FORMATION OF BEACH SAND DEPOSITS:

Heavy mineral sands are a class of ore deposit which is an important source of rare earth elements and the industrial minerals such as diamond, sapphire, garnet, and other precious metals or gemstones. Placer deposits are formed usually in beach environments by concentration due to the specific gravity of the mineral grains. Heavy minerals (aside from gold placers) exist within streambeds, but most are relatively small and of a low grade. The grade of a heavy mineral sand ore deposit is usually low. Within the 21st century, the cut-off grades of heavy minerals, as a total heavy mineral (THM) concentrate from the raw sand, in most ore deposits of this type is around 1% heavy minerals, although several are of higher grade. Total heavy mineral concentrate (THM) components are typically for:
Zircon- 1% to 50% of THM,
Ilmenite- 10% to 60% of THM
Rutile- 5% to 25% of THM
Leucoxene- 1% to 10% of THM

Typically magnetite, Chromite, garnet which is trash minerals usually accounts the remaining bulk of the THM content.

The Beach sand minerals are most recently originated minerals deposits. These are originated in southern hemisphere due to continental drifts. Due to motion between different plates and repeated weathering i.e. heating and cooling, cracks are developed in between the rocks and water gets entered into these cracks. Parent rock is subjected to weathering and erosion and transferred along with sea water and finally sediment in a suitable basin. Continued erosion due to air and water takes place and concentration goes on increasing with time.

The source of heavy mineral sands is within the erosional areas of a river where the eroded minerals are dumped into the ocean, thereafter the sediments are caught up in littoral or long shore drift. Rocks are sometimes eroded directly by the wave action and washed up onto beaches and the lighter minerals are winnowed.

The source rocks determine the composition of the economic minerals. Usually granite is the source of zircon, Rutile, monazite, and some Ilmenite. The source of Ilmenite, garnet is ultramafic and mafic rocks, such as kimberlite or basalt. Garnet is sourced commonly from metamorphic rocks, such as amphibolite schists. Precious metals are generally sourced from deposits hosted within metamorphic rocks.

**MAJOR PRODUCERS OF BEACH SAND IN INDIA:**

1. Indian rare earth limited (IREL)
2. V.V Minerals
3. Beach Mineral Company
4. Transworld Garnet Sand
5. India Ocean Garnet Sand
6. Tata Iron & Steel Company (TISCO)
FACTORS CONTROLLING FORMATION OF BEACH PLACERS:

Some of the geological and geomorphological factors that control the concentration of heavy minerals along the Indian coast are as follows:

- **Geological control:** The physico-chemical behaviour of provenance rocks, i.e., igneous, metamorphic or sedimentary and the effect of various geological processes have played a vital role in contributing sediments to form a placer deposit.

- **Climatic Factor:** The climate of the region has a great role to play in decomposing and disintegrating the rock and mineral fragments that get liberated and concentrated. Tropical to sub-tropical climate promotes deep chemical weathering along coastal region. These conditions also favoured the formation of laterites that, in effect, is a process of pre-concentration.

- **Drainage Pattern:** The availability of young and youthful rivers and their high density, coupled with climatic factors, played a prominent role in the supply of material for concentration along favourable locales, especially along the Ghat section of Kerala and Tamil Nadu coasts. The rivers joining the Bay of Bengal on the east coast, however, have attained maturity and in many cases delta systems have developed; e.g. Mahanadi, Godavari, Krishna, Cauvery etc.

- **Coastal Processes:** Wave velocity, long shore currents and wind speed also have their effects in littoral transport, sorting and deposition of placer minerals. Emergence and submergence of the coast during geological past also affected the beach placer formation. Apart from these, numerous other factors that helped in the formation of these deposits are coastal geomorphology, neo-tectonics and continental shelf morphology.

FACTORS AFFECTING PLACER DEPOSITS:

TECHNO ACTIVITY:

- Uplift and tilting
- Faulting Including Block faulting coastal faulting
- Subsidence volcanicity
CLIMATE CHANGE:
- Arid and cold or warm
- Humid and hot or cold
- Cyclic Climatic Change

SEA-LEVEL CHANGE CAUSED BY ISOSTATIC AND EUSTATIC CHANGES AND BY CONTINENTAL DIPERAL & ATTRACTION
- Falling sea level
- Rising sea level

REGULATORY FRAMEWORK FOR EXPLOITATION OF DEPOSITS:
The exploitation of beach sand deposits and separation of heavy minerals are guided under various regulatory framework and statutory provisions as follows:


- Ilmenite, rutile, zircon, monazite & leucoxene (brown ilmenite) are defined as ‘Prescribed Substances’ under Atomic Energy Act, 1962. Necessary license and approvals are to be obtained from DAE before proceeding with the installations and operation of mining and mineral separation plant.

- Monazite is one of the constituent minerals in the beach sand placer deposit, which constitutes thorium and uranium and has a potential use for nuclear application. The beach placer deposits are located within 500 m from the high tide line (HTL) of the sea shore and covered under the Coastal Regulatory Zone (CRZ). Under the notification, the entrepreneurs have to obtain No Objection Certificate (NOC) from the State Pollution Control Board, Dept. of Environment of the State Govt. and also from MoEF, Govt. of India prior to the installation of plants within CRZ.

COASTAL ZONE REGULATION:
It is permissible to mine inside the Coastal Regulation Zone for “those rare minerals not available outside the Coastal Regulation areas”. The minerals to be mined in this leasehold fall in Schedule I of MM (R&D) Act 1987 and fulfill the condition prescribed for mining inside the Coastal Regulation Zone. Hence mining operations in this household will not be affected by Coastal Zone Regulations of Govt. of India.
HM Reserve (in million tonnes)

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<th>WORLD</th>
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<th>CHAVARA</th>
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<tr>
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<td>80</td>
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<td>0.9</td>
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<tr>
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<td>84</td>
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Production of IREL:

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<th>OSCOM</th>
<th>MANAVALAKURCHI</th>
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<td>90,000</td>
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<td>9,500</td>
<td>10,000</td>
<td>3,000</td>
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<td>ZIRCON</td>
<td>14,000</td>
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<td>SILLIMANITE</td>
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<tr>
<td>ZIRFLOR</td>
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MINE PLANNING ACTIVITIES;

Preliminary Investigation:
- Prospecting and Exploration
- Deposition evaluation
- Selection of Equipment
- Set Sequence of Operation
- Phased acquisition of land

Current Mining Activity:
- Guide operating personnel
- Dredge path planning
- Giving drilling data at closed intervals
- Map showing approach road, power lines, water lines etc.
- Monitor advance rate of dredge and depth of cutting
- Prepare production statistics
- Ensuring rehabilitation of mined out area
- Promotion of ecological aspects with the help of systematic plantation
SAND MINING POLICY:

- Mining leases are to be granted solely for the purpose of mining only.
- Mining leases will be granted only to those factories in the State in the joint sector which produce value added products.
- Proposals for establishing such factories as mentioned above shall be examined first by the Kerala State Industrial Development Corporation before placing it before the Council of Ministers for consideration.
- A study will be conducted by the Department of Mining and Geology and the Centre for Earth Science Studies jointly as to the quantum of mineral sand which could be mined in the area, and a report given to the Government. Anotification under the relevant statute will be issued prohibiting all future uses of lands bearing the mineral sand, for other purposes.
- Action will be taken to request Govt. of India for increasing the present loyalty of mineral sand.
- The eight blocks in the Chavara Barrier Beach area, at present earmarked for Kerala Minerals and Metals Limited and the Indian Rare Earths will not be leased out to any other applicants.

CLASSIFICATION OF MINERAL BASED ON THEIR PHYSICAL PROPERTIES:

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<th>CONDUCTING</th>
<th>MAGNETIC</th>
<th>SP. GRAVITY</th>
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<td>ILMENITE</td>
<td>MONAZITE</td>
</tr>
<tr>
<td>RUTILE</td>
<td>GARNET</td>
<td>ZIRCON</td>
</tr>
<tr>
<td></td>
<td>MONAZITE</td>
<td>ILMENITE</td>
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<tr>
<td></td>
<td>RUTILE</td>
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</tr>
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<td></td>
<td>GARNET</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SILLIMANITE</td>
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</tr>
</tbody>
</table>
INDIAN RARE EARTH LIMITED
- CHAVARA
- CHATRAPUR (OSCOM)
IREL Chavara, Kollam, Kerela

INTRODUCTION:

LOCATION:

The Chavara plant is located at about 19 km from the proposed area and 1.5 km from the NH 47, Kanyakumari- Salem Highway, and this is at 13 km from the district headquarters at Kollam and 80 km from the capital city, Trivandrum. It has all the infrastructural facilities for operating the mines and processing plant. Export of the minerals is through Neendakara Port, which is about 5 km from the plant & Cochin Port which is 130 km to the North of the IRE Plant.

Production Capacity:

The present production capacity of Chavara unit stands at 154000 tonnes of ilmenite, 9500 tonnes of rutile, 14000 tonnes of zircon and 7000 tonnes of sillimanite. In addition the plant has facilities for annual production of ground zircon (-45 micron). With a sales turnover of approx. Rs 105 crores and foreign exchange earning of over Rs 39 crores, this plant caters to the requirement of a host of advanced markets viz. USA, Japan & many others in addition to meeting the needs of domestic markets. Certification IRE Ltd., Chavara was certified to ISO 9002:1994 in September 2000. Subsequently the QMS system is upgraded to ISO 9001:2000 in March 2004. The company is also certified to ISO 14001:1996 in March 2004 which was upgraded to ISO 14001:2004 in June 2006. Later all systems were integrated and this integrated system was certified to OHSAS18001:1997.
IREL Chatrapur, Ganjam, Orissa (OSCOM)

INTRODUCTION:

On August 18th, 1950 Indian Rare Earths Limited (IREL) was incorporated as a private limited company, jointly owned by the Government of India and Government of Travancore, Cochin with the primary intention of taking up commercial scale processing of monaëte sand at its first unit namely Rare Earths Division (RED) Aluva, Kerala for the recovery of thorium.

After becoming a fully fledged Central Government Undertaking in 1963 under the administrative control of Department of Atomic Energy (DAE), IREL took over a number of private companies engaged in mining and separation of beach sand minerals in southern part of the country and established two more Divisions one at Chavara, Kerala and the other at Manavalakurichi (MK), Tamil Nadu.

After a gap of about 20 years, IREL commissioned its largest Division called Orissa Sand Complex (OSCOM) at Chatrapur, Ganjam, Odisha. Today IREL operates these units with Corporate Office in Mumbai and produces/sells six heavy minerals namely Ilmenite, Monazite, Sillimanite, Rutile, Zircon, and Garnet as well as various value added products.

OSCOM was commissioned at a place called Chatrapur about 150 Kms from Bhubaneswar and about 320 km from all weather seaports Visakhapatnam to exploit the huge placer deposit across a mining area of 24.64 km2 to produce 2,20,000 ton Ilmenite having 50% TiO2 content and associated minerals like Sillimanite, Rutile, Zircon, Garnet, etc. For the first time IREL ventured into dredging and concentration operation at OSCOM. It is quite efficiently engaged in dredging of the raw sand, its upgradation, drying and finally separation plant. Customers imported ilmenite primarily for the production of slag and sulphatable TiO2 pigment. From 1992, A Thorium plant is in operation at OSCOM to produce 240 tpa mantle grade Thorium Nitrate.

GEOLOGY OF THE DEPOSIT:

The OSCOM deposit formed along the coast is the largest of its kind in India with a length of about 18km and a width of about 1.5 km. The height of the deposit varies from a few 16 meters to 15m from the surface to water table. It is usually in the form of sand dunes and the concentration of heavy minerals is highest in the surface. The concentration gradually decreases with the increase of depth. The land is barren and devoid of vegetation except occasional growth of casuarinas trees which requires less water to grow in the saline.
environment. The sand deposit is less compact, free from over burden, clay or rock in the frontal dune area closer to the sea. However, the deposit away from the sea towards the land sometimes contains clay lenses and compact sand.

The origin of the deposit belongs to the parent rock types available in the eastern ghat and the Western Ghats Mountain ranges which contain these minerals in very low concentration to call for profitable extraction. The main source rocks are Khondalites, Charnokites, Gnesis, Granites, Laterites and Sandstones etc. When the source rocks are liberated from it and transported downward by running water and rivers. A tropical climate with heavy rainfall assists in the withering process. The liberated minerals transported downward are deposited at the seashore in an unsorted condition. The river Rushikulya acted as transportation agent for the heavy minerals and deposition in Bay of Bengal.

The actual sorting and concentration takes place due to the actions of two principal agents. A breaking wave takes all the foreshore minerals to the beach but the backwash carries only the lighter minerals back to the sea. Repeated action of waves results in sorting and the concentration of heavy minerals in beach placer deposit. After the concentration is over, action of the wind further enriches the concentration by blowing away the finer and the lighter sand particles. Statigraphically, the deposit is of recent age and its country rock belongs to Pleistocene age. No fault planes joints or geological disturbances are exciting in the deposit. For the purpose of evaluation and presentation of the deposit, the OSCOM deposit is divided into two sectors viz. south and north.

**Mining Lease Area:**

- 2877.76 Hectares (from 21.03.1979 to 20.03.1999)
- 2464.054 Hectares (from 21.03.1999 to 20.03.2019)

**HEAVY MINERAL RESERVE AT OSCOM:**

<table>
<thead>
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<th>MINERALS</th>
<th>RESERVE IN INDIA(MT)</th>
<th>RESERVE IN CHATRAPUR(MT)</th>
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<td>ILMENITE</td>
<td>348.15</td>
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<td>RUTILE</td>
<td>17.940</td>
<td>1.880</td>
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<td>21.120</td>
<td>1.440</td>
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<td>MONAZITE</td>
<td>7.990</td>
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<tr>
<td>SILLIMINITE</td>
<td>130.310</td>
<td>21.230</td>
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<td>GARNET</td>
<td>107.020</td>
<td>32.610</td>
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LOCATION:

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<th>DIRECTION</th>
<th>LATITUDE</th>
<th>LONGITUDE</th>
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<td>85°03’23”</td>
</tr>
<tr>
<td>Central position</td>
<td>19° 18’ 33”</td>
<td>84° 58’ 36”</td>
</tr>
<tr>
<td>Southwest</td>
<td>19° 15’ 38”</td>
<td>84° 55’ 00”</td>
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INFORMATION ABOUT OSCOM:

LOCATION:

Matikhalo village, Chatrapur taluka, Ganjam dist., Odisha state. (Lat. 19 Degree 16’ North, Long. 84 Degree 33’ East, Height about 17m)

WORKS TERRAIN:

Plain, Seashore

CLIMATIC CONDITION:

The Climatic Cond. pertaining to site are generally as Indicated Below;

- 14 Degree celcius
- 32.2 Degree celcius
- 16.6 Degree celcius
- 87% (May-June)
- 65% (Nov-Dec)

MEANWIND SPEED:

7 to 12 kms (Dec-Jan), 20 to 3 Kms (Apr-May). A supper Cyclone with a wind speed of 200 km per hour hit the IREL, OSMOS site on 17th Oct 1999

ANNUAL MAIN RAINFALL:

About 2010 mm having more than 80% rain fall during the months of June to October

SUSCEPTIBILITY TO EARTHQUAKE:

Falling under zone-2 as defined IN I : 1983. However an increased Horizontal seismic coefficient corresponding to zone-4 shall be used for design purposes

RAILWAYS:

The main board gaunge line of east coast Railway line connecting Kolkata and Chennai passes at a distance of 7 km from the boundary of the plant. The major railway station are
BBSR At a distance of about 22 km and Chatrapur at a distance of about 6 km. IREL has private broad gauge railway siding extending from Chatrapur railway station to exiting IREL plant.

**SEA PORT:**

Kolkata port I at a distance 550 km by road/rail vizag port I at a distance of 360 km by road/rail.

**AIRPORT:**

The nearest airport I at BBSR at a distance of 160 kms by Road. Flights are available to BBSR from Kolkata, Mumbai, Chennai and New Delhi.

The actual sorting and concentration takes place due to two principal agents. A breaking wave takes the foreshore minerals to the beach and the backwash carries the lighter minerals back to the sea. And this to and fro action of waves results in sorting and the concentration of heavy minerals in beach placer deposit. Action of the wind enriches the concentration by blowing the finer and the lighter sand particles. The OSCOM deposit can be classified into two sectors viz. south and north for the purpose of evaluation and presentation of the deposit.

**Mining Lease Area:**

2877.76 Hectares from 21/03/1979 to 20/03/1999 2464.054 Hectares from 21/03/1999 to 20/03/2019
<table>
<thead>
<tr>
<th>PROPERTIES</th>
<th>ILMENITE</th>
<th>RUTILE</th>
<th>ZIRCON</th>
<th>MONAZITE</th>
<th>GARNET</th>
<th>SILLIMANITE</th>
<th>THORIUM</th>
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<tr>
<td>Chemical Formula</td>
<td>FeTiO₃</td>
<td>TiO₂</td>
<td>ZrO₂SiO₂</td>
<td>(La₂Ce₂,Y₂)PO₄</td>
<td>A₁B₂(SiO₄)₃</td>
<td>Al₂O₃SiO₂</td>
<td>Th(NO₃)₄·5H₂O</td>
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**Chemical Composition (Typical)**

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<tr>
<td>CaO</td>
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<td>MgO</td>
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<td>ZrO₂</td>
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<td></td>
<td>65</td>
<td></td>
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<td>2.2</td>
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<tr>
<td>Th</td>
<td>42 ppm</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>U</td>
<td>&lt;3 ppm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>ThO₂</td>
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<tr>
<td>Acid Insolutes</td>
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<tr>
<td>Total Oxides</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>66.7</td>
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<tr>
<td>Impurities in product (max %)</td>
<td>Gar-1 Mon-0.1</td>
<td>Zir-1.5 Mon-0.3</td>
<td>Sill-2, Rut-0.5, Mon-0.3</td>
<td>Ilm-4.0</td>
<td>Qtz-4, Mon-0.3</td>
<td></td>
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</tr>
</tbody>
</table>

**Basic Unit Operation:**

The complete operation at Indian Rare Earths Ltd can be broadly classified as:

- Mining/Dredging & Preconcentration [Dredging & Wet Upgradation Plant (DWUP)]
- Heavy mineral Upgradation [Heavy Mineral Upgradation Plant (HUP)]
- Mineral separation [Mineral Separation Plant (MSP)]
Dredging and Wet Upgradation Plant (DWUP):

The OSCOM have a huge placer deposit with a length of 18 Kms and width of 1.5 Kms running parallel to the coast of Bay of Bengal. Northern boundary of the mining area is Rusikulya River and southern boundary is Gopalpur town. The estimated reserves are 230 MT (1.5m below MSL) and 440 MT (6m below MSL). Mining is divided in two sections; North section and South section. The whole mining area is classified in three zones; plenty zone, Intermediate zone and rare zone.

This plant is in complete floating condition. It floats in a pond having diameter 200m and depth of 6m. The whole unit can be divided in two groups:
1) Mining/dredging
2) Pre-concentration.

Mining:

The mining procedure followed for the excavation of beach sand is completely different from the surface or underground mining. The procedure followed is commonly known as DREDGING. Dredging can be defined as an excavation activity or operation which is carried out at partly underwater, in shallow depth of sea or fresh water areas with the purpose of gathering up bottom sediments and disposing of them at a different location. A dredge is a device used for dredging for scraping or sucking the seabed. A dredger is a boat or ship equipped with a dredge. The process of dredging creates wastes (excess material), which are conveyed to another location different from the dredged area. The dredge Capacity is about 500 TPH and dredge depth is nearly 6m. The RPM of the motor used is 368 with a power of 525KW. In OSCOM, There are two different types of dredge used for dredging purposes:

Cutter Suction Dredge:
A cutter-suction dredger's (CSD) suction tube has a cutter head at the suction inlet, used to loosen the earth and convey it to the suction mouth. The cutter can also be used for hard surface materials like gravels or rocks. The dredged material is usually sucked up by a wear resistant centrifugal pump which is discharged through a pipe line or to a barge. In recent years, in order to excavate harder rock without blasting, dredgers with more powerful cutters have been built.

Bucket wheel Dredge:
The bucket-wheel dredge is identical to the cutter suction dredge apart from 24 the position of wheel excavator which is used in lieu of the rotary cutter. In both the cases, the cutter attached to the ladder rotates and cuts the sand and thus make a suspension of sand in water which is pumped out to the Trommel.

Pre-concentration:

In this stage, the amount of heavies is upgraded up to 90%. Then it is sent to HUP for further treatment. The suspension formed by the dredger is pumped to the Trommel with aperture size is 4mm, which rotates at 6RPM with a motor power of 37KW. The undersize of the Trommel is sent to bins from where it is sent to the spirals for concentration and the oversize usually containing pebbles, grass and other waste materials. In spirals 4-stage of cleaning takes place i.e. Rougher, Cleaner, Recleaner and Scavenger. Each spiral with 144 starts and each used at 2TPH and the total capacity is 576 TPH. Concentrate from the rougher spirals is sent to cleaner spirals, middlings to Scavenger spirals and tailings to the Hydrocyclone from where the overflow (water) is sent to Trommel discharge and the underflow is the rejects (sand) which is thrown for back filling of the pits. Cleaner concentrate is sent to Recleaner, middlings is recirculated and tailings to the scavenger. Recleaner concentrate is final concentrate which is sent to HUP (Heavy Upgradation Plant),
middlings is recirculated and tailings are sent to cleaner. The scavenger concentrate is sent to cleaner circuit, middlings is recirculated and tailings are sent to Hydrocyclone. By this process the amount of heavies are improved to 90-92%

**Heavy Upgradation Plant (HUP):**

This is the stage where the concentration of heavy is further upgraded to 98%. The feed to HUP plant is the Recleaner concentrate of the DWUP where heavy minerals concentration is 90-92%. The heavy minerals are received from Dredge and Wet upgradation plant (DWUP) at the Re-pulping area of Mineral Separation Plant (MSP). These materials are pumped for upgradation in heavy Upgradation Plant (HUP) at MSP. When HUP is not in operation the material is stockpiled at RPA. These accumulated heavies are pushed for pumping to HUP be the help of Earth Moving Equipments (EMEs) whenever required. In HUP, the feed is treated in gravity separation equipment like spirals and Hydrocyclones and the unwanted lighter material is pumped to reject dumping yard and the upgraded heavy mineral is pumped to the dry feed yard through hydrocyclones for natural dewatering and finally it is fed to main plant By EMEs for drying and further separation.

**Mineral Separation Plant (MSP):**

In the mineral separation plant (MSP), the heavy minerals like Ilmenite, Rutile, monazite, zircon and Sillimanite are separated from the upgraded feed minerals on the basis of their physical properties like electrostatic & magnetic property, surface characteristics and specific gravity. The plant comprised of different floor and equipped with different material handling equipment like bucket elevators, belt conveyors, screw conveyors, drag conveyors to facilitate smooth transport of materials to the desired machines for example Rotary Dryer, High tension separators, Magnetic separators, Shaft dryers, Electrostatic Separators etc. Beside this, there is a wet processing circuit which comprises of Spirals, Floatex, Wet Tables, Flotation cells etc and Slurry Pumps are used to transport materials from one point to another.

**Annual Production Capacity of MSP:-**

Ilmenite: 220000 TPA  
Rutile: 7400 TPA  
Zircon: 5000 TPA  
Sillimanite: 8000 TPA  
Monazite: 2350 TPA
MONAZITE PROCESSING PLANT (MoPP).
MONAZITE:

Monazite is a reddish-brown phosphate mineral containing rare earth metals. It occurs usually in small isolated crystals. It has a hardness of 5.0 to 5.5 on the Mohs scale of mineral hardness and is relatively dense, about 4.6 to 5.7 g/cm³. There are at least four different kinds of monazite, depending on relative elemental composition of the mineral;

- Monazite-(Ce), (Ce,La,Nd,Th)PO₄ (the most common member),
- Monazite-(La), (La,Ce,Nd)PO₄,
- Monazite-(Nd),(Nd,La,Ce)PO₄,
- Monazite-(Sm),(Sm,Gd,Ce,Th)PO₄.

The elements in parentheses are listed in the order of their relative proportion within the mineral; lanthanum is the most common rare earth element in monazite-(La), and so forth. Silica (SiO₂) is present in the trace amounts, as well as small amounts of uranium and thorium. Due to the alpha decay of thorium and uranium, monazite contains a significant amount of helium, which can be extracted by heating.

Monazite is an important ore for thorium, lanthanum, and cerium. It is often found in placer deposits. India, Madagascar, and South Africa have large deposits of monazite sands. The deposits in India are particularly rich in monazite.

Monazite is radioactive due to the presence of thorium and, less commonly, uranium. Because of its radioactive nature, monazite is used for monazite geochronology to study geological events, such as crystallization, heating, or deformation of the rocks containing monazite.

MINERALISATION EXTRACTION:

Because of their high density, monazite minerals concentrate in alluvial sands when released by the weathering of pegmatites. These so-called placer deposits are often beach or fossil beach sands and contain other heavy minerals of commercial interest such as zircon and ilmenite. Monazite can be isolated as a nearly pure concentrate by the use of gravity, magnetic, and electrostatic separation.

Monazite sand deposits are inevitably of the monazite-(Ce) composition. Typically, the lanthanides in such monazites contain about 45–48% cerium, about 24% lanthanum, about 17% neodymium, about 5% praseodymium, and minor quantities of samarium, gadolinium, and yttrium. Europium concentrations tend to be low, about 0.05%. South African "rock" monazite, from Steenkampskraal, was processed in the 1950s and early 1960s by the Lindsay Chemical Division of American Potash and Chemical Corporation, at the time the largest producer of
lanthanides in the world. Steenkampskraal monazite provided a supply of the complete set of lanthanides. Very low concentrations of the heaviest lanthanides in monazite justified the term "rare" earth for these elements, with prices to match. Thorium content of monazite is variable and sometimes can be up to 20–30%. Monazite from certain carbonatites or from Bolivian tin ore veins is essentially thorium-free. However, commercial monazite sands typically contain between 6 and 12% thorium oxide.

MONAZITE-(Ce)

(MONAZITE POWDER)
ACID CRACKING:

The original process for "cracking" monazite so as to extract the thorium and lanthanide content was to heat it with concentrated sulfuric acid to temperatures between 120 and 150 °C for several hours. Variations in the ratio of acid to ore, the extent of heating, and the extent to which water was added afterwards led to several different processes to separate thorium from the lanthanides. One of the processes caused the thorium to precipitate out as a phosphate or pyrophosphate in crude form, leaving a solution of lanthanide sulfates, from which the lanthanides could be easily precipitated as a double sodium sulfate. The acid methods led to the generation of considerable acid waste, and loss of the phosphate content of the ore.

ALKALINE CRACKING:

A more recent process uses hot sodium hydroxide solution (73%) at about 140 °C. This process allows the valuable phosphate content of the ore to be recovered as crystalline trisodium phosphate. The lanthanide or thorium hydroxide mixture can be treated with hydrochloric acid to provide a solution of lanthanide chlorides, and an insoluble sludge of the less-basic thorium hydroxide.
EXTRACTION OF RARE-EARTH METALS FROM MONAZITE ORE:

(Process flow diagram for extraction of rare-earth metals from monazite ore using hydrometallurgy)

The following steps detail the extraction of rare-earth metals from monazite ore. The process requires many neutralizations and filtrations;

- **Grinder:** Grind monazite ore to ~150 micrometers. Monazite ore contains 55–60% rare-earth metal oxides along with 24 to 29% P2O5, 5 to 10% ThO2, and 0.2 to 0.4% U3O8.

- **Digestion:** Crushed monazite is mixed with highly concentrated sulfuric acid (93% acid) at feed temperatures of 150 to 180 °C. The ratio of acid to ore varies depending on the
concentration of the ore (unable to find ratio range). The digester is stirred vigorously with a robust agitator and operates at temperatures between 200 to 300 °C. Acid is charged into the reactor and heated before the ore. The insoluble product coats the grains of crushed ore. The temperature in the reactor rises due to heat released from the exothermic reactions. After ~15 minutes, the viscosity of the solution has increased and the solution is similar to a dough. The product reacts for 3 to 4 hours. It is then removed from the digester before the solution hardens. The ratio of sulfuric acid to sand removed is 1.6 to 2.5.

- **Dissolution**: The contents of the reactor are cooled to 70 °C and leached with 30 °C water. A ratio of 10 parts water to mass of ore originally added is used. This leaching process continues for 12 to 15 hours.

- **Filtration**: All solids from step three are filtered off. Such solids include: silica, rutile, zircon, ilmenite, and undigested monazite residues. The resulting solution is called monazite sulfate.

- **Dilution**: Diluted the monazite sulfate with 6–7 parts water at 30°C.

- **Neutralization**: Add NH₃(aq) to neutralize to a pH of 1.1 to form a selective precipitate of thorium-phosphate cake.

- **Filtration**: Collect thorium phosphate precipitate during filtration of neutralized monazite solution. Extraction of rare-earth metals from monazite ore

- **Dryer**: Feed thorium-phosphate cake through a dryer at ~120 °C to create concentrated thorium phosphate.

- **Neutralization**: Add NH₃(aq) to remaining monazite solution to create rare-earth-metal precipitate at a pH of 2.3.

- **Filtration**: Filtrate out the RE precipitate to yield the concentrated rare-earth metal hydroxides.

- **Neutralization**: Add NH₃(aq) to remaining filtrate to a pH of 6. This creates a uranium concentrated precipitate.

- **Filtration**: Filter remaining solution to yield uranium concentrate. The final products yielded for this process are thorium-phosphate concentrate, RE hydroxides, and uranium concentrate.
# Latest Scenario in Rare Earth and Atomic Minerals in India:

## Major Minerals of RE of Commercial Importance

<table>
<thead>
<tr>
<th>Minerals</th>
<th>Chemical Formula</th>
<th>Countries of Origin</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonate</td>
<td></td>
<td>USA, China &amp; Australia</td>
<td>Processing relatively simpler than Monazite. It has larger content of Europium compared to Monazite. In China it is associated with iron ore mining.</td>
</tr>
<tr>
<td>Bastnaesite</td>
<td>(Ce,La) FCO₃</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phosphate</td>
<td></td>
<td>Australia, India, Malaysia, Brazil, Thailand &amp; Korea</td>
<td>EG content more or less uniform around 60% and minerals available in placer beach sand resources. The ore contains Th &amp; Uranium are radioactive.</td>
</tr>
<tr>
<td>Monazite</td>
<td>(Ce,La,Th&amp; U) PO₄</td>
<td>Malaysia, India, China</td>
<td>Yttrium major constituent. In Malaysia production is associated with Tin mining.</td>
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<tr>
<td>Xenotime</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Apatite</td>
<td></td>
<td>CIS, South Africa</td>
<td>Occures in Copper, Tin, Phosphate mining</td>
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<tr>
<td>Ion Exchange clay</td>
<td></td>
<td>China</td>
<td>Unique deposits found only in southern China. Through lowest in rare earth contents easiest to concentrate from the ore. Rich source of Y, Eu, Tb &amp; Dy.</td>
</tr>
<tr>
<td>Ion Exchange clay</td>
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</table>
MONAZITE PROCESSING PLANT AT INDIAN RARE EARTH LIMITED:

Entire phosphate values are recovered in caustic soda process
The plant at which different types of products are obtained from monazite, is known as monazite processing plant. Again the monazite processing plant is divided into three plants, such as:

![Diagram]

MoPP
- ATTACK PLANT
- ACTIVE PLANT
- NTP PLANT

These three plants are interdependent upon each other, i.e. the products of Attack plant goes to the Active plant for processing and products are obtained, again these products are fed to the NTP plant and the products are obtained. In this process the products are obtained at MoPP are are export to the outside for sale.

**ATTACK PLANT:**

Generally the plant name is attack plant because in this plant the attack of Monazite and Caustic Soda (NaOH) occurs and the operating temperature is 140°C. The attack is done in a 16 m³ reaction tank. For this attack the ratio of Monazite and NaOH is chosen is 10:8, i.e. in this process the amount of Monazite dust chosen is 10 tonne and the amount of Caustic Soda is 8 tonne. At IREL the NaOH is import from Jay Shree Chemicals, Berhampur. The reaction of monazite and caustic soda occurs in the reaction tank for 9 hrs. After the complete operation two products are obtained at the end of attack plant operation such as; MH Slurry (Mixed Hydrochloride Slurry) and TSP (Tri Sodium Phosphate).
At first monazite sand is fed to the feed hopper then it passes through different belt, screw and bucket conveyor for the purpose of transport. The size of monazite is reduced in the ball mill. Then it crushed monazite particles passes through classifier and also several cyclone separators. After the separation in the cyclone separator the monazite is distributed among four reaction tanks. Such as R-101(A), R-101 (B), R-101(C), R-101 (D). These R-101 tanks are reaction tanks which contains agitator for proper mixing purpose. The size of these tanks are 16 m³. In these reaction tanks the mixing of monazite and caustic soda (NaOH) occurs and for this type of attack the operating temperature is taken as 140°C. The quantity of monazite and NaOH is taken in the ratio 10:8 or 1:0.8 i.e if the amount of monazite is taken 10 tonne then the amount of NaOH is taken as 8 tonne. To get proper product the ratio should be exactly taken. This reaction of Mo and NaOH is done for 9 hours. After the attack the product from the reaction tank goes to the distributor tank. Then it is distributed among different leaching tanks such as T-104(A), T-104(B), T-104(C), T-104(D), T-104(E), T-104(F), T-104(G). The tanks R-101(A) and R-101(B) are connected with T-104(A), T-104(B), T-104(C) and the tanks R-101(C) and R-101(D) are connected with the rest leaching tanks. The leaching operation is done for 20 hours. When the leaching operation is done after 1st settling from tank T-104(A), T-104(D), T-104(E), T-104(F) MH Slurry is obtained. Then 2nd settling is done. In this second settling spillage water or hot water is added with the MH Slurry. After the 2nd settling is completely done final product of attack plant which is the MH slurry is formed. This MH Slurry is supplied to the Active plant. In the other case when the 1st leaching operation is done from tank T-104(B), T-104(C) after 1st decant TSP Solution is formed and stored in the tank T-106. 100-150 kg of sodium sulphate is added with TSP solution and the mixing time is 8-10 hours, then it goes to T-107. From T-107 the TSP Solution goes to the crystallizer. In crystallizer the operating temperature is maintained 23-25°C. Then the crystals send to tank T-108 and then to the centrifuge. Then it goes to the cyclone separator. After the end of this operation Tri Sodium Phosphate (TSP) is formed. In IREL the TSP powders are packed and are transported for sale. So in attack plant two types of products are obtained such as; MH slurry and TSP (Tri Sodium Phosphate). From these two products of attack plant one product is transported for sale which is the Tri Sodium Phosphate and the another one which is the MH slurry is used as the feed for Active plant. Again this MH slurry is processed in the active plant to produce other products.

**ACTIVE PLANT:**

Generally in the active plant the MH slurry which is the product of attack plant, is used as the feed. After all the processes are over, three types of products are obtained such as; RE (Rare Earth), Cake, Alamine circuit.
Thorium & rare earths hydroxide cake

1. Leaching tank
2. Filter
3. Deactivation tank
4. Drum filter
5. Evaporator
6. Flaker
7. Jumbo bag

Hydrochloric acid

pH 3
70°C

Slurry

Thorium hydroxide cake

RECl₃ soln.

Na₂S
Na₂SO₄
BaCl₂

Slurry

For R.E. fractionation by solvent extraction,
R.E.F. production, R.E.O. Production & Hydrated cerium oxide production.

Pb-Ba-cake for disposal

ReCl₃ Flake
MH SLURRY

TANKS A/B
STORAGE TANK

FILTER PRESS
(PLATE AND FRAME)

Filtrate recycled to the attack plant and cakes to the tanks

CAKE OF FILTER PRESS + REGENERATED ACID = SLURRY

RE EXTRACTION TANK + 30% HCl + FeCl₂
(pH 2.8 to 3.0)

FILTER PRESS

FILTRATE

NORMAL RE Chloride TANK

RE TANK DEACTIVATION + MgSO₄ + BaCl₂ + Na₂S

RE TO SELL

CAKE + WATER

THORIUM DISSOLUTION TANK + HCl

FILTER PRESS

CAKE TRANSFER

FILTRATE

ALAMINE CIRCUIT
At first MH slurry is taken as the feed in the active plant, then it goes to the storage tanks A/B. The slurry from the storage tank goes to filter press. Then the filtrate recycled to the attack plant and the cakes are recycled to tanks. The cake filter press is mixed with the regenerated acid and a slurry is formed. Then the slurry goes to the Rare Earth (RE) Extraction tank. In thin RE Extraction tank the slurry is mixed with 30% HCL, FeCl₂ and the pH is maintained from 2.8 to 3.0. Then it goes to the filter press. From this filter press filtrate and cakes are formed. The filtrate is sent to the normal RE Chloride tank and then it is sent to the RE deactivation tank. In this RE deactivation tank MgSO₄, BaCl₂ and Na₂S are added. Then at last Rare Earth (RE) is produced. In the other case water is added to the cake and then it goes to the thorium dissolution tanks. In this thorium dissolution tank HCL is added. Then it goes to the filter press. Cake and filtrate are produced from this filter press. At last Alamine Circuits are produced from the filtrate.

**NTP:**

The final products of the active plant are feed for the NTP. Generally the products of the active plant such as uranium and thorium are used as the feed for the NTP. Again the NTP is divided into two plants such as Uranium plant and Thorium plant. In the Uranium plant pure
uranium and in the Thorium plant pure thorium is produced. In these two plants solvent extraction process is used.

(URANIUM PLANT)

In the Uranium plant the iron and uranium mixture is mixed with Na₂CO₃. Then iron hydroxide and uranyl carbonate are produced. But iron hydroxide is soluble and uranyl
carbonate is insoluble. Both the products are mixed and then are sent to filter. From the filter iron cake and filtrate with high carbonate are produced. Then the filtrate high carbonate is mixed with NaOH and then mixed with Na₂Cl₂O₇ and HNO₃ dissolution. Then uranyl nitrate is produced and after solvent extraction raffinate and pure solution are obtained. The pure solution is then mixed with NH₃ and at last the final product of the uranium plant which is (NH₄)₂U₂O₇ produced. This product is known as Nuclear Ammonium Diuranium (NADU).
In Thorium Plant the thorium oxalate is mixed with NaOH and Th(OH)₄ cake is formed. Then the cake is mixed with Na₂C₂O₇ and HNO₃. Then 40% TSP (Tri Sodium Phosphate) is produced. After solvent extraction raffinate and phosphate solution are produced. Then it is sent to the evaporator. After evaporation it is again sent to the crystallizer. Then Th(NO₃)₄ crystals are formed. These crystals are sent to the centrifuge and at last Thorium is produced.

**EQUIPMENTS USED IN MoPP:**

There are so many types of equipments used in the monazite processing plant. Such as belt conveyor, screw conveyor, bucket conveyor, cyclone separator, agitator, evaporator, crystallizer, filter press and centrifuge etc.

**BELT CONVEYOR:**

![Image of belt conveyor](image-url)

The belt conveyors are used in the plant for the purpose of transport only. By the help of this conveyors the the materials are transported from one place to another. By using these types of conveyors the transportation cost is reduced. The belt conveyor contain two pulleys in which one is driver pulley and the other one is driven pulley. The pulleys are connected with a belt. When the pulley rotates, the belt also moves. The materials which are going to transport are put on the belt. When the belt moves the materials are transported. The loaded belt is supported during its carrying run by closely spaced rollers, known as idlers.
SCREW CONVEYOR:

The screw conveyors are also used for the purpose of transportation of material. It is used only for the transport of materials in the horizontal direction. It contains a electric motor and a screw or spiral flight mounted on a shaft. The feed is fed to this conveyor in one side. When the motor shaft rotates, the materials are transported from one region to another.

BUCKET CONVEYOR:
The bucket conveyors are also used for the transportation of materials only in vertical direction. This conveyor contains number of buckets which are connected with two pulleys. From these two pulleys one is driver and another is driven pulley. For the vertical transportation of materials the bucket conveyors are used.

**CYCLONE SEPARATOR:**

![Image of a cyclone separator](image)

By the help of a cyclone separator the separation of a particle from an air, gas or liquid is done. In this separation no filters are used. It is otherwise known as cyclones. Cyclones consist of a cylindrical section at the top and a conical section at the bottom. The dust-laden enters to the cylindrical section through the inlet pipe at the top, tangentially at a high velocity of about 30 m/s. The gas then moves downward in a helical motion, forming a peripheral vortex inside the cylindrical chamber. The dust particles gain centrifugal forces and are thrown towards the wall, which then moves downward and are discharged from the bottom outlet. While the dust-free gas, after reaching the bottom changes direction and follows a smaller diameter rotating path back towards the top against gravity. The outlet section has a downward extending pipe, known as vortex finder, projected below the gas inlet pipe to cut the vortex and to prevent short-circuiting of the gas streams.
AGITATOR:

The agitator is used for proper mixing purposes. It contains blades at the lower end which connect with a motor with a shaft. When the motor shaft rotates, the blade also rotates. Generally agitators are connected with tanks. The tank contains solid and liquid mass, by the help of the agitator slurry is produced.

EVAPORATOR:

Evaporator is a device in a process used to turn the liquid form of a chemical substance such as water into its gaseous form/vapour. The liquid is evaporated or vaporized, into a gas form of the targeted substance in that process.
**CRYSSTALLISER:**

The crystallizer is an equipment by which a solid or crystals are formed. Where the atoms and molecules are highly organized into a structure, is known as crystals.

**FILTER PRESS:**

An industrial filter press is a tool used in separation process, specifically to separate the solid and liquids.
CENTRIFUGE:

A centrifuge is a piece of equipment that puts an object in rotation around a fixed axis, applying a force perpendicular to the axis of spin that can be very strong. The centrifuge works using the sedimentation principle, where the centrifugal acceleration causes denser substances and particles to move outward in the radial direction. At the same time, objects that are less dense are displaced and move to the centre. The radial acceleration causes denser particles to settle to the bottom of the tube, while low density substance rise to the top.

USES AND APPLICATIONS OF HEAVY MINERALS:

(HEAVY MINERALS)
Ilmenite & Rutile:


As Titanium (Ti) sponge/metal: Used in Chemical industry, Aerospace & Aviation industry, Surgical equipments, Electrical turbines tubing, Bullet proof vests, Different alloys in Iron & steel industry, Immersion heater tubes, Consumer goods, Spectacle frames, Golf clubs. Used for coating of welding electrodes.

Zircon:

Used in Ceramics, Foundries, Refractories, Glazing tiles, Television and Computer monitors and White wars. It is also used in manufacture of Zirconium chemicals/metal, American diamond, Scratch free bracelets, Cutting tools, Yttria Zirconia as oxygen sensors. Zircon free from Hafnium is used in nuclear reactors as cladding tubes to hold nuclear fuel.
SILLIMANITE:

Mainly used for the manufacture of High grade refractory bricks, high Alumina Refractories, Cement kilns and Heat treatment furnaces.

Garnet:

Used for manufacture of Blasting media, Abrasives, Grinding wheels, Mosaic cutting stones, Decorative wall plasters, Ceramics, Polishing of picture tubes, Glass polishing & Antiskid surface for roads, air strips, runways, water filter, water jet cutting, Artificial Granite tiles/Heavy duty floor tiles, cleaning of casings/pipes in petroleum industry and as a gemstone.
Monazite:

Extraction of thorium concentrate and rare earth compounds.
THANK YOU