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(Part- I : GENERAL REVIEWS)

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RESEARCH & DEVELOPMENT

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GOVERNMENT OF INDIA
MINISTRY OF MINES
INDIAN BUREAU OF MINES

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5 Research & Development

Recognising the paramount importance of safety, economy, speed and the efficiency in extraction of mineral resources and its convergence into viable economic alloys and metals, National Mineral Policy (NMP), 2019 has accorded higher priority to Research & Development (R&D) programmes. With a view to promote R & D in the Mining Sector, Ministry of Mines has launched a comprehensive Science & Technology Programme which includes R&D component.

The underlying principle behind R&D component of Science and Technology (S&T) programmes is to foster utilisation of the available mineral resources judiciously, economically, efficiently in an sustainable manner. Under the R&D component of the S&T Programme, Research projects are funded through grant-in-aid by Ministry of Mines. The broad thrust areas for supporting research in Mining Sector include (i) Prospecting exploration for strategic and rare earth minerals; (ii) Mining methods; (iii) Improve efficiency in process, operations, recovery of by-products and reduction in specification and consumption norms; (iv) Metallurgy and mineral beneficiation techniques to utilise lower grade and finer size ores; (v) Extraction of value added products from mine waste, plant tailings, etc.; (vi) Development of new alloys and metal related products, etc.; (vii) Evolve low capital and energy saving processing systems; and (viii) Production of materials of high purity.

Based on scrutiny which passes through different stages of evaluation including presentation of shortlisted projects before the Project Evaluation and Review Committee (PERC) and final approval of an inter-ministerial Standing Scientific Advisory Group (SSAG), grants are given to the projects submitted by R&D institutions.

During the 19th PERC meeting held on 06-07th August 2019 at JNARDDC, Nagpur, a total of 130 project proposals, as received under S&T Program Scheme of Ministry of Mines for the year 2019-20, were screened. After screening, 30 proposals covering five areas, namely (i) Geosciences and Exploration; (ii) Mining; (iii) Mineral Processing & recovery from waste; (iv) Metal Extraction (Metallurgical processes); and (v) Alloys, specialty materials and product; were shortlisted for further presentation by the respective Principal Investigators (PIs). In addition to the above, three projects as recommended by the 18th PERC for resubmission, 14 completed projects and 4 ongoing projects were also reviewed by the committee. Based on the detailed review and evaluation, the PERC recommended 11 (Eleven) Project Proposals with or without changes to SSAG. The PERC also recommended for acceptance of 13 final reports and reviewed 4 ongoing projects.

The projects recommended by the PERC were further considered during 51st meeting of the SSAG held on 17th September 2019 at New Delhi. After detailed deliberation, SSAG approved 10 project proposals without any change and one project with modifications/remarks for the year 2019-20 (Table-1).

The final report of the 13 projects was considered by the SSAG (Table-2). After deliberation, the SSAG accepted the final report and approved the closure of project subject to finalisation of accounts and other relevant procedures. Based on request of PI, SSAG approved to extend the period of project on "Rare-earth mineral concentration in the beach sands of Uttara Kannada district, their economic viabilities and sustainable mining" (S.D.M. College of Engg. & Tech. Dhanbad) up to September, 2019 without any additional financial implication and to permit to use the available grant till September, 2019.

A new portal dedicated to the S&T Scheme under the aegis of Ministry of Mines, viz. SATYABHAMA portal (research.mines.gov.in), was launched by Hon'ble Minister of Mines and all new project proposals will be received through this portal henceforth.

Table -1: Details of Projects Approved under S & T Programme, Ministry of Mines for 2019-20

Sl. No.	Project Title	Implementing Institution	Cost & Duration of Project
1.	Recovery Studies of gold and other values using non cyanide reagents from Tailing Dump of Bharat Gold Mines Ltd,	NFTDC, Hyderabad	Total Cost: ₹ 90.43 lakh (Capital - ₹ 23 lakh; Recurring - ₹ 67.43 lakh) Duration: 1 year
2.	Process Feasibility studies for the development of high purity aluminium through segregation process	NFTDC, Hyderabad	Total Cost: ₹ 33.15 lakh (Capital - ₹ 15 lakh; Recurring - ₹ 18.15 lakh) Duration: 1 year
3.	Processing of spent and natural graphite for energy and aerospace application.	CSIR-IMMT, Bhubaneswar	Total Cost: ₹ 23.10 lakh (Capital - Nil; Recurring - ₹ 23.10 lakh) Duration: 2 years
4.	Production and certification of certified reference materials (CRMs) for the analysis of aluminium alloy	JNARDDC, Nagpur	Total Cost: ₹ 76.40 lakh (Capital - Nil; Recurring - ₹ 76.40 lakh) Duration: 2 years
5.	Optimisation of digestion efficiency in Bayer process by ascertaining the ideal size fraction of bauxite feed	JNARDDC, Nagpur	Total Cost: ₹ 41.10 lakh (Capital - Nil; Recurring - ₹ 41.10 lakh) Duration: 1 year
6.	Utilisation of aluminium dross to achieve zero waste – A bench-scale study	JNARDDC, Nagpur	Total Cost: ₹ 74.34 lakh (Capital - ₹ 15 lakh; Recurring - ₹ 59.34 lakh) Duration: 2 years
7.	Value addition of calcined bauxite for possible use as abrasives in waterjet cutting applications	SSN College of Engg, Chennai	Total Cost: ₹ 29.98 lakh (Capital - ₹ 25 lakh; Recurring - ₹ 4.98 lakh) Duration: 1 year & 6 months
8.	Mineral chemistry, isotope geochemistry, geochronology and metallogeny of rare and rare-earth metals present in the alkaline-carbonatite complexes associated to the Narmada-Son rift zone, western India	BHU, Varanasi	Total Cost: ₹14.99 lakh (Capital - Nil; Recurring - ₹ 14.99 lakh) Duration: 9 month (1st Phase)
9.	Development of Novel Nanoporous hollow Fibre membrane based unit for the effective treatment of Mine waste water	NIT, Surathkal	Total Cost: ₹ 5 lakh (Capital - Nil; Recurring - ₹ 5 lakh) Duration: 6 months
10.	Direct production of Fe-Cr-Ni-Mn stainless alloy from mine waste by thermal plasma process	CSIR-IIMT, Bhubaneswar	Total Cost: ₹ 38.31 lakh (Capital - ₹ 10 lakh; Recurring - ₹ 28.31 lakh) Duration: 2 years
11*	Noble metal extraction by soft chemistry	IIT, Madras	Total Cost: ₹ 34.64 lakh (Capital - Nil; Recurring - ₹ 34.64 lakh) Duration: 2 years

Source: *Minutes of 51st meeting of SSAG held at MoM, New Delhi*

**** Modification/Remark (***i) The primary aim should be to develop and understand the mechanisms by which such gold-bearing minerals (as in quartz matrix) can be digested using biochemical compounds; (ii) Investigation of potential candidate biochemical compounds for digestion of gold from tailings; (iii) Cost-effective synthesis of potential soft chemicals for leaching of gold; (iv) Separation of gold and other metals from solution containing other precious metals, such as, Pt, Pd, Rh and Re; (v) Collaborate with NFTDC for scaling up of such potential soft chemicals. NFTDC will also provide tailings for this study; (vi) Project should be focussed on tailings as the source materials. Start from BGML tailings for this project which will be provided by NFTDC for lab-scale work; (vii) To collaborate concurrently with NFTDC to develop flow sheet based on biochemical leaching of gold-bearing minerals and tailings; (viii) With the above direction/objectives, the revised title of the project will be – "***Identification and Investigation of efficacy of potential biochemical molecules for extraction of gold and other noble metals from tailings and waste sources***".

Table -2: Details of Acceptance of Final Report and Closure of Completed Projects under S & T Programme, Ministry of Mines during 51st meeting of SSAG

Sl. No.	Project Title	Implementing Institution
1.	Development of viable technique for assessment of reclaimed land and for safety of structures under settling environment.	National Institute of Rock Mechanics
2.	Estimation of seismic hazard in and around the mines out areas of Kolar Gold Fields.	National Institute of Rock Mechanics
3.	Integrated approach for development of process models and pilot production of aluminium alloy extrudates using porthole dies.	JNARDDC, Nagpur
4.	Multi Centric Study of dust-related diseases in stone mines and development of sustainable preventive programme.	National Institute of Miners Health
5.	Synergistic utilisation of aluminium industrial wastes for development of geopolymeric building materials.	JNARDDC, Nagpur
6.	Development of standard protocol of field audiometry for notifying noise induced hearing loss.	National Institute of Miners Health
7.	Developing downstream application of strip cast aluminium alloys. (AA8011 & AA3004)	JNARDDC, Nagpur; VNIT, Nagpur; and NALCO, Bhubaneswar
8.	Postural risk analysis of mining equipment operators and its relation to musculoskeletal disorders.	National Institute of Miners Health
9.	Effect of modified seed properties in precipitation of aluminium hydroxide from bayer liquor.	JNARDDC, Nagpur
10.	Large-scale digital database creation of Bauxite & Laterite deposits of Maharashtra State using geo-informatics technology.	JNARDDC, Nagpur and Maharashtra Remote Sensing Application Centre, Nagpur
11.	Estimation of Morphodynamicity and its remedial action using Red mud-based concrete at coastal zone of Eastern Odisha.	JNARDDC, Nagpur and IIT, Bhubaneswar
12.	Status report on work carried out nationally and internationally on Red Mud to benchmark future investigation in the country.	JNARDDC, Nagpur
13.	Synthesis, characterisation and photo-catalytic performance of metal doped semiconductor nano materials.	Aligarh Muslim University

Source: *Minutes of 51st meeting of SSAG held at MoM, New Delhi*

RESEARCH & DEVELOPMENT

The Research & Development (R&D) work in the field of Ores & Minerals is being carried out by IBM, JNARDDC, CSIR & allied laboratories, other research organisations relating to mineral/ metal and various mining & mineral-based industries. As per available information, details of some of the R&D work conducted or completed by various organisations during 2019-20 are furnished below:

Indian Bureau of Mines (IBM)

Important R&D activities regarding ore dressing carried out by Mineral Processing Division, IBM during the year 2019-20 are summarised below-

1. Copper Ore

Bench-scale Beneficiation Studies on Copper-bearing sample from Gangas block, Rajsamund district, Rajasthan: A copper-bearing sample from Gangas block, Rajsamund district, collected by GSI as a part of G-2 exploration was received for bench-scale beneficiation study to evolve a process for producing a copper concentrate assaying more than 18% Cu with maximum possible recovery.

The sample assayed 0.56% Cu, 7.02% Fe (T), 4.43% FeO, 5.12% Fe_2O_3, 51.22% SiO_2, 14.58% Al_2O_3, 78.39% Al, 2.97% CaO, 4.49% MgO, 2.38% S (T), 0.78% TiO_2, 5.17% Na_2O, 1.58% K_2O and 2.59% LOI.

Chalcopyrite, Bornite and Covellite are the copper-bearing ores/minerals present in very minor to trace amount. Quartz was present in predominant amount whereas feldspar and mica (muscovite and biotite) were present in major amount. Iron oxides (magnetite, haematite & goethite), carbonates (calcite and dolomite), amphibole, pyrrhotite, pyrite, sphalerite, tourmaline and epidote were the other minerals occurring in very minor amount to trace amount in the sample.

Beneficiation studies employing froth flotation yielded a copper concentrate assaying 21.4% Cu with 84.26% copper recovery (Wt % yield 2.2).

The Copper bearing sample has potential to produce a metallurgical grade concentrate.

2. Iron Ore

Bench-scale Beneficiation Studies on an Iron Ore Sample from Jumka, Pathariposi Block, Sundargarh district, Odisha: An iron ore sample from Jumka, Pathariposi Block, Sundargarh District, Odisha was received from Mineral Exploration Corporation Limited for conducting bench-scale beneficiation studies with an objective to enrich iron content present in the sample for its further use in iron and steel industries.

The sample assayed 60.48% Fe (T), 4.86% SiO_2, 4.07% Al_2O_3, 0.15% TiO_2 and 3.87% LOI.

Mineralogical studies revealed that the sample consists predominantly of haematite with subordinate amounts of goethite/limonite and minor amounts of clay. Very minor to trace amounts of quartz, gibbsite, martitised magnetite, feldspar, mica (muscovite, biotite), ilmenite and pyrite were noticed in the sample.

Beneficiation studies comprising scrubbing, screening and gravity separation yielded two concentrates from two different beneficiation routes adopted as described below-

Route-I: A composite concentrate obtained assayed 62.95% Fe (T), 2.97 % SiO_2, 2.88% Al_2O_3 and 3.32% LOI with iron recovery of 92.6% and wt % yield of 87%.

This composite concentrate may find application in sinter making.

Route-II: A composite concentrate obtained assayed 64.93% Fe (T), 1.48 % SiO_2, 2.29% Al_2O_3 and 2.79% LOI with iron recovery of 82.7% and wt % yield of 74.5.

This composite concentrate may also find suitable industrial application.

3. Limestone

Bench-scale Beneficiation Studies on F-Block Jasper-bearing Limestone Sample: A jasper-bearing limestone sample from M/s Kesoram Industries Ltd, Telengana, was received for bench-scale beneficiation studies with a view to produce a limestone concentrate suitable for cement production.

The limestone sample assayed 38.68% CaO, 26.93% SiO_2, 1.05% Al_2O_3, 0.94% MgO, 0.91% Fe_2O_3 and 30.81% LOI.

Mineralogically, carbonate (calcite and dolomite) occur as fine to coarse aggregates in anhedral shape, associated with quartz, clay and iron oxides. Quartz grains occur in the form of microcrystalline to cryptocrystalline variety of chalcedony and jasper. Jasper is impure opaque colored quartz whereas chert is massive form of chalcedony. Most of the cryptocrystalline quartz carries extremely fine-grained inclusions of carbonate and iron oxides.

The beneficiation process route involving crushing and grinding of the sample followed by direct froth flotation, yielded a CaO-rich concentrate assaying 49.62% CaO, 9.26% SiO_2, 9.70% AI, 38.54% LOI with 90.3% CaO recovery and weight per cent yield of 70.2.

The recovery of limestone ore/minerals on plant-scale is expected to be higher than obtained in the laboratory-scale studies, as the cleaner tails would be re-circulated back into the circuit within the plant.

This will enable, further, recover of CaO values from the cleaner tails and improve the overall concentrate yield at the plant-scale.

4. Manganese Ore

Bench-scale Beneficiation Studies on a Manganese Ore Sample from Devada Blocks, Garividi Manganese Belt, Vizianagaram district, Andhra Pradesh: G-2 stage investigation of Manganese ore sample from Devada Block was

received from Geological Survey of India, Project Manganese, Camp-Cheepurupalli, Vizianagaram district, Andhra Pradesh, for conducting bench-scale beneficiation studies with an objective to produce a manganese concentrate suitable for end industrial uses.

The sample assayed 27.68% Mn, 15.47% Fe (T), 10.64% SiO_2, 6.49% Al_2O_3, 2.11% CaO, 1.42% MgO, 0.52% P, 7.10% BaO, 0.05% Na_2O, 0.40% K_2O and 0.09% S.

Mineralogical studies revealed that the sample consisted of major amount of psilomelane and mangalomelane with subordinate amounts of goethite/limonite and subordinate to minor amounts of clay, pyrolusite, cryptomelane and quartz. Minor to very minor amounts of feldspar, lithiophorite, apatite, mica (muscovite) and garnet and traces of jacobsite and manganite were also noticed in the sample.

Detailed beneficiation studies carried out employing screening, classification, gravity separation techniques viz. jigging, tabling & multi-gravity separation and magnetic separation yielded a composite concentrate assaying 35.18% Mn,11.01% Fe and 5.81% SiO_2 with a Mn distribution of 75.4% (wt % yield 58.8). The Mn:Fe ratio is 3.19:1.

The composite concentrate may find suitable industrial application.

5. Low Grade Iron Ore

Beneficiation Studies on a Low-grade Iron Ore Dump Sample from village Chaballi , Kadapa district, Andhra Pradesh: A low-grade iron ore-fines sample was received from M/s Benita Industries Limited for bench-scale beneficiation studies with an objective to up-grade the ore to produce a concentrate assaying about 55% Fe (T) with an optimum recovery.

The sample assayed 37.41% Fe (T), 0.72% FeO, 28.14 % SiO_2, 8.28% Al_2O_3, 5.7% LOI, 0.32% Mn, 0.54% CaO, 0.33% MgO, 0.75% TiO_2, 0.10% P and <0.05% S.

Mineralogical analysis indicated that the sample contained major proportion of iron-bearing minerals (haematite and goethite/limonite). Quartz + feldspar and clay + gibbsite/mica (sericite) were seen presents in subordinate amounts. Magnetite + martitized magnetite, carbonate, pyroxene/ amphibole and pyrite were present in very minor to trace levels.

Detailed beneficiation studies involving scrubbing, screening, grinding & gravity separation yielded a concentrate assaying 61.91% Fe (T), 5.82% SiO_2, 1.99% Al_2O_3 and 1.50% LOI with Fe (T) recovery of 34.1% (Wt % yield 20.6). However, the combined concentrate (I+II+III) assayed 59.72% Fe (T), 7.10% SiO_2, 2.76% Al_2O_3, and 1.94% LOI with Fe (T) recovery of 50.0% (Wt % yield 31.3).

Thus an iron ore concentrate suitable for metallurgical industry could be obtained from the low-grade iron ore dump sample which assayed less than the threshold value.

6. Low-grade Banded Magnetite Quartzite Ore

Bench-scale Beneficiation Studies on a Low-grade Banded Magnetite Quartzite (BMQ) Ore Sample from Sanjeevarayakote, Bellary district, Karnataka: A low-grade banded magnetite quartzite ore sample from Sanjeevarayakote, Bellary district, Karnataka was received for beneficiation studies. The objectives of the investigation were to characterise the sample by chemical and mineralogical studies and upgrade the iron content with maximum possible grade and recovery and to reduce the SiO_2 content as much as possible.

The sample assayed 36.18% Fe (T), 42.62% SiO_2, 0.15% Al_2O_3, 43.87% Fe_2O_3, 5.50% FeO, 0.05% Mn, 0.03% P, 1.82% CaO, 0.91% MgO, 1.05% LOI and traces amount of TiO_2 and S (T). The sample mainly consisted of quartz and magnetite + martitised magnetite in major amount along with minor amount of goethite/limonite, carbonates, mica and very minor to trace amount of pyrite, chlorite, serpentine/clay, ilmenite, and tourmaline.

Tabling of the sample ground to minus 0.147 mm (-100#) yielded a table concentrate assaying 68.08% Fe (T) and 2.76% SiO_2 with Fe (T) recovery of 54.6% (Wt % yield 29.4). The table middling product, ground to all passing 0.076 mm and subjected to low intensity magnetic separation (Ferrous Wheel) at 600 gauss yielded a magnetic fraction assaying 63.35% Fe (T) and 9.03% SiO_2 with Fe (T) recovery of 12.8% (Wt % yield 7.4). The table slimes was also subjected to low intensity magnetic separation (Ferrous Wheel) at

600 gauss, which yielded a magnetic fraction assaying 64.21% Fe (T) and 8.13% SiO_2 with Fe(T) recovery of 3.7% (Wt % yield 2.1).

Combining the table concentrate and magnetic fractions of both table middling and table slimes yielded a composite concentrate assaying 66.97% Fe (T) and 4.24% SiO_2 with Fe(T) recovery of 71.1% (Wt % yield 38.9). The specific gravity of the combined concentrate was 4.89.

The composite concentrate did meet the specifications as desired by the party.

7. Rock Phosphate Tailings

Bench-scale Beneficiation Studies on Plant Tailings Sample from Jhamarkotra Mines, Rajasthan: A rock phosphate plant tailings slurry sample from IBP plant of RSMML, Jhamarkotra was received with an objective to evolve a process for recovery of phosphate mineral being lost in plant tailings.

The sample assayed 10.5% P_2O_5, 3.51% SiO_2, 0.84% Fe (T), 0.18% Al_2O_3, 27.56% CaO, 17.85% MgO, 0.67% S(T) and 33.62% LOI.

Carbonates (calcite and dolomite) were present in predominant amount whereas apatite was present in subordinate amount. Quartz was present in minor amount whereas clay, feldspar, amphibole, tourmaline, mica (muscovite and biotite) and iron oxides (haematite and goethite) were observed to be present in trace amount.

Detailed beneficiation studies employing froth flotation on as received sample ground to all - 300 mesh yielded a phosphate concentrate assaying 32.85% P_2O_5 with recovery of 67.32% (Wt.% yield of 21.7).

The sample is amenable to beneficiation for recovery of P_2O_5 content enriched concentrate.

Jawaharlal Nehru Alumnium Research Development & Design Center (JNARDDC)

1. Completed Projects

1.1 Nano Processing of Industrial Rejects for Use as Additives in Mix-designs for Improved Pozzolanic Reaction Efficiency, in Association with VNIT, Nagpur (S&T - Mines): The main objective of this research work is to utilise the abundantly available industrial wastes; Red Mud, Fly Ash, Granulated Blast Furnace Slag, Lime Sludge, Sandstone Sludge in useful manner by making it nano using either top down or bottom up approach and increasing its surface to volume ratio to use it for industrial catalytic and adsorbent activities.

JNARDDC selected Granulated Blast Furnace Slag (GBFS), Fly Ash (FA), Lime Sludge (LS), Red Mud (RM) and Sandstone Sludge (SS) for partial replacement of cement and developed process for preparation of building blocks with desired/ enhanced physico-mechanical properties. Aluminium industrial waste ,i.e., Red Mud (RM) was collected from alumina refinery NALCO, GBFS from Bhilai Steel Plant, Chhattisgarh, whereas, other wastes (Fly Ash, Sandstone Sludge, Lime Sludge) were collected from local industries nearby Nagpur. Two different methodologies (chemical and mechanical) were used to carry out the nano processing of the collected industrial wastes.

During project investigation, it was observed that selected wastes were not toxic and these wastes after modification in nanomaterials could be secondary resource for building and construction with enhanced physico-mechanical properties, i.e., GBFS and fly ash for building applications. The extracted nanoparticles from red mud and lime sludge could be used in other applications, such as, adsorbents, drug delivery applications, etc.

The industrial rejects which has high percentage of alumina but low silica can be utilised for alkali activated concrete/building blocks with zero cement. This will reduce the GHG emissions as well as the embodied energy of the building products.

In the next stage, techno-economical process viability at pilot scale with aim for commercial utilisation will be explored with industry to achieve the well advocated Make in India programme of Govt of India.

1.2 Utilisation of PLK (Partially Lateritised Khondalite) as a Potential and Value Added Filler material with Specific Reference to White Ceramics and Pigments, NALCO and CVRCE, Odisha: The main objective of this research work is to develop a process for utilising Partially Laterised Khondalite (PLK) as a potential and

value-added filler material for manufacturing white ceramics and pigments.

The collaborative R&D identified the best possible processing option for NALCO's PLK and developed a chemical treatment process for selective removal of iron oxide (Fe_2O_3) to generate low iron PLK material, which is useful as a resource at ceramic and paint/pigment industries. The efficacy and quality of low iron PLK material have been confirmed on the basis of product validation studies. The studies also confirmed the suitability of material developed from NALCO's PLK as low-cost binder/filler.

The final report recommended to NALCO that there is a wider R&D scope to explore further on the possibilities of utilising NALCO's PLK material in many other non-metallurgical applications, viz. preparation of Fused Alumina, Nano-silica, etc. where bauxite is used as raw material. Since good quality bauxite reserves are available in the country for aluminium metallurgy, the alumino-siliceous reserves which are lying unutilised can to be used for non-metallurgical needs.

1.3 Development of Inline Automated Anode Butt Monitoring System to Measure Anode Butt Parameters, NALCO, Bhubaneswar: The project aims to develop an automated visual inspection system of anode butts processed at the rod shop.

An automated visual inspection system with software has been developed for Image acquisition and Image Analysis using Matlab. During the project period various image Analysis techniques have been tried to develop final software for determining the various parameters of the anode butt. The final Image Analysis software is measuring around 15 parameters for each anode butt assembly automatically through Image Analysis for calculating the desired anode butt parameters.

The software acquires four numbers of Images for each Anode from different locations and are saved with time stamp in the Desktop PC installed at the control room and the calculated results are stored in a CSV file.

Thus a user-friendly Image Analysis software package has been developed to represent the calculated anode butt parameters. The understanding gained through this project will help reduce net carbon consumption by adjusting anode manufacturing processes and optimising aluminum electrolysis process.

1.4 Development of Wi-Fi enabled Sensor Arrangement for Online Measurement of Anode Current distribution of Aluminium Electrolysis Cell, NALCO, Bhubaneswar: The objective of the project was to develop a Wi-Fi enabled sensor arrangement for online measurement of real time anode current distribution of individual aluminium electrolysis cell leading to reduction in cell instabilities and improvement in pot control and efficiency/energy savings.

JNARDDC successfully developed the Wi-Fi system which is capable to measure the individual anode currents for any of the 960 pots and transfer the data through Wi-Fi at the Control room of Potline-II. Master unit captures the current data through radio frequency from all sixteen-slave units installed at individual anodes.

After receiving the data from the slave unit, Master unit transmits the data to Potline-II through Wi-Fi Network. Software has been developed and installed at Potline-II control office for acquisition, storage and representation of the current data of each anode of a particular cell in a tabular and graphical form. Experimental results at the site show that the measuring instrument has high measurement accuracy.

Online current distribution measurement helps to observe changes in current distribution with changing conditions in the cell for a period of time and in turn will help in understanding the cell phenomena and troubleshooting the problems, which will lead to improve cell efficiencies and reduction in cell instabilities. The continuous measurement of anode current distribution will open up many research gates with respect to the correlation with the unmeasureable and unpredictable events/aspects of the electrolysis process.

1.5 Utilization and Development of Process for Recovery of Strategic Rare Earths from Industrial Waste – Bauxite Residue at Lab-scale in Association with HINDALCO (Dept. of Science & Technology & Industry partner- HINDALCO): The main objective of this research work was to develop a cost-effective process for recovery of

rare-earth elements from bauxite residue. The Process comprised steps viz. (i) Physical beneficiation/pre-concentration of bauxite residue (red mud) using multigravity separator/Hydro cyclone; (ii) Leaching and extraction of REEs using different mineral acids; and (iii) Recovery of rare-earth elements, i.e., Scandium oxide.

The Indian red mud (bauxite residue) used in this study was characterised thoroughly and contained 48.0±4 ppm Sc, 58.5±4 ppm La and 98.1 ±8 ppm Ce. Among different REEs, scandium is the most strategic one. There has been no record of scandium deposits with concentrations over 100 ppm. Resources with scandium content between 20 and 60 ppm can be considered as an ore. Sc_2O_3 (40-50 mg) was recovered from 1 kg red mud with promising purity in the first batch by precipitation with sodium hydroxide/oxalic acid followed by calcination. The understanding gained through this project will help to extract strategic metal values from red mud. A conceptual/ experimental flowsheet to recover scandium from red mud has been proposed for future process development and production. The flow sheet developed will be very useful for Aluminium Industry in converting waste to wealth.

1.6 Technological Characterization of Bauxite Sample for Establishing the Mass Balance of the Process Design of the Expansion Study at Vedanta Ltd, Lanjigarh, Kalahandi, Odisha: The main objective of this research work was to undertake technological characterisation of bauxite for establishing the mass balance of the process design for the expansion of Vedanta Alumina refinery at Lanjigarh, Odisha.

The Kodingamalli bauxite is gibbsitic in nature with good amount of alumina (44%) moderate in silica (2.78%) content, high in Fe_2O_3 content (25-26%) and low in TiO_2 content (2.47%). The TOC is also low around 0.11%. The average value of THA and MHA was 39.38% and1.7% respectively. The reactive silica was 2.3% with about 0.5 % quartz. The bond work index determined showed a lower value of 9.26 kWh/ton and Rod Mill Index 7.78 kWh/ton indicating a lower energy requirement for grinding.

The pre-desilication studies carried out at 100 °C at 800 gpl solids concentration with ROM bauxite indicated that a residence time of 4 - 6 hours can bring down silica level in desilicated liquor below 1 gpl. Further pre-desilication with a blend of 30% desilicated bauxite and 70% ROM, was carried out and the value of 1.0 gpl in the desilicated liquor is achieved in a span of 120 - 240 minutes for all the experiments. The addition of pre-desilicated bauxite as seed does not indicate a rapid desilication. The experimental studies on pre-desilication has been conducted in a Batch mixed reactor, the kinetic studies for pre-desilication has been determined using ROM bauxite and mixture of 30 % pre-desilicated bauxite + 70% ROM bauxite. The time required for the liquor silica concentration in the liquor to fall below 1.0 gpl has been determined as 3 - 4 hours.

Thus, JNARDDC provided the critical parameters to Vedanta by undertaking bondwork index tests, impurities extraction test in plant and synthetic liquor, flocculant screening, pre-desilication studies, braking point digestion tests, bomb tests, scale up digestions tests, mud settling tests, lager settling tests, rheology tests etc.

This research findings of the technological evaluation of Kodingamalli bauxite was found to be useful to Vedanta and Worley Parsons (Technology supplier of Vedanta) in designing, manufacture and supplying the refinery equipment for establishing the mass balance of the process design of the expansion study at Vedanta limited, Lanjigarh, Kalahandi, Odisha.

1.7 Technical Feasibility Study for Extraction of Alumina as AlF_3 from Low-grade Bauxite, International Bauxite, Alumina & Aluminum Society- IBAAS, Nagpur: The major objectives of project was to convert the aluminium compound (gibbsite, monohydrate) present in Indian bauxite to aluminium fluoride using the fluoride reagents and test the process for its technical viability on laboratory scale in terms of suitability of fluoride reagents (1-2), Impurities present in the products and probable waste generation.

JNARDDC successfully carried out the technical feasibility on laboratory-scale study using different fluoride reagents. During the study three routes were studied, namely, (i) HCl-HF route (ii) Fluorosilicic acid (H_2SiF_6) route and (iii) Hydrofluoric acid (HF) route. The final report contains the technical details of bauxite and processes, which will help in deciding the process

to be adopted based on availability of raw materials.

2. Ongoing Projects 2019-20

2.1 Fabrication of Advanced Ceramic Nano coatings for Automotive Applications with Christ University (Sponsored by Ministry of Mines)*:* The project aims to develop a technology to prepare nano sized plasma spray powder from nano ceramic (commercial) compositions involving alumina and zirconia (in line with Make in India Concept). The outcome of the project could lead to overall import substitution in the field of automotive sector applications.

2.2 Techno-economic Survey of Aluminium Scrap Recycling in India with Metal Recycling Association of India (Sponsored by Ministry of Mines): Indian Aluminium Recycling Industry is currently considered as unorganized, represented by around 5,000 Micro Small and Medium Enterprises. Scrap collection is largely unorganised coupled with insufficient awareness, leading to a major proportion of scrap going to landfill rather than recycling. Current recycling rate in India is only 25% compared to the world average of 45%. The country has a long way to go before it can become a major aluminium recycler and feed the secondary metal market which is dependent on imports. Presently key concern areas of aluminium recycling are lack of structure for aluminium scrap handling and secondary metal recovery.

On this background the survey report will assist the Ministry of Mines in establishing the techno-economic status of the Aluminium Recycling Industry in the country and in due course help in formulation of policies pertaining to this Industry.

2.3 To Study the Fire Retardancy of Nano-ATH in Polymers with Central Institute of Plastics & Engineering Technology, Bhubaneswar (Sponsored by Ministry of Mines): Aluminium hydroxide is a common inorganic additive used in a wide range of industrial applications. One of its applications is its use as a fire retardant. Polymer based materials are now recognised as key components in many important industries, such as, construction, automotive, electronic and aerospace due to their outstanding physical and electronic properties, cost-effectiveness, high versatility and portability. However, one severe problem with many polymers is that they are highly flammable and can produce large amounts of toxic smoke during combustion, which poses a great threat to human safety. In order to tackle this problem the project has been undertaken to explore the use of nano-ATH as flame retardant fillers into polymer matrices because of its specific properties of high surface area and good dispersibility. The project aims to develop new process and product using aluminium trihydroxide and polymer matrix for various applications.

2.4 Bench-scale Study on Extraction of Pure Silica and Smelter-grade Aluminium Fluoride from Coal Fly Ash (Sponsored by Ministry of Mines): Coal Fly Ash (CFA) is one of the solid waste generated in thermal power plants during the process of power generation. India's commercial energy demand is met through the country's vast coal reserves and the coal fly ash generating from all coal-based thermal power plants are accumulating over the years which typically contains 27-31% alumina (Al_2O_3), 56-60% silica (SiO_2) and 9-13% oxides of elements (Ca, Mg, Na, Fe, Ti etc.).

Pure silica is used in structural materials, microelectronics (as an electrical insulator, semiconductors etc.) and as components in the food & pharmaceutical industries.

In this project work, efforts will be carried out to study bench-scale (0.5-1 kg CFA) extraction of pure silica and aluminium fluoride by treating coal fly ash (CFA) with appropriate mineral acid.

2.5 Optimisation of Digestion Efficiency in Bayer Process by Ascertaining the Ideal Size Fraction of Bauxite Feed (Sponsored by Ministry of Mines): The alumina refineries are presently operating upon the feed size of the bauxite to ball mill after conducting a series of experiments before setting up of plant. But over the years, bauxite characteristics may vary especially if there is a change in bauxite origin.

Accordingly, to attain the same digestion efficiency a thorough investigation has been undertaken in the above project for recommending the optimum particle size of the feed bauxite to digestion.

2.6 Utilisation of Aluminium Dross to Achieve Zero Waste – A Bench-scale Study Project (Sponsored by Ministry of Mines): The main objective of the project is to develop the bench-scale process for preparation of Poly Aluminium Chloride (PAC) from waste aluminium dross and to prepare castable refractory from residual dross for industrial applications to achieve zero waste.

The potential benefit in preparing PAC from aluminium dross is providing alternative source to primary material and reduction in waste disposed to landfills.

2.7 Production and Certification of Certified Reference Materials (CRMs) for the Analysis of Aluminium Alloy (Sponsored by Ministry of Mines): The main objective of the project is to produce certified reference materials (CRMs) for aluminium alloys at JNARDDC for the benefit of the Aluminium Industry and to provide import substitute. Being accredited with ISO 17025 by NABL for its analytical facilities, JNARDDC is well-placed to produce CRMs. In this regard, accreditation in accordance with ISO 17034 is under progress. Initially, the development of CRM for one wrought and one cast alloy will be taken up and the range will be expanded subsequently.

This will be an import substitute to high quality CRMs for Aluminium Sector.

2.8 Development of Ceramic Proppant from Low-grade Materials (Partially Lateritised Khondalite -PLK, Fly ash, etc.) - Phase-II Scale-up studies (Sponsored by NALCO, Bhubaneswar): Based on the successful lab-scale process already developed by JNARDDC the scale-up project for developing ceramic proppant from low-grade materials (Partially Lateritised Khondalite -PLK, Fly ash, etc.) under Phase-II has been undertaken.

The process is an effort for converting unutilised materials into value-added products. An effort towards 'Make in India' and 'Swatch Bharat" zeal.

2.9 An Innovative and Viable Process for Recovery of Iron Values from Red Mud and Processing of Non-iron Material for Developing Value-added Products – Complete Utilisation of Red Mud, Sponsored by NALCO, Bhubaneswar (Jointly with IIMT, Bhubaneswar & Eesavyasa Tech, Pvt. Ltd, Telangana)**:** Project aims to develop an innovative and viable process for recovery of iron values from red mud and processing of non-iron part for its application as an insulating product with an aim for complete utilisation of red mud. JNARDDC will be the nodal agency and the deliverables shall include mass and energy balance of the developed process.

2.10 Development of a Process Technology at Lab-scale for Low Cost Production of 3N (99.9%) Pure Alumina, Sponsored by Dept of Science and Technology, New Delhi (in collaboration with IIT, Bhubaneswar & Anna University)**:** The project aims to develop the process know-how for the low-cost production of 3N pure alumina suitable for LED (Light Emitting Diode) and Semiconductor applications.

Efforts are on to get the required product at much low temperature. Study of cost economics for 3N pure alumina synthesis process will also be evolved.

The country does not have a production base of LED due to import of 3N and 4N alumina. In view of the market, product potential and availability of raw materials in India, the current proposal has a commercial potential to add to the vision of "Make in India" programme.

National Institute of Rock Mechanics (NIRM)

National Institute of Rock Mechanics carries out a number of investigations in the area of rock engineering and rock mechanics. The Institute extends R&D support and expertise to the Mining Sector (underground, opencast and quarries), Energy Sector (hydel, thermal and nuclear power) and Infrastructure Sector (rail, road, metro, irrigation, urban construction, etc.). Of late it has expanded its activities to the Oil Sector (specialised testing), Defence Sector (onshore and offshore) and other miscellaneous sector (archaeology, environment, etc.). Key area of activities of the Institute involves site characterisation which includes geological, geophysical and geotechnical investigations, excavation engineering, controlled blasting, numerical modelling, engineering seismology, seismotectonic studies, mine design, slope stability, laboratory testing of rock samples and wire ropes and in situ testing of various mining accessories using NDT technique. During the

current reporting period, i.e., 2019-20, three S&T projects have been completed by the Institute. The Institute has also completed 83 industry projects between 1st January and 31st December, 2019.

Some of the major ongoing projects that are being executed by the Institute during this financial year include: Geodetic and deformation monitoring of Sardar Sarovar Dam and its underground powerhouse cavern; Vibration impact analysis on underground ONGC pipe line passing through Surat airport; Engineering geological investigation for slope stability of the hillock above Polavaram Hydroelectric Project; Monitoring ground vibration and air over pressure due to blasting carried out for construction of various civil engineering installations associated with Kudankulam Nuclear Power Plant; Geophysical studies to identify isolated boulders in the underground tunnels of Bangalore metro rail project; Feasibility study for siting nuclear power site at Chatrapur Odisha; Instrumentation and analysis of data pertaining to dam complex of Punatsangchhu Hydroelectric project at Bhutan; Determining safe bearing capacity and in situ rock mechanics parameters at the Arun Hydroelectric project in Nepal and detailed seismotectonic evaluation of proposed Nuclear power site at Jaitapur.

National Institute of Miners' Health (NIMH)

National Institute of Miners' Health conducts applied research in the field of occupational health and hygiene among persons employed in mining and mineral-based Industry with the vision of ***"Safe Mines and Healthy Miners"*** and the mission ***"Indian Mining and Mineral Industry sans occupational Diseases"***. The Union Government has approved to dissolve National Institute of Miners' Health (NIMH) and merge/ amalgamate with ICMR-National Institute of Occupational Health (NIOH), Ahmedabad, Ministry of Health & Family Welfare (MoH&FW). The Clientele/sponsored projects undertaken by the Institute during the year 2019-20 are given below:

(i) Dust, noise and vibration studies at NALCO Damanjodi.

(ii) Work place monitoring studies at NMDC-Kirandul, Bacheli and Panna.

(iii) Work place monitoring studies at Sadera (RCCPL).

(iv) Work place monitoring studies at ACC - Gagal, Kymore.

(v) Work place monitoring studies at Ambuja Solan and Bhatapara.

(vi) Periodical Medical Examination of employees of Gujarat Mineral Development Corporation.

(vii) Initial and Periodical Medical Examination of contract workers of Panchpatmali Bauxite Mines, Damanjodi, NALCO.

The Institute has completed one S & T project (Sponsored by Ministry of Mines), titled *"Postural risk analysis of Mining equipment operators and its relation to Musculoskeletal Disorders"*.

CSIR-Central Glass & Ceramic Research Institute (CGCRI)

1. R&D on Magnesite for Refractory Application

Two major magnesite sources of India (viz Salem, Tamil Nadu and Almora, Uttarakhand) are unsuitable for high temperature refractory application due to presence of silica, lime and iron oxide as impurities These impurities form low melting phases during refractory application and hence Indian refractory industries largely depend on imported good quality magnesite. CSIR-CGCR is working on improvement of high temperature properties of impure Salem magnesite by beneficiation or by judicious selection of additives to reduce the low melting phase formation. Reduction in the silica content of the magnesite was achieved by reverse froth flotation technique. Addition of zirconia and tailoring of the lime/silica ratio improved the thermo-mechanical properties of the sintered magnesite aggregates. Magnesium aluminate spinel was also developed using Salem magnesite through thermal plasma processing route. Purification of impure Almora magnesite through fusion technique in presence of additives in electric arc was carried out at CSR-CGCRI. Preliminary study indicated increased the MgO content of the fused magnesia to 91.81% from 83.85% with a significant reduction of impurities.

2. R&D on Sillimanite Beach Sand for Refractory Application

Alumina-based refractories are widely used in several high temperature structural applications. Sillimanite beach sand is an industrial by-product generated during rare earth extraction from beach sand. This sand is a pure form of alumino silicate. Synthetic alumina silicate aggregates with good thermo-mechanical properties were developed by reaction sintering sillimanite beach sand and calcined alumina. Shaped and castable refractories have been developed using these aggregates. Performances of these refractory products are at par with the commercially available aggregates.

CSIR-Central Electrochemical Research Institute (CECRI)

1. Research & Development - Ore preparation and processes

Research and development work was carried out in the field of extractive metallurgy and ore preparation, having bearing on Mineral Industry.

(i) Processing of High phosphorous and High Manganese ores" sponsored by Vedanta, Sesa Iron ore, Goa.

(ii) Extraction of metallic Zinc ash and Zinc through electro-hydrometallurgical processes" for Deep constructions, Gujarat.

(iii) Electrowinning of metallic iron from ferrous sulphate solution" sponsored by JSW Ltd.

2. Research & Development - Minerals and Mineral-based Products in Construction Activities, Substitution, etc.

A feasibility study was made for the first time by using graphite ore tailings (GOTS) obtained from Tamil Nadu Minerals (TAMIN), Sivaganga as a replacement material for river sand in making mortar and concrete. As-received GOTS and treated GOTS (T-GOTS) at 1,000 °C (1,832 °F) were replaced with river sand and various percentages of replacement ranging from 10 to 100%, and their strength evaluation, were done by conducting compression and split tensile tests in mortar and concrete. Bond strength was evaluated using a pullout test and the permeability characteristic was assessed by water absorption and effective porosity tests. The quality of the concrete was assessed by electrical resistivity and ultrasonic pulse velocity measurements. The corrosion resistance evaluation was done by half-cell potential measurement, alternating current impedance or electrochemical impedance spectra, and potentio-dynamic polarisation studies. From the studies, it is observed that river sand may be replaced with 40% T-GOTS and can be effectively used for structural repair applications.

3. Research & Development - Recovery of Marine Chemicals and By-products, viz, Salt, Potash, Bromine, Iodine, Gypsum and Magnesium chemicals

Electrowinning of Magnesium Metal from Spent Magnesium Chloride Liquor by Molten Salt Electrolysis sponsored by United Phosphorous Limited.

4. Research & Development - Metallurgy and Mineral Processing

4.1 Extraction of Neodymium Metal by Molten Salt Electrolytic Process (Sponsored: Indian Rare Earths Ltd): The objective of this project was to produce Rare-earth metals & alloys from Rare-earth oxides/chlorides produced by IREL from Beach Sand Minerals. The deliverables achieved are stated below:

(i) Electrowinning of neodymium metal (Nd_{99}) from molten salt electrolytes successfully carried out under optimised conditions using chloride melts

(ii) Electrowinning of neodymium – iron, used as master alloy for NdFeB magnets, demonstrated at various current densities and bath compositions

(iii) Yield: Nd metal at 10 g/batch & Nd-Fe alloy at 100 g/batch → Scaling-up in progress

2. Electro-hydrolysis of Low-grade manganese ore to gamma MnO_2 (Sponsored: TATA Steel Limited): The objective of this project was to develop an Electrowinning process for the preparation of γ-manganese dioxide from low-grade Indian manganese ores. The deliverables achieved are as below:

(i) The manganese ore received from Tata steel Ltd was ball milled and analysed for its composition using X-ray Diffraction and XRF.

(ii) The finely ground ore was then leached with sulphuric acid and iron impurity was removed by precipitation. The final light pink electrolyte had Mn concentration of 55-60 g/l.

(iii) Electrowinning was carried out at 2 liters capacity using polished stainless steel sheet cathode and titanium mesh anode. Electrolysis was carried out by varying the current density at on elevated temperature.

(iv) The deposited γ-MnO_2 was scraped from the anode, washed with DM water and examined for its purity by XRD, XRF and FT-Raman Spectroscopy, and micro-structure was studied using FE-SEM.

3. Effect of Impurities on Zinc Electroplating: Comparison of Special High Grade (99.995%) and Electroplating Grade (99.997%) Zinc Raw Material (Sponsored: Hindustan Zinc Limited): The objective of the project was to understand the effect of impurities in EPG and SHG grade zinc in terms of current efficiency, micro-structure and corrosion resistance. The deliverables achieved are as below:

(i) EPG-Zn exhibited better Current Efficiency during acidic zinc electroplating

(ii) Zinc samples electroplated from EPG-Zn exhibited more compact and crystalline micro-structure and exhibited better corrosion resistance than SHG-Zn

CSIR-National Metallurgical Laboratory (NML)

CSIR-NML continues to play a vital role in providing scientific solutions to the industries in the areas of minerals, metals and materials. The R&D work carried out by CSIR-NML in Mineral Processing during 2019-20 is as below:

1. Technological Process Flow Sheet for Beneficiation & Extraction of Tungsten from Gold ore Tailings: The objective was to develop technological process flow sheet for beneficiation and extraction of tungsten metal from scheelite-bearing gold ore tailings sample. With detailed characterisation and process mineralogical studies, the mine waste was subjected to beneficiation and hydrometallurgical extraction at bench-scale and at large scale. The mine waste sample was observed to be extremely fine-grained, 73% passing through 12mm with scheelite as the only tungsten-bearing mineral. It contains gangue minerals including silicates like quartz, plagioclase, perthite, biotite, amphibole; oxides, such as, spinel, rutile, chromite, magnetite; and sulphides like arsenopyrite, pyrite, chalcopyrite, pyrrhotite. Detailed bench-scale/large batch beneficiation studies were carried out involving different techniques towards pre-concentration of plant tailings sample suitable for subsequent hydrometallurgical extraction of tungsten. Bulk pre-concentrate was produced through pilot-scale campaigns of about 100 tonnes material for subsequent hydrometallurgical extraction studies through large-scale leaching experiments. The pre-concentrate was subjected to hydrometallurgical processing involving alkali leaching followed by solvent extraction and stripping producing ammonium para-tungstate (APT). Tungsten metal powder with 99.9% purity was produced from APT. Based on the beneficiation and hydrometallurgical extraction studies carried out, technological process flow sheet was developed for beneficiation and extraction of tungsten from gold ore tailings sample.

2. Technology for Dry Beneficiation of Thermal Coal: NML has undertaken a collaborative R&D project with CMPDI and MCL on the development of technology for dry beneficiation of non-coking coals from MCL. Detailed mineralogical/maceral and chemical characterisation, washability study and dry beneficiation studies were carried out on the two high ash thermal coal samples from MCL. Based on the dry beneficiation involving air fluidised vibrating deck, technology was developed for dry beneficiation of thermal coal assaying 42-46% ash producing clean coal with 34% ash, suitable for application in thermal power plants.

3. Pilot-scale Beneficiation of Low-grade Limestone for Cement Making: The study was carried out on a low-grade siliceous limestone with representative characteristics that assayed 43.57% CaO, 0.69% MgO, 17.35% SiO_2, 1.21% Al_2O_3 and 34.72% LOI, with a view to reduce silica content in limestone below 12% for use in manufacture of cement. The mineralogical study revealed calcite to be the major constituent with laminae of shale consisting of microcrystalline quartz, kaolinite and muscovite. Earlier, a detailed bench-scale beneficiation study was carried out and a flotation-based process was developed for beneficiation of low-grade siliceous limestone

sample. In the present study, the results of bench-scale beneficiation were validated through pilot-scale studies and process flow sheet was designed and material balance was computed. A limestone concentrate assaying 47.4% CaO with 11.3% SiO_2 and 96% recovery was achieved.

4. Plant Performance Audit of Lawa Gold Ore Concentrator: The gold ore from Lawa Gold Ore mines was studied at CSIR-NML. Performance of the plant was not satisfactory. The gold extraction process basically included concentration of gold ore by physical separation followed by smelting. The tailing of physical separation was treated through hydrometallurgical process. In order to understand the reason behind low recovery, a survey was undertaken for the physical separation unit. The survey involves collection of samples from different streams followed by calculation of percent solids, assay and sizing of each stream. Various bottlenecks and the reason behind low recovery was identified for the purpose of addressing the problem. Mass balancing around the circuit was performed using the sizing, percent solid and assay data.

5. Advanced Gravity Concentration of Chromite Ore Beneficiation Plant Tailing: Objective of this study was to develop a process for recovery of chromite values from chromite ore beneficiation plant tailing. The initial efforts were put in to characterise the plant tailings by chemical and mineralogical analyses using optical microscope, X-ray diffraction and SEM. The study revealed that goethite, magnetite, haematite, chromite, kaolinite, gibbsite are the major minerals with minor amount of magnesio-ferrite in the chromite plant tailing sample. Chromite occurs interlocked within silicate mineral or martite and requires liberation. Chromite tailing was beneficiated by using Falcon concentrator.

6. Flotation Studies on Low-grade Rock Phosphate Sample from Jordan: Bench- and large-scale flotation studies were carried out with an objective to upgrade ore with 52% tricalcium phosphate (TCP) to 70% TCP with silica content below 8%. Initially, the sample was subjected to scrubbing, screening/classification and desliming for preparing feed for flotation. The deslimed two size classes, coarse and fines, were subjected to concentration by froth flotation, separately. Sodium silicate along with emulsion of sodium oleate and diesel oil was used as depressant and collector, respectively. Finally, the result obtained during the bench-scale test was validated at a large scale. Solid and water balance was established for each flotation scheme.

7. Reduction of Reactive Silica in Bauxite for Use in Alumina Production: In the present investigation, studies were carried out on processing of bauxite for possible reduction in reactive silica content to below 4% from a feed containing reactive silica ~6%. The beneficiation study included bench-scale scrubbing and washing followed by pilot-scale validation of the bench scale results. Bench- and pilot-scale beneficiation studies were carried out at CSIR-NML and the results of the studies demonstrated that there was appreciable reduction in the reactive silica content (<3.6%) with increase in total available alumina content in the beneficiated product.

8. Processing of Limestone and Clay Samples for White Cement: In order to make clinker for white cement, it is necessary to minimise the amounts of iron and other transition elements (titanium, chromium, manganese, nickel and zinc) in the raw mix composition. The Fe_2O_3 content in limestone and clay studied was 0.068% and 0.45%, respectively. Attempts were made towards removal of mineral contaminants from limestone and clay by processing samples involving wet high intensity magnetic separation. Processing of the samples by wet high intensity magnetic separation has given encouraging result. It is proposed to optimise the process parameters to get maximum yield of limestone and clay with high rejection of gangue materials. The detailed study is in progress.

9. Beneficiation of Waste Dump Manganese ore Fines for Production of Ferroalloys: In the present investigation, it was aimed to develop beneficiation process flow-sheet for upgradation of the low-grade manganese ore for use in ferromanganese/silicomanganese application. Three different low-grade manganese ores were studied through physical, chemical and mineralogical characterisation. The mineralogical study revealed the presence of haematite, goethite, pyrolusite, psilomelane/

manganomelane, todorokite, kaolinite, gibbsite and quartz. Goethite, pyrolusite and psilomelane/ manganomelane are intimately associated at very fine scale. The response of the ores to different beneficiation methods is under study.

10. Beneficiation of Low-grade Dolomite Ore: A collaborative R&D project has been undertaken to study the characterisation and beneficiation of three different types of dolomite samples having different chemistry towards the reduction of alkali and silica contents for application in iron & steel making. The study aims at developing process for reduction of K_2O level to preferably less than 0.2%. Characterisation studies of all the three samples were carried out by megascopic, optical microscopic and XRD studies to identify the mineral phases in the as received samples, their textural relationship, optical characteristics, mode of occurrence and distribution. Dolomite is the dominant mineral with occasional calcite. Muscovite, biotite, K-feldspar and quartz were observed as the major gangue minerals and the abundance increases as the SiO_2 and K_2O increase. As the liberation of gangue minerals are found in finer size for all the three types of ore, beneficiation studies have been carried out by froth flotation technique to reduce the K_2O and silica level. Froth flotation study was conducted with varied process parameters. The results are encouraging and work is in progress.

Manganese Ore India Ltd (MOIL)

MOIL has carried out R&D activities to improve the safety and productivity in the mines by introducing modern technology in collaboration with CSIR R&D laboratories, reputed academic and R&D Institutions of the country. MOIL has engaged and was associated with several institutions for many R&D projects - (i) CSIR-Central Institute of Mining & Fuel Research, Nagpur and Dhanbad; (ii) CSIR-National Metallurgical Laboratory, Jamshedpur; (iii) CSIR-National Geophysical Research Institution, Hyderabad; (iv) CSIR-National Environmental and Engineering Research Institute, Nagpur; (v) Indian Institute of Technology, Kharagpur; (vi) Indian Institute of Technology, (Formerly Indian School of Mines), Dhanbad; (vii) National Institute of Technology, Rourkela; (viii) Visvesvaraya National Institute of Technology, Nagpur; (ix) National Institute of Rock Mechanics, Kolar Gold Fields; and (x) Indian Institute of Engineering Science and Technology, Shibpur. Significant R & D projects undertaken are listed below-

1. Mine Environment

1.1 Ventilation: Ventilation reorganization studies for deeper levels have been conducted by Indian Institute of Technology (IIT), (formerly ISM), Dhanbad for Balaghat Mine. Ventilation drifts have been relocated at Balaghat Mine and sinking has been commenced for 5m diameter ventilation drifts. It will help improve the face ventilation and productivity of underground sections of Balaghat Mine. Moreover, as per the recommendations of the IIT, Kharagpur for deeper level ventilation, large diameter ventilation fan with energy saving devices has been commissioned at newly constructed evasee at Gumgaon Mine. It has improved the ventilation standard in underground section of Gumgaon Mine and resulted in improvement in production.

1.2 Sustainable Development Framework: Collaborative scientific research for evaluation of environmental parameters in and around Kandri and Munsar mine has been completed for on line continuous monitoring of air, water and noise parameters on experimental basis by Indian Institute of Engineering Science and Technology (IIEST), Shibpur.

2. Mines Safety

2.1 Mining Subsidence: In-house 3-D analysis of subsidence parameters have been carried out by MOIL and found that there are no noticeable movements in any orthogonal direction above the ground at Munsar mine. In-house prepared subsidence parameter scientific report has been vetted by IIT, Kharagpur. The subsidence monitoring by in-house developed 7 pillars for micro-analysis has been designed for better safety.

2.2 Rock Mechanics: CSIR-CIMFR, Nagpur and Dhanbad centre have been engaged to design support system for better safety and productivity of ROM at Balaghat and Ukwa underground mines. Accordingly, advanced support system has been adopted for better safety standards.

3. Mineral Conservation: R&D studies conducted by National Institute of Rock Mechanics (NIRM), KGF for stope design have been implemented at Munsar mine. The modified stope design has increased the quantity of manganese ore in underground for exploitation by around 20%. Further, long hole drill and blast method for semi-mechanised operation is in experimental stage at the mine for safety and productivity improvement.

4. Mining Technology

4.1 Rock Mechanics: MOIL has designed in-house rock mechanics software 'MOIL-RMR' for rock mass characterisation and support design. It is indicating RMR & Q and putting the values directly in graph without any human-machine interference (HMI) and indicating roof span, stand-up time and designated support for method of workings for better safety.

4.2 Underground Mechanisation: For mechanical handling of ROM in drifts and stopes, SDL along with modern electro-hydrostatic drill machine – Universal Drilling Machine (UDM) has been introduced on experimental basis at Chikla and Gumgaon Mine. This helps for faster development of drivages and removal of ROM and waste rock from underground.

4.3 Alternative to River Sand: R&D wing of MOIL has used old refuse overburden material with crushing, screening and heat treatment of material at Munsar mine for hydraulic transportation in underground for stowing. Bench-scale studies and field trials confirm that the treated old refuse overburden material could be used for hydraulic transportation for stowing in underground with or without river sand. Further field trials are in progress at mine site. This will help reduce the consumption of river sand in substantial quantity in future years. Besides, trials are going on at mine site with combination of bottom/pond ash for substitute of river sand for hydraulic stowing in mines. Such field trials have also been completed at Balaghat mine.

5. Mineral Beneficiation: R&D studies on "Bench-scale beneficiation study on a manganese ore sample from Balaghat mine" have been carried out by Modern Mineral Processing Laboratory and Pilot Plant, Indian Bureau of Mines, Nagpur for recovery of sand and manganese separately. This has generated composite Mn concentrate assaying 40.82% Mn and 16.39% SiO_2 with a Mn and SiO_2 distribution of 49.6% and 9.2%, respectively (wt % yield 27.6). A composite sand concentrate assaying 15.46% Mn and 63% SiO_2 with Mn and SiO_2 distribution of 46.1% and 84.5% respectively (wt % yield 66.7) was also obtained.

6. Modern Radar Technology: Time Domain Refractrometry (TDR)-based wireless system for slope stability monitoring has been installed at Dongri Buzurg open-cast mine in collaboration with NIT, Rourkela. Studies for better safety and productivity are in progress.

7. Metallurgical Studies: CSIR-IMMT and CSIR-NML combine optimised process for reduction of Fe impurity in final EMD product to the lowest level possible, i.e. <100 PPM, and MnO content in EMD was also improved. In-house plant results also show consistent results of iron less than 100 PPM.

8. In house R & D in Cement Concrete: Pre-cast concrete columns and beams have been prepared for concreting work in underground drifts. This has improved the safety standard and reduced time for erecting of concrete supports in underground drifts. Installation is in progress at Gumgaon Mine.

National Mineral Development Corporation Ltd (NMDC)

NMDC R&D centre is dedicated to undertake product and technology development projects related to ores, minerals and steel making to maintain its excellence in process performance. R&D centre has made significant contribution not only to NMDC operating projects but also to Indian industries and is recognised by Department of Scientific and Industrial Research (DSIR).

R&D centre undertakes works related to mineral processing, flow sheet development, mineralogical studies, material handling & storage, metallurgical studies of iron ore and coal, chemical analysis etc. Various research projects completed by the R&D Centre.

1. Projects of NMDC Mines/Projects

(i) Physical and metallurgical characterization of iron ore samples received from Bailadila sector

(ii) Physical and metallurgical characterisation of pellet samples of NMDC Pellet Plant

(iii) Various samples received for characterisation and chemical analysis from Investigation department

(iv) Characterization of coking coal sample

2. In-house Developmental Research Projects

2.1 Conservation of Energy

(i) Utilisation of microwave heating in iron ore pellet making

(ii) Utilisation of mining waste (slimes)

(iii) Study on flow characteristics of different iron ores of India

(iv) Study on energy requirement for firing of iron ore pellet using oil/gas/ coal/ electrical heating including microwave

(v) Pelletisation studies on iron ore (blue dust)

2.2 Technology Absorption

(i) Beneficiation studies with high ash coal sample

(ii) Study on red mud for making value-added products

(iii) Study of making of value-added product from slimes/tailings

2.3 Collaborative Programmes under progress

Sl. No.	Collaborating Institutes	Title and Nature of Work
i).	CSIRO, Australia	Characterisation and beneficiation studies on laterite/ goethite iron ore. Development of dry beneficiation technology for processing of hydrated iron ore.
ii).	IIT, Bhubaneswar	Optimisation of Silos, Bins and Hoppers design through modeling, primarily intended for iron ore storage.
iii)	CSIR-IMMT, Bhubaneswar	a) Modeling & Optimisation of high concentration Iron ore fines/concentrate slurry pipeline for Indian Iron Ore Processing Industry. b) Development of application of Nano iron oxide obtained from blue dust in energy & sensors devises. c) Dry beneficiation of Iron ore and coal using VSK Separator
(iv)	NIT, Raipur	Study on improvement of potability of ground water in surrounding area of mines
(v)	CSIR-CIMFR	Development of Vision enhancement system for foggy weather

Tata Steel Ltd

1. Projects under Research and Development

1.1 Implementation of Second Stage Hydrocyclone trials at Ores, Mines & Quarries (OMQ) to Recover the Iron Values from Online Slime: In the absence of adequate beneficiation facility at Noamundi, ~15% of wet run-of-mine is discarded as slime having ~8% aluminium oxide (Al_2O_3) and ~55% iron. Based on modelling and simulation results, continuous trial of 25 tonnes/ hour capacity was carried out using modular second stage hydrocyclone plant at Noamundi for a period of 30 days. The trials have indicated a potential to recover approximately 50% iron value from slime having ~4.5% aluminium oxide and ~62% iron.

1.2 Wollastonite Flux Trials at Iron Ore Pellet plant, to Improve the Pellet Strength and Productivity: Wollastonite-based calcium silicate has been established as flux in iron ore pelletisation to improve the pellet strength and productivity. Trails at 6 MTPA pelletising plant at 1.3% dosage successfully improved the pellet Cold Compressive Strength by 30 points.

1.3 Process for Rapid Heating of Non-coking Coal to Coke through Microwave Energy: The process has demonstrated the technology at bench-scale with 40% non-coking coal in the coal blend and the Company is planning to upscale the technology to a continuous coke making at a scale of 1 tonne/hour.

1.4 Cyanide removal from Steel Industry Effluents: 5 m^3/hour Pilot study of new advance oxidation process for tertiary treatment for cyanide removal below 0.2 PPM of total cyanide has been established.

1.5 Value from Waste: Established a process for using water-cooled and air-cooled Ferrochrome slag material in applications, such as, bitumen road, concrete and fly ash slag bricks.

1.6 Online Laser Profile Measurement at H Blast Furnace: A laser profile meter system installed at H Blast Furnace images real time top burden profile. An algorithm is developed which further processes the image data to generate critical insights for blast furnace operators, such as, check for non-uniformity in distribution, burden descent rate, layer profile, coke ratio distribution across the diameter of furnace across all radial points amongst others.

2. Process Improvement

2.1 Mining & Beneficiation

(i) An insight development on application of blast free mining technology (Surface Miner) in hard rock (Underground Coal Study: ~80 Mpa), such as, overburden material (sandstone, shale etc.) near West Bokaro has been conducted.

(ii) The identification of strata monitoring parameters and suitable instruments to understand strata behaviour and design suitable support system for Jharia group coal mines has been conducted.

(iii) Assessing and improving screw classifier performance at wet plant, Noamundi Iron Ore Mines.

(iv) Finalising 0.6 MTPA slime beneficiation using High Gradient Magnetic Separator (HGMS) plant at Noamundi.

(v) Finalising paste thickener technology for slime disposal at OMQ.

(vi) Improving efficiency of Gomardih dolomite for production of magnesium by TechMag process through thermodynamic feasibility study. This can yield magnesium with grade of 99.6% purity.

(vii) Enhancing process visibility at West Bokaro Washery#3 by installing of 6 flow meters and 6 density meters in critical locations of Washery#3 fines circuit – flotation, vacuum belt filter, reflux classifier.

(viii) Enablers to improve flotation performance: (a) Lab studies in Hydrophobic Hydrophilic Separation (an advanced version of oil agglomeration) at Virginia Tech. (USA) indicate possibility to achieve higher yields at a significantly lower ash (>9%) and moisture (<2%) simultaneously. (b) Trial and regularisation of additional Coagulant and flocculant in effluent of Bird Centrifuge at Bhelatand Coal Preparation Plant, resulting in 0.58% yield gain on Raw Coal basis. (b) 0.4% clean coal yield improvement on raw coal basis established by replacement of conventional rotor-stator in 3 flotation cells (out of 12) with new generation mixing mechanism (Float Force) developed by Outotec.

2.2 Agglomeration

(i) Developing iron ore distribution model with the aim to optimise overall cost (logistics and value in use) across the sites.

(ii) Improvement in Sinter Reducibility Index from 73.9 to 76, sustaining the Reduction-Degradation Index average as per MoU with blast furnace.

2.3 Blast Furnaces

(i) Utilising of 3.15 mm to 5 mm size sinter at 'I' blast furnace has led to a greater proportion of agglomerates in the blast furnace burden with a consequent improvement in gas utilisation and reduction in the fuel rate.

(ii) Deploying of the raw flux prediction system in Level 2 across F, G, H and I blast furnaces which streamlined the indiscriminate addition of raw fluxes under varying raw material chemistries thereby leading to realisation of a consistent slag chemistry regime.

(iii) Developing an operating philosophy of a large blast furnace using two stoves. The same has enabled sustenance of stable blast furnace operations in the event of a stove outage.

(iv) Improvement in Pulverised Coal Injection rate at Blast Furnace at TSK from 151 kg/thm to 177 kg/thm by improving the injection capacity.

2.4 Ferroalloys

(i) Established new way of electrical power reduction in ferrochrome production at Bamnipal by addition of ferrosilicon as reducing agent through a series of lab trials.

(ii) Developed practice for re-using ferrochrome fines as value-added product. The plant trial will take place in FY 2020-21.

2.5 Process Visualisation & Diagnostics

(i) Developed Virtual pile making model using real time data for Noamundi iron ore pile facilitating visibility of chemical composition and material mix of every location of 100 kilo tonne pile, to identify and take corrective action in order to reduce standard deviation of iron ore fines quality.

(ii) Successful trial of image-processing-based foreign particle detection system in raw material conveyer belt to eliminate any breakdown due to high density material (e.g. concrete boulders mixed with coal) entering the grinding circuit of mills.

(iii) Developing real time alert system for coke ovens to improve operational efficiency and oven health.

2.6 Process Energy & Emission

(i) Formed CO_2 impact centre to drive CO_2 reduction ideas. About 12 million tonnes of CO_2 ideas were identified.

(ii) Reusing disposed Electro Static Precipitator dust in agglomeration process, washing of dust trial done in I Blast Furnace Gas Cleaning Plant.

(iii) Developed CO_2 intensity model for iron-making to diagnose the deviation.

2.7 Characterisation and Specialty support

(i) Higher Value-added Downstream Product from Coal Tar: For better realisation from coal tar, a by-product of coke making process, the technology team and R&D team are exploring the possibility to manufacture General Purpose Carbon Fiber and High-Performance Carbon Fiber from it and to characterise the carbon fiber for suitable standard applications.

(ii) Manufacturing of Sustainable and Green Construction Materials from LD Slag: Tata Aggreto & Tata Nirman are two brands created to upcycle Steel Slag into sustainable building materials, such as, different grades of Paver Blocks, Fly Ash bricks, etc. These value-added products are characterised by higher durability, lower water absorption capacity and better compressive strength as compared to traditional building materials.

(iii) Comprehensive Collaborative Study on Utilisation of LD slag in Portland Slag Cement: In this collaborative project with National Council of Cement and Building Materials, Faridabad, LD slag samples from other major integrated steel plants in India were also covered.

2.8 Raw Material Holding System

(i) Reduction in rail idle freight in Outbound logistics to ₹ 261/tonne in 2019-20 from ₹ 338/tonne in 2018-19.

(ii) In-house modification of Single Wagon Tippler to handle 'BOST' rake that has reduced the dependency of 'BOXN' wagons for material handling.

(iii) Improved throughput of Value Added Products to 391 KT in 2019-20 from 200 KT in 2018-19.

(iv) Reduction in Man-Machine interface by administrative control by use of designated pathways, drop gate installations, and Reinforced Cement Concrete Toe wall at Rail siding.

2.9 Coke Plant

(i) Development of In-house integrated Level II system for the operation of Coke Drying Quenching using Advanced Analytics.

(ii) Development of common pushing and charging schedule for both the Coke Oven Batteries using Advanced Analytics.

(iii) Improvement in defects in coke strength after reaction through coal yard management.

Hindustan Copper Ltd (HCL)

HCL has undertaken the following R&D projects:

(i) ICC R&D activity was carried out and established an experiment for Extraction and Recovery of Copper metal from ESP dust by Leaching and Electro wining.

(ii) NABL accreditation for laboratory at ICC & TCP is under progress.

Hindustan Zinc Ltd (HZL)

Specific areas in which R&D has been carried out by HZL in FY 2020 are given below-

(i) Testing of alternate reagents like Silver promoter, Graphite depressant, Cyanide replacement and strong frothers on various ores.

(ii) Minor metal mapping of mine tailings.

(iii) Exploring chloride-based leaching for low-grade bulk concentrates and smelter residues.

(iv) Evaluating techniques to address graphite challenges arising in ores.

(v) Studied the impact of lead re-grinding on lead/ silver recovery.

(vi) Development of a novel process to recover metal values from Rampura Agucha Mine tailings.

(vii) Studied the effect of pH on Galena and silver-bearing minerals recovery on flotation of Rampura Agucha ore.

(viii) Mineralogical characterisation of various HZL ore samples to predict mesh of grind and its implications for processing.

(ix) Explored germanium potential in various streams and collaborating with institutes for germanium recovery.

(x) Jarosite moisture reduction and sustainable usage in Construction Sector.

(xi) Zinc Hydro-smelter circuit study to improve Copper recovery in cemented cake.

(xii) Explored control leaching and solvent extraction to generate enriched cobalt cake from purification cake.

(xiii) A sustainable anode mud leaching process has been developed to maintain optimum manganese level at zinc hydro smelter and recover lead silver values.

(xiv) Developed process to generate zinc sulphate crystals from zinc dross.

The benefits derived as a result of the above R&D are given below:

- Trials of new silver promoter resulted in improved silver recovery at Zawar. Trials are in progress at SK mines.
- Mineralogical characterisation and liberation assessment helped in identifying reasons for misplacement and metal losses in tailings, there by suggesting opportunities for improvement.
- Enhanced mine to metal recovery by exploring unconventional leaching technologies for smelter residues and low-grade concentrate.
- Improvement in lead recovery by 2% and reduction in zinc misplacement in lead concentrate by lead middlings regrinding.
- Improved realisation from by-products by grade enhancement.
- Tapping minor metal potential in existing streams.
- Enhanced realisation from value-added products.
- Sustainable usage of Jarosite and other wastes.