Indian Minerals Yearbook 2021

(Part- I : GENERAL REVIEWS)

60th Edition

RESEARCH & DEVELOPMENT

(ADVANCE RELEASE)

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 which include rock mechanics, mine designing, mining equipment, energy conservation, environmental protection and mine safety; (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.

Ministry of Mines has launched SATYABHAMA (Science and Technology Yojana for Aatmanirbhar Bharat in Mining Advancement) Portal (research.mines.gov.in), dedicated to project proposals under Science and Technology Programme Scheme of Ministry of Mines. 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 year 2020-21, project proposals under the S&T Scheme of Ministry of Mines were invited online through SATYABHAMA portal. As per Minutes of 20th PERC meeting held during 23-25 Nov. 2020, a total number of 383 project proposals were received online on the portal. A two-stage review process was adopted to evaluate the proposals for recommendation to Standing Scientific Advisory Group (SSAG). The first stage comprised of preliminary screening of the proposals done by a team of experts constituted by Ministry of Mines. Based on the guidelines as adopted in 14th PERC, the experts conducted pre-screening of the proposals. After screening, 102 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 review in the second stage. These 102 project proposals were presented by the respective Principal Investigators (PIs) and evaluated by the committee during the VC meeting held on 23-25 Nov 2020. Based on the detailed review and evaluation, 28 new Project Proposals were recommended with or without changes to SSAG while 68 Project Proposals were not recommended. A total of 6 Project Proposals were to be revised and resubmitted in next PERC. In addition to the above, 38 ongoing projects were reviewed by the committee.

Besides, progress reports/final reports, requests for time extension, etc. of ongoing projects under the S&T Programme Scheme of Ministry of Mines were also considered by the committee for review in the 20th PERC Meeting and Review Meeting of PERC (held on 21-22 January, 2020).

The projects recommended by the PERC were further considered during 52nd meeting of the SSAG held on 24th December 2020 through video conferencing. Chairman/Secretary (Mines) suggested the need to focus on applied R&D projects with outcomes which could be translated into benefits for the society. After detailed deliberation, SSAG approved 28 project proposals (Table-1).

The SSAG also approved foreclosure of the following 3 projects recommended by PERC:

(i) Geochemical Studies of the Archaean Greenstone Belts of the Aravali Craton, Northwestern Indian Shield: Implications for Crustal Evaluation and Economic Potential— Aligarh Muslim University, Aligarh

(ii) Development of a Low-cost Portable Optical Reflectance Spectrometer for Mining and Mineralogy— Indian Institute of Technology, Madras

(iii) Development of capacitive deionisation technology for the extraction of germanium and selenium: Two elements of strategic relevance— IIT, Madras, Chennai

After deliberation, the SSAG accepted the final report and approved the closure of the 18 projects (Table-2) and release of remaining funds, subject to finalisation of accounts and other relevant procedures.

In view of the COVID-19 pandemic, the SSAG has approved, based on recommendations of PERC, time extension for 27 ongoing projects.

Table -1: Details of Projects Approved under S & T Programme, Ministry of Mines during 52nd meeting of SSAG

Sl. No.	Project Title	Implementing Institution	Project Cost & Duration of Project
1.	Studying, modelling and evolving a new blasting technique for open cast mine excavations near the proximity of structures (beyond 50 m) using the structural response analysis and dynamic FEM	CSIR, Central Institute of Mining and Fuel Research	Cost: ₹ 38.19 Lakh Duration: 3 year
2.	Recovery of copper from water bodies nearby copper mines using microbial electrochemical systems	IIT, ISM Dhanbad (Partner-Hindistan Copper Ltd	Cost: ₹ 25 Lakh Duration: 18 month
3.	Corrosion and wear resistant advanced coatings based on high entropy alloys for mining equipment	IIT, Delhi	Cost: ₹ 24 Lakh Duration: 2 year
4.	Design, analysis and development of Rheo gravity die cast Al-15Mg2Si-4.5Si composite based light weight Bucket links for Mining Excavators	CSIR Central Mechanical Engineering Research Institute (Partner - LA-CAST Metals & Components Pvt. Ltd, Mahalaxmi Auto Industries)	Cost: ₹ 55 Lakh Duration: 2 year
5.	Development of empirical methodology for design of Crown Pillar during transition from opencast to under-ground mining for Indian Mines	CSIR Central Institute of Mining and Fuel Research	Cost: ₹37.8985 Lakh Duration: 3 year
6.	Determination of optimum safe distance of toe of dump from crest of open-pit for stability of pit slope under different geo-mining conditions	CSIR Central Institute of Mining and Fuel Research (Partner -HZL, Tata Steel and SAIL)	Cost: ₹ 52 Lakh Duration: 2 years
7.	Development of Ready-To-Use Assorted Sand for Construction Activities from Zinc Refining Wastes and Marble Powder	Manipal University Jaipur (Partner -HZL and Manak Sangemermer Pvt. Ltd)	Cost: ₹ 30 Lakh Duration: 2 years
8.	Preparation of synthetic zircon from zircon minerals of beach sand, its characterisation and value addition as thermal and electrical insulator	C.V. Raman Global University, Bhubaneswar (NGO -Society Raman Education)	Cost: ₹ 10 Lakh (seed money) Duration: 1 year

(Contd.)

Table – 1 (Contd.)

Sl. No.	Project Title	Implementing Institution	Project Cost & Duration of Project
9	Geo-technological evaluation of Bauxite and Laterite deposits of Chhattisgarh State by using Geospatial technology under Smart Mining 4.0	JNARDDC, Nagpur (Partner– Chhattisgarh Council of Science & Technology, Govt. of Chhattisgarh, Raipur)	Cost: ₹ 45 Lakh Duration: 2 year
10.	Development of low cost filler material utilising Lithomargic clay for Paint Industry as per IS 68 2006 standard	JNARDDC, Nagpur (Partner– Mundle Paint and Chemicals)	Cost: ₹ 45 Lakh Duration: 2 year
11.	Fabrication of Al_2O_3 containing cellulose based Ag NPs encapsulated Collagen dressing and investigation of its Therapeutic Opportunities in Diabetic Wound Healing	Kalinga Institute of Industrial Technology & JNARDDC, Nagpur	Cost: ₹ 30 Lakhs (₹ 15 Lakh each) Duration: 2 year
12.	Design, synthesis and fabrication of donor-acceptor based fluorescent sensing organic-nanomaterials and devices for detection and quantification of rare-earth elements in minerals	University of Calcutta	Cost: ₹ 54.935 Lakh Duration: 2 year
13.	Extraction and isolation of Al, K, Li, Rb and Cs from Mica	CSIR Institute of Minerals and Materials Technology	Cost: ₹ 9.975 Lakh Duration: 1 year
14.	Development of process for making High Pure Quartz or Silica and Metallic Silicon from low-Grade naturally occurring quartz	CSIR Institute of Minerals and Materials Technology	Cost: ₹ 15 Lakh (seed money) Duration: 1 year
15.	Development of India specific scientific framework to promote the beneficial reuse, rehabilitation or remediation of landscape affected by abandoned mines or flyash ponds or slags	IIT, BHU Varanasi; IIT, Bombay; NIT, Rourkela; NIT, Surathkal; IIT, Guwahati; IIT, Indore; IIT, Roorkee; IIT ISM Dhanbad; IIT, Kharagpur; IIT, Madras; IIIT, Hyderabad; Nalanda University and IIT, Kanpur (Partner - MOIL, Hindalco and Triveni Earth Movers)	Cost: ₹ 49.98 Lakh Duration: 2 year
16.	Employing metallurgical silicon to develop new class of silicon composites for structural applications	IIT, Bhubaneswar	Cost: ₹ 37.997 Lakh Duration: 2 years
17.	Bioleaching of lithium from minerals and low-grade ores of Indian origin	CSIR Institute of Minerals and Materials Technology	Cost: ₹ 12.936 Lakh (seed money) Duration: 1 year
18.	Production of high pure manganese metal organic frameworks (Mn-MOFs) and their derivatives from low-grade manganese ores for supercapacitor applications	CSIR Institute of Minerals and Materials Technology	Cost: ₹ 10 Lakh (seed money) Duration: 1 year
19.	Development of Alternative flux Material from Red Mud for Steel Dephosphorisation	CSIR Central Electro-chemical Research Institute	Cost: ₹ 10 Lakh (seed money) Duration: 1 year
20.	Development of prototype aluminium seat frame for passenger buses	JNARDDC, Nagpur and Automotive Research Association of India	Cost: ₹ 100 Lakh (JNARDDC – ₹ 60 Lakh; ARAI – ₹ 40 Lakh) Duration: 2 Years
21.	Sustainable ion exchange resin-based technology for rare earth extraction	IIT, Madras	Cost: ₹ 52.51 Lakh Duration: 2 years
22.	Bio-electrochemical reclamation of titanium and other rare-earth metals from red mud waste using a modified microbial fuel cell approach	PSG Institute of Advanced Studies (NGO – PSG and Sons Charities)	₹. 9.99 Lakh (seed money) Duration: 1 year

(Contd.)

Table – 1 (Contd.)

Sl. No.	Project Title	Implementing Institution	Project Cost & Duration of Project
23.	Exploring the practicability of extracting platinum and palladium from the mineral beds of Village Sittampudi in Salem District of Tamil Nadu — An Experimental and Molecular Dynamics Approach	NIT, Trichy	Cost: ₹ 15 lakh (seed money) Duration: 1 year
24.	Development of perovskite-based materials using inexpensive RE mixed oxides precursors derived from Indian beach sands for room temperature magnetic refrigeration applications	CSIR Indian Institute of Chemical Technology	Cost: ₹ 51 Lakhs (MoM – ₹ 31 Lakh, CSIR – ₹ 20 Lakh) Duration: 1 year
25.	Recovery of galena, sphalerite from lead zinc tailings by integrated energy efficient ultrafine comminution and novel shear floc-flotation and its impact on downstream Paste fill	IIT, Hyderabad and CSIR Institute of Minerals and Materials Technology (Partner – HZL)	Cost: ₹ 25 Lakh (MoM - ₹ 10 lakh seed money; HZL - ₹ 15 Lakh) Duration: 1 year
26.	Additive manufacturing of Rare-earth based Nd-Fe-B magnets	International Advanced Research Centre for Powder Metallurgy and New Materials	Cost: ₹ 52 Lakh Duration: 2 years
27.	Innovative approach to recover chromite value from low-grade chromite ore, fines and slimes by dry and wet beneficiation technique	CSIR Institute of Minerals and Materials Technology	Cost: ₹ 10 Lakh (seed money) Duration: 1 year
28.	Process development for the recovery of tungsten values from lean grade Indian resources.	CSIR Institute of Minerals and Materials Technology	Cost: ₹ 10 Lakh (seed money) Duration: 1 year

Source: *Minutes of 52nd meeting of SSAG.*

Table -2: Details of Acceptance of Final Report and Closure of Completed Projects under S & T Programme, Ministry of Mines during 52nd meeting of SSAG

Sl. No.	Project Title	Implementing Institution
1.	Development of super thermal aluminium (STAL) conductor for Indian Power Sector.	JNARDDC, Nagpur & NFTDC, Hyderabad (Jointly)
2.	Simulation of simultaneous rock fractures at multiple scales.	IIT Delhi
3.	Urban Li Battery Mining: Physio-Chemical separation of used Li ion Batteries for Recovery of Li, Co, Ni active materials and Cu, Al Metal.	Nonferrous Materials Technology Development Centre, Hyderabad
4.	Production of geopolymer-based construction material from pond ASH: an industrial waste.	Gandhi Institute of Engineering and Technology, Gunupur, Odisha
5.	Novel synthesis routes for high purity kesterites (CZTS:Cu-Zm-Sn-S; Cu-Zn-Sn-Se) and development of cost kesiterite based solar PV cells and modules.	Non-Ferrous Materials Technology Development Centre, Hyderabad
6.	Recyclability strategy or value-added utilisation of iron/manganese ore tailing/low-grade ore: evaluation of energy storage capacities .	Institute of Minerals and Materials Technology, Bhubaneswar
7.	Extraction of potash values from silicate rocks.	IIT, Roorkee, Uttarakhand
8.	Mineralogical and geochemical characterisation of Indian glauconites for alternative potassium fertilizers.	IIT, Bombay and NGRI, Hyderabad (jointly)
9.	Development of low density emulsion explosives for energy efficient blasting in environmentally sensitive areas.	IIT, Dhanbad (Indian School of Mines, Jharkhand

(Contd)

Table – 2 (Contd.)

Sl. No.	Project Title	Implementing Institution
10.	Technology Development (TRL-7) for calico-thermic reduction of rare-earth metal oxides and establishment of pilot plant for extraction and purification of samarium.	Non-ferrous Material Technology Development Centre, Hyderabad
11.	Development of Nickel containing steel from chromite overburden.	IIT, Kharagpur and Institute of Minerals & Materials Technology, Bhubaneswar (Jointly)
12.	Processed Sea sand for construction and other purposes.	Saveetha Engineering College, Saveetha Nagar, Thandlam, Chennai
13.	Novel Approach to Recover Individual Valuable Heavy Minerals from Pyriboleferrous Beach and Dune Sand Deposits.	CSIR–Institute of Minerals & Materials Technology, Bhubaneswar
14.	Nano Processing of Industrial Rejects for use as additives in Mix designs for improved pozzolanic reaction efficiency.	JNARDDC, Nagpur and VNIT, Nagpur VNIT, Nagpur
15.	Study of Alkaline – Carbonatite complexes as potential resources for REEs, Nb-Ta and U-Th.	IIT Roorkee, Uttarakhand
16.	Assessment and prediction of land surface deformation due to underground metal mining in northern Aravali Range of hills using microwave remote sensing data sets and ground based Observations.	IIT, Dhanbad (Indian School of Mines), Jharkhand
17.	Study the feasibility of treatment of seepage water from chromite mine quarries of Odisha.	National Institute of Technology, Rourkela
18.	Optimisation of digestion efficiency in Bayer process by ascertaining the ideal size fraction of bauxite feed.	JNARDDC, Nagpur and VNIT, Nagpur

Source: *Minutes of 52nd meeting of SSAG.*

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 2020-21 are furnished below:

Indian Bureau of Mines (IBM)

Important R&D activities carried out by IBM during the year 2020-21 are summarised below.

A. Mineral Processing Division, IBM

1. COPPER ORE

1.1 Bench-scale Beneficiation Studies on Copper bearing Sample (G-2 level exploration) from Northern part of Toda Ramliyas block, Sikar, Rajasthan.

The sample assayed 0.40% Cu, 5.10% Fe(T), 42.98% SiO_2, 9.76% Al_2O_3, 11.51% CaO, 9.55% MgO, 0.18% S(T), 0.63% TiO_2, 2.38% Na_2O, 1.26% K_2O, 12.11% LOI and 58.86% AI (Acid Insolubles).

Beneficiation studies using froth flotation process yielded a composite concentrate (concentrate + second cleaner tails) that assayed 27.18% Cu with Cu recovery of 87.82% (Wt% yield 1.30).

1.2 Bench-scale Beneficiation Studies on Copper bearing Sample (G-2 level exploration) from RJBN (Lode I), Bokri North Block of Jhunjhunu, Rajasthan

The sample assayed 0.27% Cu, 3.49% Fe(T), 59.81% SiO_2, 8.99% Al_2O_3, 9.23% CaO, 5.17% MgO, 0.46% S(T), 0.51% TiO_2, 6.71% LOI, 0.03% Mn.

Beneficiation study employing froth flotation process yielded a copper concentrate that assayed 19.69% Cu with 85.60% copper recovery (Wt% yield 1.18).

1.3 Bench-scale Beneficiation Studies on Copper bearing Sample (G-2 level exploration) from RJBN (Lode II), Bokri North Block of Jhunjhunu, Rajasthan

The sample assayed 0.25% Cu, 3.39% Fe(T), 70.33% SiO_2, 7.12% Al_2O_3, 7.17% CaO, 5.04% MgO, 0.42% S(T), 0.40% TiO_2, 3.82% LOI, 82.87% AI, 0.02% Mn.

Beneficiation studies using froth flotation process yielded a copper concentrate assaying 19.31% Cu, with 88.75% copper recovery (Wt% yield 1.15).

1.4 Bench-scale Beneficiation studies on a Copper Ore Sample (G-2 level exploration) from Lingsurur taluk, Raichur district, Karnataka

The sample assayed 1.06% Cu, 2.90% Fe(T), 78.06% SiO_2 and 85.28% Acid insoluble.

Froth flotation studies on as received sample ground to all -200 mesh size yielded a copper concentrate assaying 29.84% Cu, 15.41% SiO_2, 19.89% Acid insoluble with 75.6% copper recovery (Wt.% yield : 3.0).

2. IRON ORE (BHQ)

2.1 Pilot-scale Beneficiation Studies on an Iron Ore Banded Hamatite Quartzite (BHQ) Sample (Mine Reject) from Dongarbor iron ore mines, Rajnandgaon, Chhattisgarh for Industry

The sample assayed 33.5% Fe(T), 49.7% SiO_2, 1.1% Al_2O_3, 0.17% CaO, 0.032% MgO, 0.011% TiO_2, 0.03% P, 0.083% Mn and 1.2% LOI.

Pilot-scale beneficiation studies were carried out on the sample employing different techniques like crushing, screening, grinding, gravity separation employing spiral and wet high intensity magnetic separation, etc. The beneficiation process route evolved for the up gradation of Fe (T) and reduction of Silica content yielded a combined concentrate comprising of cleaner spiral concentrate and scavenger spiral concentrate assaying 61.0% Fe (T), 11.1% SiO_2, 0.7% Al_2O_3 and 0.4% LOI with Wt% yield of 26.1% and 47.6% Fe (T) recovery.

3. IRON ORE

3.1 Beneficiation Studies on a Composite Iron Ore Sample from Belgaum, Karnataka for Industry

The composite sample assayed 58.15% Fe(T), 82.57% Fe_2O_3, 5.50% SiO_2, 3.36% Al_2O_3, 0.36% FeO, 1.11% Mn, 0.12% CaO, 0.06% MgO, 0.07% P, 0.12% S(T), 0.19% TiO_2, and 6.28% LOI.

Wet High Intensity Magnetic Separation tests were conducted on sample, stage grinding of +65 mesh followed by wet magnetic separation at 2,000 gauss and cleaning of the non-mag at 13,000 gauss yielded a composite magnetic concentrate (Mag-I and II) which assayed 62.95% Fe(T), 1.45% SiO_2, 1.19% Al_2O_3 and 5.84% LOI with Fe(T) recovery of 80.4% (Wt.% yield 74.3).

3.2 Bench-scale Beneficiation Studies on a drill core Iron Ore Sample from Alaghat West Block (G-2 Stage exploration), Sundargarh District, Odisha

The sample assayed 57.87% Fe(T), 4.15% Al_2O_3, 7.17% SiO_2, 0.10% CaO, 0.04% P_2O_5, 0.06% K_2O, 0.02% Na_2O, and 5.11% LOI with traces of MgO, TiO_2 & Mn.

Beneficiation studies comprising of crushing and gravity separation techniques employing Jigging, Tabling and Multi-Gravity separation yielded a composite concentrate assaying 63.29% Fe(T), 2.06% Al_2O_3 and 3.27% SiO_2 with a total Fe recovery of 59.1% (Wt% yield 53.6).

4. MANGANESE ORE

4.1 Bench-scale Beneficiation Studies on a Manganese Ore sample (G-2 level exploration) from Cheepurupalli, Viziangaram District, Andhra Pradesh.

The sample assayed 23.66% Mn, 10.41% Fe(T), 22.65% SiO_2, 8% Al_2O_3, 1.27% TiO_2, 0.3% P, 3.84% CaO, 0.04% MgO, 11.25% LOI and of S(T) in trace amount.

Gravity separation employing tabling at -72 mesh size followed by electrostatic separation of the gravity separation products to refine the Manganese concentrate. Gravity tails were subjected to reverse flotation to recover Mn values from tails.

The concentrate-I was obtained by combining +150# conductor and middling & -150# conductor and middling of table concentrate and table concentrate & table middling which assayed 47.02% Mn with 39.0% Mn recovery (Wt.% yield 21.01).

The concentrate-II was obtained by combining -150# non-conductor of table concentrate, +150# conductor and middling of table middling, -150# conductor of table middling and non-float reverse flotation concentrate of combined table tails and slimes which assayed 33.55% Mn with 44.0% Mn recovery (Wt.% yield 33.18).

The composite concentrate was obtained by combining concentrate-I and concentrate-II which assayed 38.78% Mn with 83.0% Mn recovery (Wt.% yield 54.19).

5. COPPER –GOLD ORE

5.1 Bench-scale Beneficiation Studies on Copper-Gold Ore Sample (G-2 level exploration) from Mundiyawas Block, Alwar district, Rajasthan

The sample assayed 0.25% Cu, 44.86% SiO_2, 5.97% Al_2O_3, 1.82% S(T), 5.23% Fe(T), 12.76% CaO, 9.12% MgO, 0.42% Na_2O, 1.76% K_2O, 0.52% TiO_2, 0.04% MnO, 9.22% LOI with 56.89% Acid insoluble. The composite sample assayed 1.24 ppm Au, 7.12 ppm Ag, 0.61% Cu, 8.73% Fe(T) & 10.33 LOI.

By adopting flotation test at optimised conditions yielded a copper concentrate assaying 21.36% Cu with a Cu recovery of 70.6% (Wt.% yield was 0.80). Acid leaching followed by cyanidation recutted in the overall recovery of gold at 97.9%.

6. GRAPHITE ORE

6.1 Bench-scale Beneficiation Studies on a Low-grade Graphite Ore (G-2 level exploration) Sample from Golighat Block, Betul district, Madhya Pradesh

The as received sample assayed 6.25% FC, 4.76% VM, 0.49% moisture and 88.5% ash. The ash analysis of as received sample showed 63.5% SiO_2, 10.45% Al_2O_3, 4.98% Fe_2O_3, 2.09% CaO, 1.61% MgO, 0.93% Na_2O, 3.41% K_2O, 10.76% LOI, and 0.154% V_2O_5 respectively.

Beneficiation studies comprising grinding, screening, magnetic separation, froth flotation, gravity separation, etc. were employed by varying different parameters for concentration of graphite and vanadium-bearing minerals. The beneficiation process route evolved yielded —

(i) A composite graphite concentrate, i.e., 3rd cleaner concentrate mat assayed 57.93% FC, 39.1% Ash, 2.48 % VM, 0.47% Moisture with FC recovery of 76.4% and wt% yield 8.6.

(ii) A vanadium-bearing mineral concentrate as a co-product which assayed 0.39% V_2O_5, 1.23% FC, 92.86% Ash, 5.03% VM, 0.88% Moisture with V_2O_5 recovery of 17.7% and wt% yield 6.6.

B. TMP Division, IBM

1. Regional Mineral Development Studies (RMDS) for Effective Utilisation of Low-grade Iron Ore Fines & Slimes of Bailadila Iron Ore Mines of M/s National Mineral Development Corporation, Bailadila Sector, Chhattisgarh

This study was carried out in 2019-20 and completed in the year 2020-21. The purpose of the study was to facilitate the formulation of policies, guidelines for planning regional development of mineral pertaining to low-grade iron ore fines/ slimes, which were generated during the crushing, screening & washing process and was stacked as dumps and slimes (less than 0.15mm) that were discarded into the tailing pond. As the high-grade iron ores have got exhaustively mined, it has become imperative to use low-grade iron ores, fines and slimes to meet the growing demand. Also, generation of fines & slimes during mining & processing contributes to loss of minerals to the substantial extent of the total Run-off Mine (ROM) and are often discarded as waste into waste dumps/tailing ponds, containing considerable amounts of iron. Therefore, beneficiation of tailings/slimes has become necessary for optimal utilisation of the resources.

The study has been made to assess the low-grade ore fines/slimes (ultra-fines), available in dumps/slimes dams and those that are likely to be generated in the Bailadila sector in course of mining and processing, which can be utilised by adopting appropriate beneficiation methods to recover the valuable minerals for utilisation in Iron & Steel Industry. These rejects would otherwise remain un-utilised. Under the study, the reviews of insitu O/B removal/ROM production trend; Grade of feed to Beneficiation Plant; existing crushing & screening processes; material balance in beneficiation process flow; recovery in respect of lumps & fines (quantity/quality) for supply to

Steel Plant/Sales; low-grade fines/slimes loss/de-silted slimes (quantity/quality) and prospect of valuable minerals and review of sub-grade/low grade generation; and stacking & de-silted slimes/dumps have been carried out.

On analysing the data, the availability of low–grade ore (between 45 and 55% Fe), which is not utilised by lessee at present, varied from 22.74% to 40.34%. Immediate attention was drawn for consumption of low-grade ore available in the lease by up-gradation of the ore or by blending as per the requirement. The existing was hing methodology adopted in NMDC, involved discarding of slimes that contained Fe value between 45% & 55% or more. These slimes get usually put-up in slime dams/ponds every year in the tune of approximately 2 to 3 million tonnes. The need was felt to utilise these lost minerals by bringing them back in main stream using techniques of beneficiation involving gravity, magnetic and flotation process etc. Such recovered slimes can be used for pellet/sinter manufacturing. Based on the above study, the following recommendations for effective utilisation of low-grade iron ore fines & slimes of Bailadila Iron ore Mines of M/s NMDC were suggested:

(i) It is estimated that a decrease in alumina content in sinter feed from 3.1% to 2.5% will improve DRI by at least six points, lower blast furnace coke rate by 14 kg per tonne of hot metal yield increases productivity by about 30% under Indian operating conditions. By reducing the presence of these contaminants in the feed material, the processing of iron ore becomes viable as a result of the cost reduction in metallurgical process.

(ii) The quantities of slimes accumulated over the years, already available in fine form assay reasonably high percent of Fe. Therefore if properly beneficiated, these slimes can be considered a national resource rather than a waste of no value. The alumina content of the slimes, if brought to less than 2% Al_2O_3 in the beneficiated product will (a) lead to better utilisation of national resources, and (b) reduce environmental hazards associated with storage and disposal of slimes.

Keeping the above facts in view, attemps must be made to process the slimes to recover the iron values and this will be a step forward for conservation of natural resource and will provide opportunity for sustainable growth.

Jawaharlal Nehru Alumnium Research Development & Design Center (JNARDDC)

1. Completed Projects

1.1 To study the fire retardancy of nano-ATH in polymers with CIPET, Bhubaneswar (Central Institute of Plastics & Engineering Technology) (S&T- Mines): The objective of the project was to

(i) investigate the effect of nano or micro-ATH particles as a fire-retardant additive in thermoplastic polymers (PP & PVC).

(ii) replace/substitute the existing flame retardants used in polymer composites with nano-ATH & evaluate the performance.

(iii) examine the mechanical, thermal and flame-retardant properties of thermoplastic polymers (PP & PVC)/ATH composites obtained using ATH fillers of various particle sizes.

(iv)innovative process utilising aluminum trihydroxide (ATH) and thermoplastic polymer matrix with value addition.

The final report of the findings showed that nanosized ATH with 40–350 nm size has reduced the loading of fire-retardant filler in the polymer (PP) from 40–60% to 2-3%. It has a large surface area and improves the fire retardancy and the mechanical properties of the polymer. PP/nano-ATH nanocomposites can be suitably validated for acoustic panels used in building and construction industries based on their mechanical & flame retardancy where lightweight is a priority. Based on the successful lab scale findings, the pilot-scale level can be taken up.

1.2 Optimisation of digestion efficiency in Bayer process by ascertaining the ideal size fraction of bauxite feed (S&T- Mines): The objective of the project is summarised below:

(i) Determination of the optimum size of bauxite for digestion by grinding and characterisation of various size fractions.

(ii) Technological testing and evaluation of various size fractions of bauxite to optimise digestion efficiency.

The project attempted to investigate the chemical, mineralogical, rare earth, trace elements, petrology characteristics of the bauxites used from predominantly two regions in India, namely East Coast and Central India.

The results showed that there is a clear enrichment of SiO_2 and Fe_2O_3 in the finer fractions both for East Coast bauxite and Central India bauxite. Thus, the removal of some of these size fractions can improve the overall grade of these bauxites. However, these reductions are not appreciable to make bauxite suitable for refractory and abrasive industries.

The project findings further revealed that if the finer size fraction get rejested there will be reduction in consumption of both specific bauxite and caustic soda consumption leading to improvement in digestion efficiency. The optimum particle size of the feed bauxite to digestion was also recommended in the report. The final recommendation can be used by primary Aluminium producers utilising East Coast and Central India bauxite.

1.3 Development of a process technology (at lab. scale) for low-cost production of 3N (99.9%) pure alumina (Ministry of Science and Technology – DST, New Delhi): The objective of the project is enumerated as below:

(i) To develop the process know-how (at lab-scale) for the low-cost production of 3N pure alumina (99.9% purity).

(ii) Characterisation and Validation for Sapphire making for LED (Light Emitting Diode) and Semiconductor applications.

(iii) Theoretical study of cost economics for 3N pure alumina synthesis process and further recommendation.

The project activities involved production of high purity alumina powder (3N pure) by two different methods which later was used for the fabrication of sapphire crystal for LED applications.

The Centre has successfully developed the lab scale process know-how for low-cost production of 3N pure alumina at much low temperature suitable for LED (Light Emitting Diode) and Semiconductor applications. The cost economics for 3N pure alumina synthesis process was also evolved. Presently, India 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 process does look to have commercial potential to add to the vision of Make in India program after being suitably scaled up.

2. Ongoing Projects

2.1 Fabrication of Advanced Ceramic Nanocoatings 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 un-organised, 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 Bench-scale study on Extraction of Pure Silica and smelter-grade Aluminium Fluoride from Coal Fly Ash (CFA) (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 that get generated from all coal-based thermal power plants accumulating over the years and this 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 and pharmaceutical industries.

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

2.4 Utilisation of Aluminium Dross to Achieve Zero Waste — A Bench-scale Study Project (Sponsored by Ministry of Mines): The main objective of the project 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 that it provides alternative source to primary material and it helps in reduction of waste disposed to landfills.

2.5 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 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.

2.6 Development of Ceramic Proppant from Low-grade Materials (Partially Lateritised Khondalite -PLK, Fly ash, etc.), Phase-II Scale up Studies (Sponsored by NALCO, Bhubaneswar Odisha): 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 was undertaken.

In general, ceramic proppants is manufactured from high-grade bauxite. An attempt has been made for converting unutilised materials into value added product (proppants). This is a part of the efforts make under 'Make in India' and 'Swatch Bharat" zeal.

2.7 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 Odisha, Jointly with IIMT, Bhubaneswar & Eesavyasa Tech, Pvt Ltd. Telangana): The Project was aimed at developing 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 was to be the nodal agency and the deliverables included mass and energy balance of the developed process.

2.8 Development of Process for 4N High Pure Alumina (HPA) and Substrate Making for its Validation in LED Applications (Sponsored by NALCO, Bhubaneswar, Odisha, Jointly with IIT, Bhubaneswar & Anna University): While India is one of the highest users of LEDs, neither the raw material is prepared nor is the product manufactured in India. All LEDs that are available in market are assembled after their import. The project aims at developing an indigenous process to prepare 4N (99.99%) pure grade alumina (HPA) that has potential for use in LED applications.

2.9 TPN:59025 Instrument for Real Time Measurement of Anode Current Distribution of Aluminium Electrolysis Cell (Sponsored by Dept of Science and Technology, New Delhi): Online current distribution measurement helps to observe changes in current distribution with changing conditions in the cell for a period of time which provides option to improve cell efficiencies and reduction in cell instabilities. The project aims at developING an instrument which will be able to make real-time continuous measurement of ACD in place of existing manual measurement system for its successful commercialisation in industry.

2.10 TPN:59031 Instrument for Instantaneous and Onsite Measurement of Aluminium Electrolysis Bath Parameters (Sponsored by Dept of Science and Technology, New Delhi): JNARDDC has already developed the methodology to establish the relationship of cooling curve with bath parameters on the basis of plant and lab experiments and has successfully developed the basic instrument for instantaneous measurement of important bath parameters. The project aims at developing the instrument which can be used in plants for regular measurements of bath parameters by addition/changes in the basic instrument in the terms of software & hardware for its commercialisation.

2.11 Technology Development for Holistic Utilisation of Red Mud for Extraction of Metallic Value & Residue Utilization (Sponsored by NALCO, HINDALCO & VEDANTA and S&T (Mines) under the aegis of NITI Aayog, Jointly with NML, Jamshedpur & IMMT, Bhubaneshwar): Under the NITI Aayog initiative the primary industries and 3 R&D labs have joined hands for development of feasible processing options for all metal extraction from red mud and for further research, development and commercialisation to other industries.

3. Collaborative work

JNARDDC is collaborating with the following other agencies for various R&D projects:

1. Bureau of Energy Efficiency (BEE), Ministry of Power, Government of India: JNARDDC has successfully carried out technical evaluation under PAT-1 & 2 to support the BEE in reducing energy consumption of Aluminium Sector. Presently PAT-3 scheme is being evalvated. The recommendation will help BEE in generation and trade of e-certificates under PAT scheme. It will also be useful in setting up energy reduction targets for PAT-3 scheme.

2. NITI AAYOG: In order to make India self-reliant in Rare-Earth Extractions (REEs), NITI Aayog has identified many secondary resources for rare earth extraction among which Red Mud is the only known resource of scandium, a REE, which is more enriched as compared to native bauxite. Under the aegis of NITI Aayog, multiple institutions including JNARDDC are involved in development of feasible processing options for all metal extraction from Red Mud.

3. Bureau of Indian Standards (BIS): JNARDDC is in the process of formulating recommendations for BIS regarding setting up standards for aluminium scrap and other aluminium alloys. The Centre is assisting BIS to develop methods and methodology for testing and analysis of materials related to Aluminium Sector.

4. Central Pollution Control Board (CPCB): The Institute has submitted recommendations of Aluminium Industry for supporting CPCB in formulating guidelines for safe disposal & utilisation of waste (red mud) generated by the Aluminium Industry.

5. Russian Union of Producers, Suppliers and Consumers of Aluminium: Russian Aluminium Association, Moscow and JNARDDC, Nagpur signed an MOU on 3rd August 2020 for long-term cooperation between Russian and Indian companies related to aluminium production and transformation; knowledge and experience sharing to increase aluminium production; promoting direct partnerships between aluminium processing facilities as well as between R&D institutes; development of techno-parks (clusters) for the Aluminium Industry; setting up joint ventures between Russian and Indian enterprises including facilities producing high-level aluminium products; etc.

National Institute of Rock Mechanics (NIRM)

National Institute of Rock Mechanics carries out various 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.). 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, many innovative techniques were used to solve the industry problems. Some of the important contributions are listed below:

(i) Geophysical investigations were carried out to analyse the likely impact of the enhanced induced vibrations due to landing and take-off of the heavier and more frequent aircrafts after the proposed expansion of the runway by 260 m towards the Dumas end at Surat Airport.

(ii) World's 2nd largest lift irrigation project: The Palamuru Ranga Reddy Lift Irrigation Scheme (**PRLIS**), Telangana, would facilitate irrigating drought prone regions of the State, and the engineering geological investigations and the subsequent technical inputs of NIRM along with recommendations for suitable engineering measures would ensure the life of this project for next 100 years.

(iii) Critical Angle Excavation of Draft Tube: The strategic engineering design of excavation in the choked tunnels of the Punatsang Chu Hydroelectric Power Project, Bhutan, under adverse geological conditions enabled progress of the hydel project.

During the reporting period between 1st January to 31st December 2020, the institute received 36 new projects from the industry during the pandemic and completed 41 industry projects.

Some of the major ongoing projects that are being executed by the Institute during Jan.–Dec. 2020 include:

(i) Engineering geological investigations of cut slopes for intake pool, upstream and downstream hillock above pressure tunnels and powerhouse area and tailrace pool of Indra Sagar Polavaram Hydro Electric Project;

(ii) Geophysical investigation to study the rock mass condition around the sinkholes and abandoned coal working in the Umariya District, MP;

(iii) MASW survey and measurement of vibration parameters around tailing dam of Bailadila mines;

(iv) Scientific Study for assessing the stability of pit & dumps and design for strengthening of benches for opencast;

(v) BPM & benches above proposed decline portal of Kaliapani Chromite Mine, Balasore Alloys Ltd.

(vi) Scientific Study for stability assessment and monitoring of Pit and Dump at 3 nos. Budgauna, Hinauti and Majhgawan Limestone mines at Sidhi Cement works;

(vii) Determination of Insitu stress parameters (Magnitude, Direction & Gradient) of the overlying roof strata for orientation of Longwall panel at Muraidih Colliery, Barora Area, BCCL, Dhanbad;

(viii) Analysis of Geotechnical & Geodetic Instrumentation Data at C-3 Package of Punatsangchhu-II Hydroelectric Project, Bhutan; Cap Rock Stability at Central Baroi Mine, HZL vis-a-vis Depillaring of Remnant Pillars – A Critical Appraisal;

(ix) Blast Design for Graded Material to Construct Break Water for Vizhinjam, Thiruvananthapuram, HOWE Engineering Projects (India) Pvt Ltd.

(x) Monitoring of ground vibration and air overpressure due to blasting carried out for construction of Hydro-Technical Structure of unit 3 and 4 at Kudankulam Nuclear Power Plant, Kudankulam, L&T, Tamil Nadu;

(xi) Procedure for controlled blasting and monitoring of ground vibration for rock excavation at Kaiga 5&6 site, Kaiga, NPCIL;

(xii) QA support for the On-going Geological/ Geotechnical investigations at Mahi Banswara Rajasthan Atomic power project.

CSIR–Central Electrochemical Research Institute

1. R&D (Ore Preparation and Processes)

Research and development work carried out in the field of extractive metallurgy and ore preparation, having bearing on mineral industry are given below:

(i) Processing of High phosphorous and High Manganese ores, sponsored by Vedanta, Iron ore Sesa, 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. R&D in building Materials (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 (1832 °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. R&D work on Recovery of Marine Chemicals and By-products, viz, Salt, Potash, Bromine, Iodine, Gypsum and Magnesium Chemicals:

Electro winning of Magnesium Metal from Spent Magnesium chloride Liquor by Molten Salt Electrolysis sponsored by United Phosphorous Limited.

4. R&D Projects on Metallurgy and Mineral Processing

4.1 Extraction of Neodymium Metal by Molten Salt Electrolytic Process (Sponsored by Indian Rare Earths Ltd)

The objective is to produce Rare-earth Metals & Alloys from Rare Earth Oxides/Chlorides produced by IREL from Beach Sand Minerals. The following deliverables were achieved:

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

(ii) Electrowinning of neodymium–iron, used as master alloy for NdFeB magnets, was 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 is in progress.

4.2 Electro-hydrolysis of low-grade manganese ore to gamma MnO_2 (Sponsored by Tata Steel Ltd)

The objective is to develop an Electrowinning process for the preparation of γ-Manganese dioxide from low-grade Indian manganese ores. The following deliverables were achieved:

(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 a 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 microstructure was studied using FE-SEM.

4.3 Effect of impurities on zinc electroplating: Comparison of Special High Grade (99.995%) and Electroplating Grade (99.997%) Zinc raw material (Sponsored by Hindustan Zinc Ltd.)

The objective was to understand the effect of impurities in EPG and SHG grade zinc in terms of current efficiency, microstructure and corrosion resistance. The following deliverables were achieved:

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

(ii) Zinc samples electroplated from EPG-Zn exhibited more Compact and Crystalline microstructure 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. Mineral Processing Division of CSIR-NML has been engaged in R & D in characterisation, beneficiation and agglomeration of ores and mineral fines. Presently, the Mineral Processing Division is focusing on Fine particle processing, Dry beneficiation, Mathematical modeling simulation, Plant performance auditing improvement, and Equipment development. During 2020-21, the following were some important R&D programmes and projects that were under execution:

(i) Mission Mode Mroject on Strategic Minerals — Production of Lithium Salt from Ores

NML laboratory is working on the development of indigenous technology for production of lithium from hardrock ores under a CSIR—Mission Mode Project on Bulk Chemicals. The objective of the research was to develop process flow sheet for beneficiation and extraction of lithium salts from ore. Three lots of lepidolite- bearing rocks and one spodumene -bearing rock were sourced for the research. The Li_2O content in sourced lepidolite samples varied from 1.9% to 2.8% whereas that in spodumene sample it was 3.1%. Mineralogical study revealed that albite, quartz and muscovite -were the major gangue minerals in both lepidolite- bearing and spodumene-bearing rock/pegmatite. Preliminary beneficiation study revealed that Li_2O content in lepidolite concentrate was 4% and in spodumene concentrate weas 5.1% and the work is in progress. Preliminary hydrometallurgical processing revealed that roasting of lepidolite-bearing rock followed by mineral acid leaching resulted in recovery of 99% Li in the leach liquor.

(ii) Dry Beneficiation of Limestone Samples for Removal of Iron -bearing and other Magnetic Impurities.

The objective of the present study was to beneficiate limestone samples through dry magnetic separation and Air table for reducing of iron from 1.5% to 0.08% Fe_2O_3 for rejected limestone and from 0.2% to 0.08% for regular limestone. To prepare clinker for white cement, it is pertinent to minimise the iron and other transition elements (titanium, chromium, manganese, nickel and zinc) in the raw mix composition. High-grade limestone containing less than 0.068% Fe_2O_3 and less than 0.015% MnO is generally used for such purpose. Limestone deposits in BWC mines is highly associated with lateritic coating. The iron in laterite adversely affects the white cement quality. The current project was aimed at exploring the possibility of removal of iron and other transition elements from limestone of BWC to improve the clinker quality. Based on characterisation and liberation studies, it was proposed to beneficiate limestone through dry magnetic separation and Air table for the separation of contaminants from limestone. In addition, it was also proposed to develop beneficiation process for reduction of impurities present in rejected limestone sample at the mining site for its ultimate utilisation.

(iii) Continuous Pilot -Scale Reverse Flotation of Iron Ore

The objective of the present study was to validate the results of continuous operation of pilot scale flotation studies that were done earlier by treating 15 tonnes of iron ore through reverse flotation. Extensive iron and steel production has resulted in depletion of high- grade iron ores. As a result, the thrust is on beneficiation of low - grade ores. Moreover, decrease in threshold value of tailings/ reject Fe (< 45%) as per statutory norms demands beneficiation of inferior grade iron ore. These ores comprise heamatite, goethite (iron minerals) along with kaolinite and quartz (gangue minerals). Reverse flotation method was used for beneficiation of iron ores wherein silica gangue could be selectively floated from iron ore using reagents. The sponsor had carried out studies on different reagent scheme to improve the selectivity of the flotation process. With encouraging results of batch- scale studies (20-25 kg) in an earlier project carried out at CSIR NML, continuous pilot-scale flotation of 15 tonnes of iron ore will be experimented for the validation of the bench- scale results.

(iv) Pilot - scale Study on Hydrocyclone

Weir EnSci has developed a new Cavex Hydrocyclone with a double effect overflow (DEO) system for a high capacity performance with an efficient classification performance. M/s Weir Mineral EnSci, Bengaluru approached CSIR–NML for conducting pilot- scale testing with their newly developed Cavex 100 cyclone. With mutual consultation pilot scale testing was conducted by using iron ore slime at different operating conditions. The products were analyzed for particle size distribution in Malvern Laser Particle Size Analyzer. The mass balancing as well as size wise data recovery was obtained for all experiments to predict the performance of this newly designed hydrocyclone. A much finer cut size can be achieved with this DEO system compared to conventional hydrocyclone. With the help of this DEO system, final loss to overflow can be minimised.

(v) Advanced Gravity Concentration of Chromite Beneficiation Plant Tailing

NML undertook bench - scale beneficiation studies to recover chromite values from plant tailing sample to produce preferably 40% Cr_2O_3 using water only cyclone and Falcon concentrator. Detailed characterisation of the tailing sample was carried out which revealed the presence of chromite, goethite, heamatite and clay silicates in the sample. Goethite was the major constituent of the tailing sample. Chromite was seen interlocked in silicate minerals or the goethite heamatite matrix. The separation performance of Falcon concentrator and Water-only cyclone for recovery of chromite value from plant tailing was investigated. The experimental scheme was designed and the process parameters were optimised by the design of experiment software. It was observed that around 32% of chromite value was recovered from plant tailing by Falcon concentrator with 4 chromite content of 40% in a single-stage operation. Results also indicated that it is difficult to enhance the chromite content of the product to 40% using water-only cyclone. It can enhance the chromite content to a maximum of 25.3% with 25.8% of mass yield in a single-stage operation with the present granulometry. Experimental investigation revealed that the separation performance of the Shaking table was better than the Falcon concentrator with the present granulometry of the sample. However, the throughput rate of the Falcon concentrator was much higher than the Wilfley Shaking table.

(vi) Processing of Low -Grade Dolomite Ore

A collaborative project was undertaken for characterization and beneficiation studies of three different types of dolomite samples from Gomardih mines near Rourkela, Odisha, for reduction of alkali and silica content for iron and steel making applications. The objective was to develop a process for reduction of K_2O to < 0.2% and SiO_2 to 0.5% for ROM sample containing 5% silica and to 3% silica for low - grade samples containing around 12% silica. Mineralogical characterisation of the samples was carried out by optical microscope and XRD studies were carried out to identify the mineral phases in the as received samples, their textural relationship, optical characteristics, mode of occurrence and distribution. The valuable mineral in all the samples was dolomite with gangue minerals, like, calcite ($CaCO_3$), plagioclase feldspar (Na, Ca (Al, $Si)_3O_8$), muscovite ($KAl_2(AlSi_3O_{10})(OH)_2$), biotite ($K(Mg,Fe)_3 AlSi_3O_{10}(OH)_2$), orthoclase feldspar ($KAlSi_3O_8$) and quartz ($SiO_2$) in different proportions. Due to the interlocking of the gangue minerals within the carbonate matrix, beneficiation studies were carried out with the fine feed material for all the three dolomite samples. As the density of the dolomite and gangue minerals are very close to each other, and as the minerals lack magnetic susceptibility & gravity, magnetic separation could not be performed. Therefore, froth flotation was the only method for reduction of SiO_2 and K_2O content. It was found that suitable dosage of sodium silicate used as depressant and collector dosage together was effective for reducing the K_2O and silica content to the desired level.

(vii) Studies on Beneficiation of Bauxite Sample for Reduction of Reactive Silica

In the present investigation, studies were undertaken on processing of bauxite samples sourced from Chhattisgarh region for possible reduction of reactive silica to ~4% from a feed containing high reactive silica ranging from ~6 – 11.5%. Characterisation of the bauxite ore revealed that the sample exhibits various types of textures, like, oolitic, colloform and replacement. The sample contained abundant gibbsite and boehmite, followed by clay, altered/translucent silicate and opaque minerals (Feoxides/hydroxides) and anatase. The beneficiation study included scrubbing and washing, gravity separation, magnetic separation and froth flotation studies. Scrubbing and washing studies demonstrated that there was significant reduction in reactive silica content (~2%) with increase in total available alumina content in the washed product. The project is in progress.

(viii) Beneficiation Studies on Low - Grade Manganese Ore Samples: In the present investigation was aimed at designing beneficiation process flowsheet for upgradation of the low - grade manganese ores for use in ferromanganese/silicomanganese with the reject containing < 10% Mn. For this purpose, three different low grade manganese samples were sourced and characterised. The samples were ferruginous in nature. Mineralogical studies showed that the manganese ore samples had predominantly pyrolusite, goethite/limonite and manganomelane with minor amounts of cryptomelane, clay, lithiophorite and heamatite. Todorokite, manganite, quartz, mica (muscovite, biotite), feldspar (orthoclase) and gibbsite were noticed in very minor to trace amounts. Different beneficiation schemes were studied on these samples and their responses were observed. It was possible to produce desirable concentrate for ferromanganese/silico chrome application maintaining 10% Mn in reject using combination of physical beneficiation followed by low intensity magnetic separation on pretreated sample.

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. For many R&D projects, MOIL has engaged and was associated with several institutions, viz. (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 Technology (NIT), Raipur; (x) National Institute of Rock Mechanics, Kolar Gold Fields; (xi) Indian Institute of Engineering Science and Technology, Shibpur; and (xii) IMT Bhubneshwar. Significant R & D projects undertaken are listed below:

1. Mine Environment

***1.1 Ventilation**:* Ventilation reorganisation studies for deeper levels have been conducted at Gumgaon by Indian Institute of Technology (IIT), Kharagpur. Accordingly, large diameter ventilation fan has been installed at Gumgaon Mine with energy saving devices. The studies are going on at Chikla and Ukwa Mine. Moreover, Ventilation reorganisation studies for deeper levels have been conducted by Indian Institute of Technology (IIT), (formerly ISM), Dhanbad for Balaghat Mine and accordingly the ventilation drifts have been re-located at Balaghat Mine and sinking has been completed for 5m diameter ventilation drifts. The above operations have helped in improving the face ventilation and productivity of underground sections of mine.

1.2 Sustainable Development Framework: Collaborative scientific research for evaluation of environmental parameters in and around Kandri and Munsar mine has been completed for online continuous monitoring of air, water and noise parameters on experimental basis by Indian Institute of Engineering Science and Technology (IIEST), Shibpur. A patent application has been filed jointly by MOIL and IIEST, Shibpur for the Real–time zero waste water quality observing system in February, 2020 for publication and the project was completed in March, 2021.

2. Mines Safety- Mining Subsidence: In-house 3-D analysis of subsidence parameters were carried out by MOIL and it was found that there are no noticeable movements in any orthogonal direction above the ground at Munsar mine. Accordingly, MOIL has filed for patent for the method used to determine the subsidence at mining site, which was published in October, 2019. This in-house prepared subsidence parameter scientific report was vetted by IIT, Kharagpur. The subsidence monitoring by in-house developed seven pillars for micro-analysis and these were designed for better safety.

3. Mineral Conservation: R&D studies conducted by National Institute of Rock Mechanics (NIRM), KGF for stope design have been implemented at Chikla and 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 at Munsar underground mine.

4. In-house Mining Technology

4.1 Rock Mechanics: MOIL has designed in-house rock mechanics software MOIL-RMR for rock mass characterisation and support design. Patent has been filed for a system and a method for rock mass characterization and rock support system in mining for publication in January, 2020. It indicates RMR&Q and putting the values directly in graph without any human machine interference (HMI) and indicates roof span, stand-up time and designated support for method of workings for better safety. Production of final examination report is in progress.

4.2 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 can be used for hydraulic transportation for stowing in underground with or without river sand. MOIL has filed and got a patent for a composition useful as an alternative material for hydraulic stowing in an underground mine and method thereof. The same was published in April, 2018 with final examination report submitted in March, 2021. Any waste material which is excavated from the earth can be utilised for this process and processed material could transfer its geo-engineering strength up to 80% from the in situ to the product —These have been confirmed from the field trials. The invention, a Made in India Technology, has for reaching potential as any waste material lying in the mine acould be put to use.The effect of this saving the river sands which is scarce natural resource.

5. Space technology – Remote sensing: MOIL has identified manganese -bearing areas in terms of an MoU with National Remote Sensing Centre (NRSC), Hyderabad for remote sensing studies of four districts of Madhya Pradesh, namely Balaghat, Chhindwada, Jabalpur and Jhabua. On the basis of the report, MOIL has carried out field survey and applied for permission for core drilling from Govt. of Madhya Pradesh in potential zones of these four districts. Recently, Govt. of Madhya Pradesh has reserved 850 km^2 and 487 km^2 areas in Balaghat and Chhindwara districts respectively, to carry out exploration work. This will enable MOIL to take up exploration project in the reserved areas of Balaghat and Chhindwara districts. Applications for other two districts, i.e., Jabalpur and Jhabua, are in process is rather high.

6. Pani Project (Mining outside the State of Maharashtra and Madhya Pradesh): In a move to spread its operations in other States, MOIL has entered into an MoU with Gujarat Mineral Development Corporation (GMDC) to explore possibilities of manganese mining. To start with, Pani area of Chhota Udepur district has been identified and, a tripartite MoU among MOIL, GMDC and Mineral Exploration Corporation Limited (MECL), has been entered into for carrying out exploration. MECL has carried out exploration and proved reserves and resources of ~ 7.00 Million MT so far have been established. Preparation of feasibility report for mining of manganese ore in the area is in progress at MOIL.

7. R&D Labs: Mine planning department of the Company has established a Remote Sensing and Petrological Laboratory to study petrological and mineralogical characteristics of samples collected in field from different areas. This would help knowing the genesis of ore and to make use in geological reports for onward submission to various statutory authorities in DGMS, IBM, DGM, etc. The planning department is also procuring hand held XRF, XRD and DGPS instruments for analysis of field samples and also to do DGPS survey in new areas.

MOIL has also established a Geographic Information System (GIS) and Remote Sensing laboratory with ERDAS, ARC GIS and Surpac software along with petrological microscope for capacity building of R&D works and for study of all operating and future mine leases for mine planning and design.

Besides, Work on Rock Mechanics Laboratory with modern rock testing machines as per ISRM standards is in progress and it will have rock mechanics numerical modelling softwares for core testing.

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 are enumerated below:

1. Projects of NMDC Mines/Projects

(i) Development of vision enhancement system for foggy weather at Bacheli (In collaboration with CSIR–CIMFR).

(ii) Testing with VSI and HPGR for comparative crushing data of iron ore fines from Donimalai/Kumaraswamy for beneficiation plant, Donimalai.

(iii) Evaluation of indigenous wear liner to be used in NMDC mines- —An import substitution initiative for ATMANIRBHAR BHARAT.

(iv) Study on physical, metallurgical & flowability properties of coking coal sample received from NISP, Nagarnar.

(v) Physical and metallurgical characterisation of iron ore samples received from Bailadila sector.

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

2. In-house Developmental Research Projects

2.1 Conservation of Energy

(i) Development of iron ore pellet from Kumaraswamy fines suitable for gas - based DRI process.

(ii) Utilisation of microwave heating in iron ore pellet making.

(iii) Utilisation of mining waste (Slime) to produce Bricks/Tiles.

(iv) Investigation on the effect of temperature on the rheological properties of iron ore slurry.

2.2 Technology Absorption

(i) Beneficiation studies with high ash coal sample

(ii) Study on SMS slag and exploring its prospect in agriculture

(iii) Study on 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 (Completed in Oct 2020).
iii)	CSIR-IMMT, Bhubaneswar	a) Modeling & Optimisation of high concentration Iron ore fines/concentrate slurry pipeline for Indian Iron Ore Processing Industry (Completed in Mar 2021). 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

During the year under review, in order to utilise and generate value from the captive low-grade raw materials, the company has completed the lab -scale studies to utilise captive low-grade manganese ore and produce high value products such as Electrolytic Manganese Metal and High Purity Manganese Sulphate to cater to the requirements of the battery manufacturing industry.

Besides, some efforts made towards technology absorption in respect of ores & minerals and mineral based products are given below:

A. Projects under Research and Development

1. Jamshedpur

1.1 Seam Specific Reagent for Lower Seam Coals of West Bokaro: Tata Steel R&D in collaboration with a foreign university has developed a new reagent which increases floatability of lower seam coals by (i) increasing their C-C/C-H content on the surface making it more hydrophobic; and (ii) aggregating finer coal particles to minimise porosity and improving surface properties. An increase in fine clean coal yield of 7.5% for lower seam coals was observed as compared along with a decrease of 1% product ash content. The overall increase on ROM basis is 1% with the new reagent. Pilot -scale trials (capacity 400 kg/hr) are under progress with different seam coals.

1.2 Reduction of Alumina in Iron Ore from Wet Processing Plant of Noamundi using Dispersant: The alumina reduction is about 1.2% in wet lumps and 0.2 to 0.4% in the classifier fines through present practice of the washing process. Addition of surface active reagents help to increase the washing efficiency of iron ore. Test work with different dispersants showed that alumina could be reduced by 0.2 to 0.3% in addition to the reduction achieved by washing with water alone. Two dispersants were selected for plant -scale trials based on lab- scale experimentation. First phase of plant trials has been conducted for two weeks in February 2021.

1.3 Smart Lance System for LD vessel: To improve blowing operation in LD vessel and avoid subjective assessment of the onset of slop by operating personnel, a lance positioning and control system, known as Smart Lance was developed for LD vessel using an audiometer to measure the process noise generated by oxygen jet impinging in the steel bath. The hardware, signal processing software and smart lance algorithm were designed and developed in-house. The technology has reduced the number of slopping incidents and severity by 70%.

1.4 Calcium Ferrite for Dephosphorisation of Steel: Synthetic calcium ferrite flux was developed to decrease the phosphorous content of liquid steel. Plant trials at LD shop of TSL Jamshedpur successfully decreased the turndown phosphorous by 20 ppm and reduced the lump iron ore and calcined lime consumption by 1,000 kg and 500 kg per ton of crude steel respectively.

B. Process Improvements

1. Raw Materials Division

1.1 Mining

(i) Concept developed for paste backfilling in Highwall mining face at West Bokaro (first in the world) in collaboration with XCUMT backfill, China to increase the coal extraction ratio to more than 65% as compared to existing 30%. Lab test work at XCUMT & CIMFR is in progress to finalise material proportioning for paste backfilling and prerequisites for subsequent approval from regulatory authority (DGMS) for field trial respectively.

(ii) Novel mining approach proposed for extraction of friable chrome ore (~30 million tronne) below ultimate pit limit at Sukinda. Technical feasibility study is under progress.

1.2 Ore Beneficiation Technology

(i) Stickiness Index to Predict Iron Ore Fines Flowability**:** A project was formulated to minimise the rake unloading issue by developing a

Statistical Index to provide prior information about the flowability characteristics of fines. The collective effect of factors such as granulometry, mineralogy and ratio of wet & dry fines create the stickiness issue. Methods like principle component analysis and multiple regression were used to develop the stickiness index.

***(ii) Identification of enablers to reduce Alumina in Dispatch Fines at Noamundi*:** Several initiatives (short-term and medium-term) were identified to reduce alumina in fines. Short term initiatives are (a) Jig utilisation 100% and (b) hydrocyclones bypass) and medium-term initiative are (a) 100% classifier fine processed through jig; (b) slime beneficiation; and (c) jigging in upcoming low grade plant. These initiatives have a potential to reduce alumina by 0.37% (from 2.95% to 2.58%).

***(iii) Identification of Enablers to Reduce the K_2O and SiO_2 from Gomardih Dolomite*:** Beneficiation studies to reduce K_2O and SiO_2 from dolomite were carried out and it was observed that by flotation it was possible to reduce the SiO_2 from 12.2% to 1.31% and K_2O from 0.8% to 0.14% which is very promising from an end -usage view point.

1.3 Coal Beneficiation Technology

(i) West Bokaro Washery#3 Flotation Circuit Performance Improvement by (a) ~0.5% clean coal yield improvement (on raw coal basis) by replacement of conventional rotorstator with FloatForce (a new generation mixing mechanism developed by Outotec). 3 units of FloatForce were introduced in FY 2017-18 and based on the encouraging results, 3 more units were integrated in FY 2020-21.

(b) Approximately ~10% reduction in flotation cell level fluctuation achieved by replacement of conventional actuators with advanced FESTO actuators.

(ii) Intermediate Size (0.5mm-0.25mm) beneficiation Circuit—Reflux Classier Stabilisation at New Jamadoba Coal Preparation Plant

2. Kalinganagar

2.1 Raw Material Handling System and Logistics

(i) Elimination of man-machine interface through adoption of Robotic application in in-haul and out-haul operation of Wagon Tippler 2.

(ii) Installation of smart fencing system in Wagon Tippler 4 to prevent unauthorised entry during unloading operation of wagons.

(iii) Integrated Power Supply installation of Cabin A and B for increase of reliability of signaling operation.

(iv) Integration of Road weigh-bridge weighment Screen with VTS.

(v) Installation of Change over Visual Indicator at BF Critical Points.

(vi) Started the dosing of chemical powder in PCI that enhanced the flowability and increased the PCI rate to 200 Kg/thm even during monsoon period.

(vii) Successfully commissioned the S&T system in upline between Jakhapura & Cabin-B that will increase the flowability of inward and outward rakes in parallel mode.

(viii) Electronic interlocking system ensures safe and optimum rake movement with all interlocks in place.

(ix) In-house mechanical modification done in the reach stacker which enabled it to handle slabs along with HR Coil.

(x) Signal and Hooter installation at Outside LC's during Rake movement.

2.2 Sinter Plant

(i) Maintaining Sinter bin level >60% to improve Sinter yield and lower specific energy consumption.

(ii) Number of interruptions reduced from 1.31 per day to 0.54 per day.

2.3 Coke Plant

(i) PHCC in the coal blend was reduced from the previous lowest of 18.68% during FY 2019-20 to 14.75%.

(ii) OHCC in the coal blend was reduced from the previous lowest of 28.21% during FY 2019-20 to 19.63%.

Hindustan Zinc Ltd (HZL)

Specific areas in which R&D has been carried out by Hindustan Zine Ltd in 2020-21 are summarised below:

(i) Individual Ore Characterization at Zawar for improved metallurgical performance.

(ii) Feasibility study for Derrick Screen to replace existing cyclones to improve classification efficiency.

(iii) Feasibility study for Lead circuit re-grind and effect of pH on lead flotation to improve Lead Silver Recovery and concentrate grade at RAM which confirms that use of Lead re-grind at RAM and Derrick Screen at Zawar will improve Lead/ Silver Recovery by 2–3%.

(iv) Geo-Metallurgy Study on advance Drill Core samples for Metallurgical characterisation at SKM and RAM which improved Metallurgical performance by Geo-Metallurgical assessment of core samples to predict recovery and grades and optimise circuit parameters. For instance - Dilute Nigrosine for high graphite in SKM, use of SMBS to deal with high pyritic ore, etc.

(v) RDM Mesh of grind (MOG) study to determine optimum grinding size to improve metal recovery. New grinding circuit designing as per MOG study at Rajpura Mines for recovery enhancement.

(vi) Grinding circuit audit and Loss Matrix analysis across all Milling sites to optimise circuit performance and improve process control.

(vii) Automated mill Quality Dashboard for continuous monitoring and analytics for data based actionable.

(viii) Establishing impact of impurities in copper sulphate on zinc flotation performance at mills Thus, improved inhouse copper sulphate quality by process control at DSC ancillary.

(ix) Integration and stabilisation of commercialized project for sodium sulphate crystal generation from DSC smelter effluent.

(x) Process developed and integrated with existing plant for Raw Zinc oxide inventory dilution at CLZS Hydro-II plant, contributing ~2 500 tonne Zn & ~700 tonne Pb.

(xi) Cu Matte Plant manganese bearing stream utilisation at Zinc smelter Debari for maintaining Mn level in electrolyte.

(xii) Process audit and control to manage Cu levels in purification section at Zinc smelter Debari thereby reducing usage of fresh copper sulphate crystals.

(xiii) Field trials for usage of Jarosite in concrete.

(xiv) Collaborative project for metal recovery from Zinc smelter residues by chloride and nitric based leaching.

(xv) Generation of Zn VAP – fertilizer grade Zinc sulphate and Zinc dust from residue & secondaries.

(xvi) Mapping of minor metals at Mills, Identifying opportunities for minor metal extraction at HZL.

(xvii)COP reduction initiatives by alternate reagents, process controls and optimisation.

Hindustan Copper Ltd (HCL)

HCL has undertaken the following R&D projects:

(i) R&D Project on Study of Bond work index (BWI), flotation optimisation studies, settling & filtration studies and magnetite recovery studies from the plant tailings for selling up of Copper Concentrator plant under Rakha Copper Project at ICC has been done in collaboration with CSIR – Institute of Minerals and Materials Technology, Bhubaneswar.

(ii) Line study of Mosabani concentrator plant at ICC has been done.

(iii) Introduction of rice husk for mixing with ANFO (explosives) for Deep Hole Blasting (Production Blasting) at KCC.

(iv) Study for implementation of advanced technology for SO_2 gas recovery through amine based absorption route in existing SO_2 plant at ICC.