Indian Minerals Yearbook 2022

(Part- I : GENERAL REVIEWS)

61st 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 a 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 2021-22, project proposals under the S&T Scheme of Ministry of Mines were invited online through SATYABHAMA portal. As per Minutes of 21st PERC meeting held during 13-14 Dec. 2021, a total number of 215 project proposals were received online on the SATYABHAMA portal (research.mines.gov.in). 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, 51 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, speciality materials and product; were short listed for further review in the second stage. These 51 proposals along with 6 resubmitted project proposals (based on remarks of 20th PERC), thus totalling to 57 project proposals were examined by 21st PERC. Out of these 57 new project proposals, PERC has recommended 20 proposals for funding under S&T Programme Scheme of Ministry of Mines. Besides, progress reports/ final reports, requests for time extension, etc. of 32 ongoing projects were also considered by the committee for review in the 21st PERC Meeting and review meeting of PERC held on 9th July, 2021.

The SSAG noted that 52nd SSAG remarked to re-examine 5 project proposals which were recommended by 20th PERC. The Committee was informed that these projects were re-examined in the Ministry and in the meeting dated 8th April, 2021 chaired by Joint Secretary, Ministry of Mines. The recommendations of the said meeting were presented before the 53rd SSAG.

The proposals recommended by the PERC were further considered during 53rd meeting of the SSAG held on 20th Jan 2022. These were presented by director (Technical), Ministry of Mines & Member Secretary. After detailed deliberation, SSAG recommended/ approved 25 project proposals (Table-1).

After deliberation, the SSAG accepted the final report and approved the closure of the 17 projects (Table-2) and release of remaining funds, subject to finalisation of accounts and other relevant procedures.

Based on recommendations of PERC the SSAG has also approved, time extension for 15 ongoing projects (Table-3).

Table -1: Details of Projects Recommended/Approved under S & T Programme, Ministry of Mines during 53rd meeting of SSAG

Sl. No.	Project Title	Implementing Institution	Project Cost & Duration of Project
1.	Definition of delay sequencing in blast designs using advance analytical techniques for optimisation of blast fragmentation and improving mine economics in non-coal mines	CSIR, Central Institute of Mining and Fuel Research National Institute of Technology Karnataka Surathkal; and Anna University	₹ 42 lakhs (MoM - ₹ 40 lakhs, MSPL Limited – ₹ 2 lakhs) Duration: 2 years
2.	Investigation on the development Al-Al Cladding Material through Compound Casting Process-Experiments and Numerical Simulations	Maulana Azad National Institute of Technology, Bhopal	₹ 49.575 lakhs (MoM - ₹ 39.075 lakhs + NALCO – ₹ 10.5 Lakhs) Duration: 2years
3.	Red Mud Valorisation to Achieve Zero Waste, Conversion of Residue Into Diagnostic X-Ray Shielding Tiles After Recovery of Scandium	CSIR, Advanced Materials and Processes Research Institute; Jawaharlal Nehru Aluminium Research Development and Design Centre	₹ 7180384.00 Duration: 2 years
4.	Bio-Reverent- Recover of Ga, Ge and In through innovative biotechnology and process integration	Indian Institute of Technology, Delhi	₹ 14.9856 lakhs Dration: 2 years
5.	Un-diluted Recycling of Cast Aluminium Alloys Containing High Fe Impurity Suitable for SMEs	BML Munjal University Jawaharlal Nehru Aluminium Research Development and Design Centre	₹ 8857900.00 Duration: 2 years
6.	Novel Material Manufacturing method for Large Volume Cast Metal Matrix Nanocomposites (Ultra-Cast)	Malaviya National Institute of Technology, Jaipur & CSIR, National Institute for Interdisciplinary Science and Technology	₹ 50 Lakhs Duration: 2 years

(Contd.)

Table – 1 (Contd.)

Sl. No.	Project Title	Implementing Institution	Project Cost & Duration of Project
7.	Technology development for holistic utilisation of red mud for extraction of metallic values and residue utilisation	Jawaharlal Nehru Aluminium Research Development and Design Centre, Nagpur.	₹ 75.21225 lakhs (MoM - ₹ 30.575 lakhs + Industry - ₹ 44.63725 lakhs) Duration:3 years
8.	Polymerised Molecular Receptor as Solid Sorbents for Size-Selective Recognition and Separation of Rare-earth Elements.	CSIR, Central Salt and Marine Chemicals Research Institute	₹ 8.99 Lakhs (seed money) Duration: 1 year
9.	Production of Onyx-grade ATH (sodium bicarbonate route) using low-grade bauxite from Kuchchh region of Gujarat	Kalinga Institute of Industrial Technology, Bhubaneshwar, and Jawaharlal Nehru Aluminium Research Development and Design Centre, Nagpur.	₹ 6742500.00 Duration: 2 Years
10.	Utilisation of chromite over burden (mining waste in Odisha) as an oxygen carrier material for clean energy (hydrogen) production using chemical looping technique	Indian Institute of Technology Kharagpur M/S Tata Steel Limited, R&D, Jamshedpur	₹ 53.7 lakhs (MoM - ₹ 44.7 lakhs, , Tata Steel – ₹ 9 lakhs) 2 Years
11.	Synthesis and Development of Hybrid Carbon Nanocomposites and Polymer Emulsions as Flocculants for Mining Industry	CSIR, National Institute for Interdisciplinary Science and Technology	₹ 14.94612 Lakhs Duration: 18 Months
12.	Development of Novel Hydrometallurgical Technological Process Package for extraction and separation of Niobium, Tantalum and Rare Earths from Columbite and Tin Slag	CSIR, National Metallurgical Laboratory	₹ 50 lakhs (MoM- ₹ 40 Lakhs, MO INFRA- ₹ 10 Lakhs) Duration: 2 years
13.	Design and Development of Real-Time Ground Behaviour Monitoring System (RT-GBMS) for Underground Metal Mines — An Innovative ICT based Solution	Trident Academy of Technology, Bhubaneswar (NGO - Dinabandhu Foundation for Educational Research and Socio-economic Development) and National Institute of Technology Rourkela	₹ 49 lakhs (MoM- ₹ 39.88 Lakhs, MOIL – ₹ 10 lakhs) Duration: 3 Year
14.	Solid-state recycling of aluminium chips (waste) for production of billets for pilot-scale extrusion	Jawaharlal Nehru Aluminium Research Development and Design Centre	₹ 4988900.00 Duration: 2Year
15.	End-to-End Technology Development and Scale-up (TRL-7) for Cobalt Recovery, Cobalt alloy and components for Bio-Medical Applications	Non-ferrous Materials Technology Development Centre	₹ 198.675 lakhs (MoM- ₹ 91.295 lakhs, CuraSigna - 41.6 Lakhs, NFTDC-Hydarbad Duration: 2 years
16.	Carbonaceous Nanomaterials from Graphite Sources of Arunachal Pradesh for Electrochemical Energy Storage and Sensor Applications	CSIR–North East Institute of Science and Technology	₹ 20 lakh (seed money) Duration: 1 year

(Contd.)

Table – 1 (Contd.)

Sl. No.	Project Title	Implementing Institution	Project Cost & Duration of Project
17.	Recovery of metallic values from the discarded copper slag	CSIR, Institute of Minerals and Materials Technology	₹ 20 Lakhs Duration: 2 year
18.	Characterisation of Orogenic Style Gold Mineralisation in the BIFs of Dharwar–Shimoga Basin, Exploration Guides for Prospect-scale targeting of sub-surface Gold	Global Academy of Technology, Bengaluru (NGO - National Education Foundation)	₹ 25 Lakhs (seed money) Duration: 12 months
19.	Overburden, sand and industrial waste as mine fills and their impact on soil morpho-dynamicity and sustainable developments	Kalinga Institute of Industrial Technology (KIIT) University, Bhubaneswar	₹ 25 lakhs Duration: 3 years
20.	Development of medium strength Al-Mg-Si (AA6082 based) alloy for high-end strategic applications (extruded or drawn tubes)	Indian Institute of Technology, Gandhinagar and Jawaharlal Nehru Aluminium Research Development & Design Centre, Nagpur	₹ 9751680.00 Duration: 2 Years
21.	Geo-technological evaluation of Bauxite and Laterite deposits of Chhattisgarh State by using Geospatial technology under Smart Mining 4.0	Jawaharlal Nehru Aluminium Research Development and Design Centre, Nagpur, Chhattisgarh Council of Science & Technology, Government of Chhattisgarh, Raipur.	₹ 45 Lakhs Duration: 2 years
22.	Development of low-cost filler material utilising Lithomargic clay for Paint Industry as per IS 68 2006 standard	Jawaharlal Nehru Aluminium Research Development and Design Centre, Nagpur	₹ 45 Lakhs Duration: 2 year
23.	Fabrication of $Al_{12}O_3$ containing cellulose based Ag NPs encapsulated Collagen dressing and investigation of its Therapeutic Opportunities in Diabetic Wound Healing	Kalinga Institute of Industrial Technology, Bhubaneswar and Nehru Aluminium Jawaharlal Research Development and Design Centre, Nagpur	₹ 30 Lakhs (₹ 15 Lakhs - - KIIT and ₹ 15 lakhs –JNARDDC) Duration: 2 years
24.	Development of prototype aluminium seat frame for passenger buses.	Jawaharlal Nehru Aluminium Research Development and Design Centre, Nagpur and Automotive Research Association of India	₹ 100 Lakhs (JNARDDC – ₹ 60 Lakhs & ARAI – ₹ 40 Lakhs) Duration: 2 Years
25.	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	Indian Institute of Technology, BHU Varanasi and other institutes.	₹ 49.98 Lakhs Duration: 2 Years

Source: *Minutes of 53rd meeting of SSAG.*

Table -2: Details of Acceptance of Final Report and Closure of Completed Projects under S & T Programme, Ministry of Mines during 53rd meeting of SSAG

Sl. No.	Project Title	Implementing Institution
1.	Enhanced recovery of manganese as electrolytic manganese dioxide (EMD) from ferromanganese mine tailings through bioleaching	Siksha O Anusandhan University, Khandagiri, Bhubaneswar
2.	Development of environment friendly blasting techniques-	Indian School of Mines, Dhanbad
3.	Rare-earth mineral concentration in the beach sands of Uttara Kannada coast: their economic viabilities and sustainable mining	SDM College of Engineering and Technology, Dhavalagiri,Dharward
4.	Fabrication of advanced ceramic nanocoatings for automotive Applications-	Christ University, Bengaluru and Jawaharlal Nehru Aluminium Research Development & Design Centre, Nagpur
5.	Value-added electrochemical devices from zircon obtained from Beach sands of Odisha	Indian Institute of Technology, Bhubaneswar
6.	Development of metal-graphene alloys, Department of Materials Engineering	Indian Institute of Science, Bengaluru.
7.	Texturally controlled micro-chronological and extraction protocol studies on Pt Chromite mineralisation—Preliminary Studies	Centre for Earth Sciences, Indian Institute of Science, Bengaluru & Indian Bureau of Mines
8.	High performance of rare-earth metal as electrode material for super-capaciter application and fuel cell	Velammal Institute of Technology, Panchetti, Chennai
9.	Development of open cell aluminium foams for heat sink and EMI shielding Application	Advanced Materials and Processes Research Institute (AMPRI), Bhopal
10.	To study the fire retardancy of nano-ATH in polymers-	Jawaharlal Nehru Aluminium Research Development and Design Centre and Central Institute of Plastics & Engineering Technology (CIPET)
11.	Techno-economic survey of aluminium scrap recycling in India-	Jawaharlal Nehru Aluminium Research Development and Design Centre
12.	Assessment of Udaipur rock phosphate, low-grade potassium feldspar and lignite mine waste for the development of organo-mineral fertilizer formulations	ICAR, Central Arid Zone Research Institute, Jodhpur, Rajasthan
13.	Characterisation and beneficiation of lithium bearing minerals from Indian deposits.	CSIR–National Geophysical Research Institute and Indian Institute of Science, Bengaluru
14.	Development of ready-to-use assorted sand for construction activities from zinc refining wastes and marble powder	Manipal University, Jaipur
15.	Process Feasibility studies for the development of high purity aluminium through segregation process	NFTDC PO. Kanchanbagh, Hyderabad
16.	Value addition of calcined bauxite for possible use as abrasives in waterjet cutting applications	Dept of Mech Engg, SSN College of Engg, Kalavakkam, Chennai,
17.	Recovery studies of gold and other values using non-cyanide reagents from tailing dump of Bharat Gold Mines Ltd	Nonferrous Materials Technology Development Centre (NFTDC), Hyderabad

Source: *Minutes of 53rd meeting of SSAG.*

Table 3 - Details of time Extension to Ongoing Projects under S & T Programme, Ministry of Mines during 53rd Meeting of SSAG

S.N	Project Title Institue	Extension upto
1	Bench-scale study on extraction of pure silica and smelter-grade aluminium Fluoride from Coal Fly Ash (CFA) — JNARDDC, Nagpur	March, 2022
2	Improving fracture resistance of rocks through adhesive bonding for underground mining application — India Institute of Technology (ISM), Dhanbad	March, 2022
3	Development of novel nanoporous hollow Fibre membrane based unit for the effective treatment of mine waste water — National Institute of Technology, Karnataka, Surathkal	March, 2022
4	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 — Banaras Hindu University, Varanasi	March 2022
5	Development of a novel underground mining method for exploitation of chromite deposits from friable ore body and host rocks of Sukinda Valley, Odisha — Department of Mining Engineering, IIT, Kharagpur	June, 2022
6	Use of overburden clay as alternate for aggregate — Indian Institute of Technology Madras, Chennai & Neyveli Lignite Corporation Ltd (NLC Ltd)	June, 2022
7	Integrated geological, geochemical and geophysical studies for the delineation of chromitite extensions in Nuggihalli Schist Belt and implications for Ni-Cu+-PGE mineralisation — CSIR–National Geophysical Research Institute and Indian Institute of Science, Bangaluru	June, 2022
8	Utilisation of aluminium dross to achieve zero waste – A bench-scale study Jawaharlal Nehru Aluminium Research Development and Design Centre, Nagpur and CSIR –National Environmental Engineering Research Institute, Nagpur,	June, 2022
9	Treatment of Acid Mine Drainage for Heavy Metal Removal — Indian Institute of Technology, Mandi	June, 2022
10	Development of graphene-based membranes from graphite ore for desalination— CSIR–National Institute for Interdisciplinary Science and Technology	August, 2022
11	Investigation of the dynamics & mechanism of flocculation by polymers and biopolymers for separation of solid particles of high rate thickeners in mineral processing industries. — CSIR–National Institute for Interdisciplinary Science and Technology (NIIST), Thiruvananthapuram	December, 2022
12	Direct production of Fe-Cr- Ni-Mn stainless alloy from mine waste by thermal plasma process — CSIR – Institute of Minerals & Materials Technology, Bhubaneswar	December, 2022
13	Production and certification of certified reference materials (CRMs) for the analysis of aluminium alloy — Jawaharlal Nehru Aluminium Research Development and Design Centre, Nagpur.	December, 2022
14	Recovery of scandium metal from acid leach liquor from titanium mineral industries. — CSIR–National Institute for Interdisciplinary Science and Technology (NIIST)	January, 2022
15	Processing of spent and natural graphite for energy and aerospace application — CSIR–Institute of Minerals & Materials Technology Bhubaneswar	January, 2022

Source: Minutes of 53rd 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 2021-22 are furnished below:

Indian Bureau of Mines (IBM)

Important R&D activities carried out by IBM during the year 2021-22 are summarised below:

A. Mineral Processing Division, IBM

Copper Ore

Beneficiation studies on a copper ore, G2 stage exploration sample from Udaipur District, Rajasthan— The sample assayed 0.60% Cu, 8.60% Fe(T), 49.01% SiO_2, 9.46% Al_2O_3, 10.70% CaO, 5.82% MgO, 0.79% S(T), 1.48% TiO^2, 0.01% Zn, 0.01% Pb, 0.96% LOI, 2.1% Na_2O and 0.32% K_2O. Flotation tests with optimised condition produced a copper concentrate assaying 25.76% Cu, with 90.05% Cu recovery and wt% yield of 2.10.

Beneficiation studies on a Copper Ore, G2 stage Exploration sample from Giridih District, Jharkhand— The sample assayed 0.82% Cu, 0.14% Pb, 0.46% Zn, 3.48 ppm Ag, 4.57% Fe, 6.84 % Fe_2O_3, 73.2% SiO_2, 3.46% Al_2O_3, 2.08% CaO, 2.32% MgO and 2.58% S. The sample process route involved employing optimised grind, regrinding of rougher float and two stages cleaning. The 2nd cleaner float assayed 24.01% Cu, 3.62% Pb, 2.59% Zn with wt.% yield of 2.5 and recovery of 79.3% Cu, 69.2% Pb and 13.8% Zn respectively.

Beneficiation studies on a Copper ore, G2 stage exploration sample from Mayurbhanj District, Odisha— The sample assayed 0.32% Cu, 0.017% Pb, 0.065% Zn, 53.1% SiO_2, 11.77% Al_2O_3, 15.51% Fe_2O_3,1.07 % S(T), 3.05% CaO, 2.57% MgO, 1.24% TiO_2, 0.94 P_2O_5, 677 ppm Ni, 128 ppm Co, 44 ppm Mo and 2.28% LOI. The process route involved grinding followed by froth flotation and two stages cleaning. The 2nd cleaner concentrate assayed 23.12% Cu, 1.1% Pb, 0.76% Zn, 0.22% Ni, 0.17% Co with Cu recovery of 77.7% and wt% yield of 1.1.

Zinc Ore

Beneficiation studies on a Zinc Ore, G2 stage exploration sample from Betul district, Madhya Pradesh— The ore assayed 1.02% Zn, 0.09% Cu, 0.14% Pb, 69.05% SiO_2, 12.45% Al_2O_3, 4.60% Fe(T), 2.45% MgO, 1% S, 28 ppm Co, 30 ppm Ni, 08 ppm Ag and 114 ppm Mo. Beneficiation route comprising of grinding followed by flotation was developed. The Zn rougher float with two cleaning stages yielded a zinc concentrate assaying 50.22% Zn, 3.25% Pb, 3.03% Cu with 81.9% Zinc recovery and weight% yield of 1.8.

Graphite

Beneficiation studies on a Graphite ore, G2 stage exploration sample from Dhenkanal District, Odisha— The sample assayed 5.82% Fixed Carbon, 67.29% SiO^2, 7.86% Fe_2O_3, 7.50% Al_2O_3, 2.45% CaO, 1.55% MgO, 0.95% TiO_2, 1.21% S and 7.81% LOI. The process route evolved consisted of grinding, froth flotation and five stages cleaning of rougher float with successive regrinding of each float. The 5th cleaner concentrate assayed 68.05% FC with a FC recovery of 85.1% and wt% yield of 7.2.

Iron Ore

Beneficiation study on an iron ore, G-2 stage exploration sample from Keonjhar district, Odisha— The sample assayed 54.14% Fe(T), 3.85% Al_2O_3, 12.31% SiO_2, 0.18% P_2O_5, 0.43% TiO_2, 0.61% Mn, 0.01% S(T) and, 3.67% LOI. Dry beneficiation route employing magnetic separation and wet beneficiation route employing magnetic & gravity separation were employed. The composite concentrate assayed 63.37% Fe(T), 0.91% Al_2O_3, 3.62% SiO_2 and 2.55% LOI with a total Fe recovery of 36.8% and wt% yield of 31.3. Another Grade II concentrate assayed 62.24% Fe(T), 1.06% Al_2O_3, 5.51% SiO_2 and 2.90% LOI with a total Fe recovery of 48.3% and wt% yield of 41.8.

Beneficiation studies on an siliceous iron ore sample from Keonjhar, Odisha— The sample assayed 40.56% Fe(T), 3.53% FeO, 58.0% Fe_2O_3, 39.94% SiO_2, 0.45% Al_2O_3, 0.11% Na_2O, 0.08% K_2O, 0.08% P and 0.36% LOI. The process route employing stage grinding, gravity separation and regrinding of table middling and tails followed by Mozley gravity separation yielded a composite concentrate assaying 65.65% Fe(T), 5.83% SiO_2, 0.24% Al_2O_3 with Fe(T) recovery 92.5% and wt.% yield of 59.0.

Beneficiation studies on a Magnetite Iron Ore, G-2 stage exploration sample from Jamui District, Patna, Bihar— The sample assayed 34.67% Fe (T), 12.76% FeO, 39.38% SiO_2, 3.43% Al_2O_3, 2.45% CaO, 1.76% MgO, 0.17% Na_2O, 0.63% K_2O, 1.38% P_2O_5. The process route employing stage grinding and gravity separation yielded a concentrate assaying 67.39% Fe(T), 19.96% FeO, 3.53% SiO_2, 0.17% Al_2O_3, 0.11% Na_2O, 0.13% K_2O, 0.05% P_2O_5 with Fe(T) recovery of 83.6% and weight percent yield of 43.0.

Manganese Ore

Beneficiation studies on a Manganese ore, G2 stage exploration sample from Chota Udepur District, Gujarat— The sample assayed 19.51% Mn(T), 4.89% Fe(T), 37.41% SiO_2, 2.49% Al_2O_3, 8.58% CaO, 0.52% P_2O_5 and 0.87% BaO. The process route consisted of size reduction, wet screening, gravity separation (for coarse & fine particles separately) and magnetic separation on composite slimes. The Composite Concentrate assayed 35.06% Mn(T), 6.54% Fe(T), 13.61% SiO_2 and 1.81% Al_2O_3 with a Mn(T) distribution of 61.6% and wt.% yield of 34.0.

Rare Earth Elements (REE) and Rare Metal (RM) Bearing Carbonatite

Beneficiation studies on Rare-Earth Elements (REE) and Rare Metal(RM) bearing Carbonatite Sample, G-2 stage exploration sample from Gujarat— The sample assayed 28.84% CaO, 22.18% SiO_2, 7.69% Fe_2O_3, 3.64% MgO, 1.73% Al_2O_3, 3.11% K_2O, 1.76% P_2O_5, 0.2% CaF_2, 1.66% SO_3 and 26.97% LOI, with total REE of 4,006 ppm, Nb 1,074 ppm and Sr 3,172 ppm. R&D study employing different process route were experimented viz. (i) Froth flotation followed by gravity separation process on rougher tails, (ii) Froth Flotation process followed by wet high intensity magnetic separation, (iii) Gravity separation followed by flotation on gravity tails and wet high intensity magnetic separation on gravity middling and rougher float separately, (iv) Leaching on the as received sample with acids.

Acid leaching processes found to be more effective in enriching rare-earth elements. The leach residue assayed 8,738 ppm total REE and 2,445 ppm Nb with the recovery of 93.1% total REE and 97.1% Nb with 44% weight per cent yield.

Rock Phosphate

Beneficiation studies on a Rock Phosphate ore, G2 stage exploration sample from Lalitpur, Uttar Pradesh— The sample assayed 10.98% P_2O_5, 67.44% SiO_2, 3.26% Fe_2O_3, 2.17% Al_2O_3, 11.61% CaO, 0.38% Cl, 0.20% organic carbon and 1.47% LOI. The process route evolved consisted of crushing, grinding and froth flotation with three cleanings of rougher float. The 3rd cleaner concentrate assayed 33.70% P^2O^5 and 16.21% SiO^2 with a P^2O^5 recovery of 52.8% and wt% yield of 17.1.

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 0.15 mm) 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 substantial extent of the total run-of-the-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 in situ 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 which 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 per cent 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.

The above scenario demands concerted & innovative efforts 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 Aluminium Research Development & Design Center (JNARDDC)

1. Completed Projects

1.1 Fabrication of Advanced Ceramic Nano-coatings for Automotive Applications - S&T Mines and Christ University : The objective of the project was to —

(i) Use organic binders to prepare micron sized agglomerates of commercially available non-plasma sprayable nano-sized ceramic compositions feed stock materials, such as, Stabilised Zirconia, Alumina, Alumina –Titania etc. Raw material synthesis of nano powders also will be carried out.

(ii) Use the micron-sized spherical agglomerates consisting of nano-structured feed material into a plasma spray equipment to form nano-structured Plasma Spray Coatings on aluminium / aluminium alloy substrates.

(iii) Deposition of homogenous alumina nanocoatings on aluminium/aluminium alloy substrates using sol-gel technique

(iv) Characterisation of the as-synthesised nano-structured coatings for structural phase and microstructure, and very importantly adhesion to aluminium and its alloy metal substrates.

(v) Study the potential of using the above developed fine quality ceramic nanocoatings for certain automotive applications e.g. Zirconia-based nano- coatings for engine components (piston crown), wear resistant alumina/alumina-titania coatings for wear resistant bearings etc.

(vi) The project aimed 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 final report of the finding showed that small addition of nano-alumina to micron alumina significantly reduces the sintering temperature. 99.0MA+1.0NA from chamber offered high densification. Further optimisation of spray drying parameters to control the agglomerated particle size in the chamber is expected to provide a higher yield of the desired composite as well. In addition to the development of two technologies (nano-plasma sprayable powder synthesis & nano-coatings synthesis via APS) were filed under this project Based on successful lab-scale findings the pilot-scale work can be taken up.

1.2 Techno-economic Survey of Aluminium Scrap Recycling in India— (S&T Mines) : The objective of the project is summarised below:

(i) To "Establish techno-economic scenario of Aluminium Scrap Recycling Industry in the country" for which field survey, online survey and secondary research were carried out.

The project findings revealed that domestic recycling of aluminium provides employment apart from its energy and emission advantages, however, there are several challenges to overcome. These challenges include lack of system for domestic scrap collection and processing, high capital infrastructure for scrap pre-treatment and QA, logistics, lack of dedicated recycled zones, concerns regarding quality, lack of R&D, etc. Government initiatives like National Non-Ferrous Metal Scrap Recycling Policy (MoM), National Resource Efficiency Policy (MoEF&CC), Circular Economy in Scrap Metal (NITI Aayog & MoS), Vehicle Scrappage Policy (MoRTH), Resource Efficiency in Aluminium (MoM), Non-Ferrous Metal Import Monitoring system (MoM), Motor Vehicles (Registration and Functions of Vehicle Scrapping Facility) Rules (MoRTH), etc. are expected to address majority of these problems and prepare the domestic Aluminium Recycling Industry to increase its share in total aluminium production in near future.

1.3 Development of ceramic proppant from low-grade materials (Partially Lateritised Khondalite -PLK, Fly ash, etc.)— Phase-II-Scale up studies, NALCO, Bhubaneswar: The objective of the project is enumerated as below:

(i) Setting up of scale-up facility to produce proppants from low-grade materials (PLK, etc.), additives, and optimisation at bench-scale (10-15 kg /day processing).

(ii) Characterisation and validation of product.

(iii) Flow sheet development.

The result shows that the sphericity and roundness of granules are in the range of 0.6 to 0.8 and 0.6 to 0.8 respectively. The acid solubility of calcined granules is in the range of 2–7 %. The analysis of various calcined granules shows turbidity values in the range of 20–60 FTU/NTU which are within the limit value of = 250. The validation tests on proppant sample were carried out from an external NABL accredited laboratory. Ceramic proppants are highly useful in extraction of oil and gas as they can withstand a much greater crush strength than traditional frac sand and they also provide high conductivity to increase the oil and gas production output. Successful commercialisation of this process will lead to utilisation of low-grade materials and benefit the Oil and Gas sector.

1.4 ***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". NALCO, Bhubaneshwar (Jointly with IMMT Bhubaneswar & Eesavyasa Tech, Pvt Ltd. Telangana) :*** The objective of the project is summarised as below:

(i) Development of an innovative and viable process for recovering iron values from red mud generated at NALCO's alumina refinery.

(ii) Value-added utilisation of non-magnetic tailing as insulating material.

The test report showed thermal conductivity of geopolymer block prepared with on-mag tailing (IMMT) against vespel standard in the range 0.402 to 0.412 watts per meter-kelvin (W/(m·K). The report confirmed that the blocks are good insulating material suitable for building materials and other related applications. The finding provided a viable process option for complete value added utilisation of red mud.

2. Ongoing Projects

2.1 Bench-scale study on extraction of pure Silica and smelter-grade Aluminium Fluoride from Coal Fly Ash (CFA)– S&T (Mines) (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 accumulate. These accumulations 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 are being carried out to study bench-scale (0.5–1 kg CFA) extraction of pure silica and aluminium fluoride by treating CFA with appropriate mineral acid.

2.2 Utilisation of aluminium dross to achieve zero waste – A bench-scale study project report 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.

***2.3 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.

2.4 Geo-technological evaluation of Bauxite and Laterite deposits of Chhattisgarh State by using Geospatial technology under Smart Mining 4.0 (with Chhattisgarh Council of Science & Technology, Government of Chhattisgarh, Raipur) sponsored by Ministry of Mines: At present there is limited geo-technological information about Chhattisgarh bauxite and laterite deposits to confirm utilisation for metallurgical and non-metallurgical applications. Accordingly, JNARDDC has joined hands with Chhattisgarh Council of Science & Technology, Government of Chhattisgarh, Raipur to undertake this project. The project outcome will lead to creation of a digital database which will be highly useful to identify suitable deposits for industrial applications using geo-informatics technology. It will assist the state govt in auctioning of blocks. Efforts will be made to make the database available through Mobile App.

2.5 Solid-state recycling of aluminium chips (waste) for production of billets for pilot scale extrusion sponsored by Ministry of Mines: The aim of this project is to utilise aluminium swarf/ chips (waste) of AA6063 and AA2024, which are generated during machining of components, for the production of aluminium billets for extrusion.

2.6 Technology Development for Holistic Utilisation of Red Mud for Extraction of Metallic Value & Residue Utilisation [with NML, Jamshedpur, IMMT, Bhubaneswar, NALCO, HINDALCO & VEDANTA] under aegis of NITI Aayog sponsored by Ministry of Mines: 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 and REE enrichment from red mud and for further research, development and commercialisation to other industries. The outcome will lead to development of a Master Flow sheet for selected grades of red mud with energy and material balance equipped with techno-economic feasibility.

2.7 Red mud valorisation to achieve zero waste, conversion of residue into diagnostic X-ray shielding tiles after recovery of scandium (sponsored by Ministry of Mines with CSIR-AMPRI, Bhopal) : The main objective of this

project is to convert red mud into economically valuable very high energy X-ray and gamma ray shielding blocks, which is suitable for building radiation therapy bunkers, nuclear power plants, food sterilisation plants, etc., and thereby to promote the zero-waste concept.

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 to develop an indigenous process to prepare 4N (99.99%) pure grade alumina (HPA) that has potential for use in LED applications.

2.9 Development of DC cast Al Alloy for Yoke in automobile applications, Sponsored by NALCO Bhubaneswar (Jointly with ARAI, Pune): Automotive yoke is usually made of steel or cast iron. Aluminium alloys are widely used in automotive applications due to excellent strength-to-weight ratio which significantly reduces the fuel consumption and also enables to meet emission norms. The project aims to develop a new DC cast Al Alloy followed by development of the prototype yoke used in automobile applications.

2.10 Demonstration-cum-heat treatment, leaching-recycling and liming study of JNARDDC-NALCO process (by utilising 5,060 kg batch of 1st cut SPL)— sponsored by NALCO Bhubaneshwar): Based on the success of bench-scale studies (1kg) for detoxification of 1st cut SPL material and recovery of caustic and fluoride, JNARDDC has undertaken the Demonstration-cum-heat treatment, leaching-recycling and liming study of JNARDDC-NALCO process by utilising 50-60 kg batch of 1st cut SPL. The project aims to provide the mass balance, CAPEX and OPEX for scaling up the process to commercial level.

2.11 Instrument for Realtime measurement of anode current distribution of aluminium electrolysis cell sponsored by Dept of Science and Technology (DST, 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 to develop 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.

2.12 Instrument for Instantaneous and onsite measurement of aluminium electrolysis bath parameters : sponsored by Dept of Science and Technology (DST, 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 to develop 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.

2.13 Development and Supply of an Instrument for Instantaneous Onsite Measurement of Bath Parameters sponsored by BALCO, Korba : JNARDDC has developed unique equipment capable of simultaneous measurement of vital bath parameters which will prove to be a boon to the aluminium smelters. Measurement time is around 5 minutes and all bath parameters are instantly available which otherwise are measured separately and requires sufficiently long time (12–14 hrs). The real time bath parameters information made available by the Instrument can easily be coupled with the other known pot operating conditions, such as, noise, voltage modifiers and state of feed control which helps in improved energy efficiency, current efficiency ultimately leading to enhanced cell performance. Studies shall be undertaken of the plant conditions for customising the equipment design to meet Balco's requirements followed by plant trials, fine-tuning, demonstration/ validation (50 measurements) and training to operators.

3. Collaborative work

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

3.1. NITI AAYOG: Development of effective handling, storage, usage and management of red mud is a major concern for the global community as a whole. ln 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.

3.2 Department of Science and Technology (DST): JNARDDC has undertaken 2 projects (i) Instrument for Realtime measurement of anode current distribution of aluminium electrolysis cell & (ii) Instrument for Instantaneous and onsite measurement of aluminium electrolysis bath parameters under various R&D programs of DST.

3.3 Chhattisgarh Council of Science & Technology : (CCOST), Raipur an autonomous body of Government of Chhattisgarh joined hands with JNARDDC for Geo-technological evaluation of Bauxite and Laterite deposits of Chhattisgarh State by using Geospatial technology under Smart Mining 4.0. The joint venture activity for Bauxite Mining 4.0 will open up new vistas for utilisation of advance RS, GIS, GPS technology in the area of laterite and bauxite ore utilisation by the Aluminium industries.

3.4 CSIR – Advanced Materials and Processes Research Institute (AMPRI), Bhopal : JNARDDC and AMPRI, Bhopal have undertaken a joint project which aims to convert red mud into economically valuable very high energy X-ray and gamma ray shielding blocks, which is suitable for building radiation therapy bunkers, nuclear power plants, food sterilisation plants, etc., and thereby to promote the zero-waste utilisation of red mud.

3.5 MRAI (Material Recycling Association of India): JNARDDC successfully completed a joint project "Techno-economic Survey of Aluminium Scrap Recycling in India" with MRAI. The final survey report will assist the Government in formulating policies for the sector.

3.6 CSIR – Institute of Minerals and Materials Technology, IMMT Bhubaneswar: A joint project titled "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" was completed in collaboration with IMMT, Bhubaneshwar and Eesavyasa Tech, Pvt Ltd. Telangana. A multi-institutional project "Technology Development for Holistic Utilisation of Red Mud for Extraction of Metallic Value & Residue Utilization" is also under process".

3.7 Christ University, Bangalrur: Christ University and JNARDDC successfully developed 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 life enhancement of automobile components. Two patents were filed for the process.

3.8 Bureau of Energy Efficiency (BEE), Ministry of Power, Government of India: JNARDDC is the aluminium sector expert under PAT-2 / PAT-3 (Perform, Achieve & Trade) Scheme in the National Mission for Enhanced Energy Efficiency (NMEEE) under Climate Change of Bureau of Energy Efficiency (BEE), Ministry of Power. The Centre has successfully carried out technical evaluation under PAT1 & 2 to support the BEE in reducing energy consumption of Aluminium Sector. Presently evaluating PAT-3 scheme. The recommendation will help BEE in generation and trade of e-certificates under PAT scheme.

3.9 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.

3.10 IIT, Bhubaneswar & Anna University: The NALCO, Bhubaneswar sponsored project "Development of Process for 4N High Pure Alumina (HPA) and Substrate Making for its Validation in LED applications" is being executed in collaboration with IIT-Bhubaneswar and Anna University. 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 project outcome has a commercial potential to add to the vision of Make in India program suitable for LED (Light Emitting Diode) and Semiconductor applications.

3.11 CSIR – National Metallurgical Laboratory (NML), Jamshedpur : Under the aegis of NITI Aayog multiple institutions including NML, Jamshedpur are involved in development of feasible processing options for all metal extraction from Red Mud "Technology Development for Holistic Utilisation of Red Mud for Extraction of Metallic Value & Residue Utilisation"

3.12 Automotive Research Association of India (ARAI), Pune: ARAI is the leading automotive R&D organisation of the country affiliated to the Ministry of Heavy Industries, Government of India. ARAI is the prime Testing and Certification Agency notified by Government of India under Rule 126 of Central Motor Vehicle Rules, 1989. JNARDDC and ARAI have taken a joint project with NALCO for development of a new DC cast Al Alloy followed by development of the prototype yoke used in automobile applications. The prototype forging of yoke will be carried out at ARAI.

3.13 Ministry of Mines: JNARDDC is the designated aluminium sector expert / nodal agency for the following key authorities– (i) Non-ferrous Scrap Recycling framework (ii) Zero waste policy for non-ferrous primary and secondary sector; (iii) NMIMS (Aluminium & Copper import monitoring system) (iv) Metal Recycling Authority (MRA) – to carry out the non-statutory functions earmarked for MRA as stipulated in the "National Non-Ferrous Metal Scrap Recycling Framework 2020"; and (v) Resource efficiency in Aluminium Sector

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.

NIRM has successfully completed 50 projects of which 21 projects were from Mining Sector, 15 from Hydropower Sector, 5 from Nuclear Sector, 2 from Thermal Sector 22 from Power Sector and 6 from Infrastructure Sector and one from Oil & Gas. NIRM was awarded 56 new projects during this financial year. Out of 56 new projects, 24 projects were from Mining Sector, 14 from Hydropower Sector, 3 from Nuclear Sector, 14 from Infrastructure Sector, and one from Thermal Sector.

During the year 2021-22, NIRM has made remarkable contributions to the development of safe and economic practices for coal, metal and opencast mines under difficult geomining conditions. Major projects have been oriented to reduce the risk and hazard by modifying/ monitoring the mining methods and adopting best safety practices, while enhancing/sustaining the rate of production Some of the major ongoing projects that are being executed by the Institute during the financial year include:

(i) For Malanjkhand copper mine, numerical modelling was carried out for slope stability assessment for the open cast and to design underground stope dimensions, sequence and support system;

(ii) In situ stress was determined for designing the proposed underground mining at Baroi–Zawarmala, Mochia-Balaria and Rampura Agucha. The mining of the ore has reached up to 500 m below surface. The mine authorities are planning to develop stope blocks at lower levels below the mined out area. Insitu stress is one of the important input parameters which dictates the size of the stopes.

(iii) Impact of ground vibration was studied at Zuari limestone mine, Andhra Pradesh.

(iv) Studies were conducted at Chintalayapalle, Kanakadripalli, and Kolimigundla limestone mines, Kurnool District, Andhra Pradesh to optimise the blast design.

(v) Hindustan Zine Limited, Rajasthan intended in review options for depillaring of ramnant pillars in BK series to add a new production centre considering back filling of voids in the BK series at Baroi Mine.

(vi) A review study was conducted for the effective implementations of the stability measures recommended earlier to M/s Pallava Granites, Chimakurthy, Andhra Pradesh. The Ramco Cements Limited is setting up a green field cement plant with 3.15 MTPA Clinker, 2 MTPA Cement and 50 MW power plant at Kolimigundla Mandal, Kurnool District, Andhra Pradesh. The Ramco Cements Limited awarded the scientific study to NIRM to conduct ground vibration and air overpressure studies at these three mines.

(vii) Scientific study was conducted at Redi Iron Ore Mine of M/s Minerals and Metals, Redi Village, Vengurla Taluka, Sindhudurg, Maharashtra. The safety of the mine pit and waste disposal (dump) by keeping the minimum distance from the houses/structures to its maximum depth of working and safe minimum distance from waste dump along with safe ultimate pit slope was evaluated.

(viii) M/s Jindal Steel Work (JSW) is operating an open cast Narayana iron ore mine near the village Narayanapura, Hospet. NIRM was requested to arrive at better blast design parameters to minimise side effects and also to optimise the fragmentation that NIRM carried out during initial field investigations. Work is under progress.

(ix) M/s UltraTech Ltd has approached NIRM to conduct Scientific Study for stability assessment and monitoring of Pit and Dump at 3 sites; namely Budgauna, Hinauti and Majhgawan Limestone mines at Sidhi Cement works.

(x) Scientific Study for slope stabilisation and monitoring of ground movement of South Face, Mine 1 of NLCIL, Neyveli, Tamil Nadu was carried out. No significant movement was observed.

(xi) M/s Midwest Granite Pvt Ltd, intended to carry out scientific studies for optimising the bench parameters and design of final pit slope to work up to a depth of 150 m from the surface.

(xii) NIRM carried out MASW survey and vibration data at the top and bottom of three tailing dam of the Bailadila iron ore mine of National Mineral Development Corporation Limited in Bastar, Chhattisgarh.

(xiii) The assessment of ground conditions around the sites of sinkholes and subsidence in the coal mining district of Umaria, Madhya Pradesh was taken up by NIRM in compliance with the directions of the Hon'ble NGT.

(xiv) M/s Minerals and Metals is operating Iron Ore Mine at Village Kalane, Dodamarg Taluka, Sindhudurg district, Maharashtra. The total lease area is 32.25 ha. A detailed geotechnical study was conducted to design the slopes and assess the stability of the pit.

(xv) NIRM conducted trial blasts at Andhra Pradesh Mineral Development Corporation Ltd (APMDCL), dolomite open cast mine at Mangampet, Kadapa District, to optimise the blast design for excavation. Blasting is to be carried out in the vicinity of a public road (500 m from mining area).

(xvi) The NLC India Ltd (formerly Neyveli Lignite Corporation Limited) is operating a captive Barsingsar Lignite Mine of 2.10 MTPA (peak) near Village Barsingsar, Bikaner District, Rajasthan. A detailed geotechnical study was conducted to assess the stability of pit slope and dump of the mine.

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 (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. 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 focussing on Fine particle processing, Dry beneficiation, Mathematical modeling & simulation, Plant performance auditing & improvement, and Equipment development. During 2021-22, the following were some important R&D programmes and projects that were under execution:

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

Under 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 to 11.5%. Characterisation of the bauxite ore as revealed from the sample showed various types of textures, like, oolitic, colloform and replacement. The samples contained abundant gibbsite and boehmite, followed by clay, altered/ translucent silicate and opaque minerals (Fe-oxides /hydroxides) and anatase. The beneficiation study included scrubbing & washing, gravity separation, magnetic separation and froth flotation. Scrubbing & washing studies demonstrated that there is significant reduction in reactive silica content (to ~2%) with increase in total available alumina content in the washed product. The reduction in reactive silica in the washed product was possible because of the removal of the fine particles, which contained significant proportion of reactive silica in them. Process technologies/ flow sheets have been developed for low-grade bauxite samples obtained from different mines of Chhattisgarh region.

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

The current studies will explore the possibility of reduction of iron from 1.5% to 0.08% Fe_2O_3 for rejected limestone sample and 0.2% to 0.08% for regular limestone. Attempt was made to reduce the transition elements content from limestone to improve the clinker quality. Based on characterisation and liberation study, the beneficiation of limestone through dry magnetic separation and Air table for the separation of contaminants from limestone, was explored. In addition, a beneficiation process for reduction of impurities present in rejected limestone sample at the mining site was developed.

(iii) Development of Dry Beneficiation Process Technology for Low-grade Iron Ore for Iron and Steel Making

The current project aims to develop a dry beneficiation process technology for iron ore to produce sinter and pellet feed concentrates. Due to the unavailability of dry density separator technology for iron ore, the project aims at developing laboratory-scale dry density separators. As a part of the project, two indigenous dry separators at laboratory scales were fabricated: 1) Air pulsated stratifier 2) Terminal velocity separator. Iron ore with size range -20 mm to + 6 mm was processed in the air pulsated stratifier, and ores with size range -3 mm to +1mm was processed in the terminal velocity separator. Enhancement by 2-3% of Fe content with iron ore feed having Fe content of 59.5 to 60% was obtained in a single stage operation of the air pulsated stratifier. Similarly, in the terminal velocity separator, iron ore Fe content was enhanced by 2% in a single stage operation.

(iv) Continuous Pilot-scale Reverse Flotation of Iron Ore

Reverse flotation method is used for beneficiation of iron ores wherein silica gangue is 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 the encouraging results of batch pilot-scale studies (20–25 kg) obtained in an earlier project carried out at CSIR-NML, continuous pilot-scale flotation of 15 tons of de-slimed product of iron ore slime was conducted, and it validated the bench-scale results.

(v) Effective Utilisation of Middlings and Fines of Coking Coal Washery for Recovery of Carbon Values.

Cokis coal is a scarce commodity in India. Its reserves is about 10.8% of the total reserves of around 320 Billion tonnes. The middlings generated from the

coking coal washeries are used presenthy for power generation. It contains good amount of carbon values which can be recovered. This substantial amount of middlings can be an excellent potential source of coking coal. The coking coal resources can be conserved by recovering extra low ash coking coal from the washery middlings by suitable beneficiation processes. Keeping in view the above, a project has been undertaken to develop a suitable process for gainful utilisation of the middlings of the coking coal washeries towards the enhancement of the carbon recovery for coke making.

(vi) Processing of Hydrocyclone Underflow for Recovery of Silver

NML undertook the investigation to find the possibility of recovering silver from the hydrocyclone underflow of the Lead-Zinc beneficiation plant using enhanced gravity separator. The plant tailing consists of 179 ppm of silver. Bench-scale experiments were carried out using a Falcon concentrator. Initial experimental results indicate the prospect of upgradation of silver metal recovery from the tailing. Detailed study is in progress.

(vii) Studies on Processing of Iron ore Sample for Beneficiation Plant.

The as-received sample was assayed at 61.60% Fe, 2.72% $Al_2 O_3$, 5.70% SiO^2 , and 2.87% LOI. The mineralogical study of the sample revealed that the iron ore consists of a substantial amount of goethite and haematite. In coarser fractions, most of the haematite were seen interlocked with goethite and clay minerals. Liberation studies were carried out by modal analysis on different size classes using zoom stereomicroscope. Significant variation in concentrate yield (53–63 wt.%) was observed with 64–66 % iron content. Considering the desirable particle granulometry, around 66-67% by weight (magnetic and middling product) pellet grade material was produced with an iron content of around 63.5%.

(viii) A Study on Hydrodynamics Characteristics in Separation of Minerals in a Monolithic Flotation Column

To investigate, a monolithic flotation column was developed. The column was made of transparent cylindrical Perspex, and inside the cylindrical column, the channels were made using transparent Perspex. This column would eliminate or reduce the back-mixing in the gas and liquid phase, reduce channeling, reduce entrainment, provide homogeneous bubble size distribution, low coalescence rate and high residence time. Knowledge of flow regime and gas holdup characteristics of the system will be helpful in the improvement of a flotation column performance by reducing pressure fluctuation, by directing transport processes and by volume production.

(ix) Characterisation of Microbubbles and its Subsequent Application in fine Particle Separation

Atest sample showed Pulp density varying between 6 and 15% solid (w/w). Minimum ash of 13.07% was obtained at collector dosage of 500 gpt, but yield at this level was found to be low. For 19% ash the best yield obtained was at collector dosage of 1000 gpt. Therefore, further experiments in the flotation column were done at 1,000 gpt of pine oil with variation of airflow rate and changing other parameters. It was found that with increase in airflow rate the yield increased to 57% with 20% ash at the same operating condition.

(x) Evaluation of Binder Properties for Pelletisation

Efficacy of binder was evaluated based on characterisation of the green and fired pellets, such as, GCS, CCS, Drop number and Porosity. It was observed that impact of organic binder on pellet strength was very high and around 600 CCS was achieved by using the organic binder, but it has negatively affected the porosity and drop number.

(xi) Feasibility Studies on Flotation of High-Magnesia Limestone from Maharashtra And High-Silica Limestone from Rajasthan

The objective of this project work was to obtain a concentrate with less than 3% MgO with optimum recovery from a high-magnesia low-grade limestone analysing 43.46% CaO, 7.50% SiO_2 and 6.54% MgO. The process optimisation for MgO reduction was carried out. The work involved initial sample preparation and characterisation of the low-grade limestone followed by process methodology planning, execution by experimental studies and process optimisation for silica reduction.

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. In 2021-22 for many R&D projects, MOIL had engaged and was associated with several institutions.

Research and Development Projects

1.1 Rock Mechanics : For the use and implementation of the procured Rock mechanic instruments for mines safety, experts at CSIR Central Institute of Mining and Fuel Research (CIMFR) have been approached and they have been given the work of instrumentation, installation and interpretation of the strata conditions for a period of one year for the seven Underground Mines of MOIL Limited.

1.2 Underground Rock Mechanic Study: Underground Rock Mechanic Studies of Ukwa mine and Balaghat mine have been done by CSIR–Central Institute of Mining and Fuel Research (CIMFR) for decision making towards better productivity and safer mining environment.

1.3 Evaluation of Stoping Parameters: In accordance with proposal of the Strategic Management Group to have a trial stoping method of sub-level stoping to increase the rate of production and safety standards, CSIR–Central Institute of Mining and Fuel Research (CIMFR) was engaged for "Evaluation of Stoping parameters, stope design and implementation of planned sub-level stoping at Chikla-B section of Chikla Mine". This trial stoping method, if successful and economic, may open new possibilities for MOIL to modify our recent stoping methods for better productivity and safety.

1.4 Scientific Studies for Support Requirement: Studies for evaluation of support requirement in stope and stability assessment of drivages at Beldongri Mine are being carried out by CSIR–Central Institute of Mining and Fuel Research (CIMFR).

1.5 Ventilation Studies: Studies for ventilation at stope and concreted drive at Beldongri Mine are being carried out by Visvesvaraya National Institute of Technology (VNIT), Nagpur.

1.6 Development of New Software: To handle the vast amount of data produced in day-to-day activities at Mine Planning department, development of Data Management website/ application is under process. This will not only help to organise the large data (and prevent data loss), but will also make it easy and handy for Mine geologist to access the data at a common interface. The necessary developments are underway.

Technology Absorption

2.1 Pani Project (Mining outside in the State of Maharashtra and Madhya Pradesh): MOIL has an expertise from mine to mill in manganese ore mining in India. Gujarat Mineral Development Corporation (GMDC) has signed a MoU with MOIL to explore the possibilities of mining of manganese ore in Pani area of Chota Udepur district, Gujarat. A tripartite MoU between MOIL, GMDC and MECL has been signed to carry out exploration in Village Pani. MECL earlier carried out exploration and proved reserves/resources of manganese ore around 9.5 million tonnes. Based on the exploration work done at Pani project, TEFR has been prepared. MOIL is planning to sign a JV with GMDC to commence mining operations.

2.2 Use of Remote Sensing: On the basis of Remote Sensing studies carried out by National Remote Sensing Centre (NRSC), Hyderabad, in four districts of Madhya Pradesh, viz Balaghat, Jhabua, Jabalpur and Chhindwara, the Company has reserved area under Sub-rule (1) of Rule 67 of the Mineral (other than Atomic Hydrocarbon Energy) Concession Rule 2016 to carry out exploration work in Chhindwara and Balaghat districts and application for reservation has been done in Jabalpur and Jhabua districts. Based on the remote sensing studies and field work, the Govt. of M.P has granted reservation for exploration in two districts, i.e, Balaghat and Chhindwara. MOIL has identified few blocks in which exploration will be done in the year 2022-23. Elaborate exploration proposal has been prepared from G-4, G-3 and G-2 level of exploration.

2.3 Petrological Laboratory: To understand the genesis of the Manganese ore, Mine-Planning Department has established a Remote Sensing and

Petrological lab to study the petrological and mineralogical characteristics of samples collected in field from different areas. The data generated is being utilised in geological reports for onward submission to various statutory organisations like DGMS, IBM, DGM etc.

2.4 Rock Mechanics Laboratory: Mine planning Department has also established a Rock Mechanics lab to conduct Geotechnical studies of various lithology available at all Mines of MOIL. This will help to know various parameters of rocks which will be useful in preparation of mining plans and method of working for better safety and higher productivity. It helps to generate technical reports for onward submission to regulating authorities like DGMS, IBM, DGM etc. for safer mining operations with higher productivity.

2.5 Mine 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. It has improved the face ventilation and productivity of underground section of the mines. The studies are underway at Chikla and Ukwa Mine for productivity improvement.

2.6 Mines Safety: MOIL has installed rock mechanics instruments at 7 underground mine for safety of men and machines in the stopes as per the guideline of DGMS.

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. The R&D centre is equipped with state-of-the-art laboratory equipment to analyse different minerals, coal, metal and non-metals. Some of the facilities includes XRD, WD-XRF, ICP-AES, GFAAS, SEM,RUL, CS, Pilot coke oven, Blast furnace simulation (Softening & melting furnace), Dilatometer & Plastometer, TGA, Dry air & APIC Jig, WHIMS, Ring shear tester, Abrasion tester, Vickers hardness tester, Advanced Rheometer, Friction angle tester, Zeta potential, Automatic mineral analyser, Stereo microscope, Batch & Pilot plant facilities for Mineral processing and Agglomeration.Various research projects completed by the R&D Centre are enumerated below:

The thrust of NMDC Limited's R&D Centre is towards—

1. Conservation of Energy: Minimising the production loss due to flowability related issues in handling and storage of bulk solids (like iron ore, coal, flyash etc). Use of alternate and better screening media to achieve better productivity. Addition of external agent to wet & sticky iron ore to improve flowability and screen efficiency Utilization of mines waste for value-added product like development of building materials.

2. Technology Absorption—

(a) Development of Vision Enhancement System for foggy Weather at Bacheli.

(b) Utilising 100% iron ore fines in the existing beneficiation circuit at pellet plant Donimalai.

(c) Designing of jamming free Rapid wagon loading system in Kirandul complex.

(d) Development of technology for dry processing and beneficiation.

Apart from the above thrust areas, R&D centre also undertakes collaborative projects with reputed organisations and institutes across the globe having expertise in the field of waste utilisation, mining, beneficiation and other allied areas.

3. Projects of NMDC Mines/Projects

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

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

(c) Exploring possibilities of utilising 100% iron ore fines in the existing beneficiation circuit at pellet plant Donimalai.

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

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

(f) Design inputs for Rapid wagon loading system at Kirandul complex.

4. In-house Developmental Research Projects

(a) Process Improvement: (i) Development of high-grade pellets or ultra pure grade pellet.

(ii) Develop a process for 100% utilisation of ultra fines iron ore in sinter making.

(iii) Utilization of mining waste (slime) to produce building materials.

(iv) Investigate the effect of Alumina content on flow properties of iron ore.

(v) Development of comprehensive report on the flow characteristics of different types of coal.

b) **Strategic Technology Absorption—**

(i) Beneficiation of low-grade coal after removal of volatile matters.

(ii) Preparation of sodium base silica and recovery of TiO_2 from kimberlite.

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

c) 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)	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
(iii)	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 Partial replacement of lime by limestone as a fluxing agent in BOF process: Partial replacement of lime with limestone as a fluxing agent in the BOF process is a step towards sustainable steel making. A plant trial has been carried at LD#3 shop of TSL Jamshedpur replacing 10% of lime with limestone. This has led to a decrease in lime consumption by 700 kg/TCS, lump iron ore reduction by 400 kg/TCS and improved dephosphorisation degree by 1% and phosphorous partition ratio by 4 points. Estimated reduction in CO_2 emission was estimated to be around 2 kg/TCS.

1.2 Improvement in plant yield at wet processing plant of Noamundi through small diameter hydrocyclone: Slime generated during the washing process was treated in the existing hydrocyclone (650 mm dia.) which cuts at 45-micron to recover iron values. Further reduction in cut size helped recovering more iron values. Based on a lab study, a small diameter hydrocyclone (400 mm dia.) was

selected which cuts at 25-micron size. The labs-scale study was followed by demo trial at plant. New hydrocyclone was then installed and implemented — plant data for a period of six months showed improvement in plant yield by 1.8%.

1.3 Application of glidants to reduce stickiness of iron ore fines: The stickiness delay during unloading of Blended Fines Ore (BFO) is a concern for regular plant operations. Surface modifying glidants when coated on iron ore particles, improves flowability of the mass through sliding of interacting surfaces. Lab tests with various glidants and lubricants showed that stickiness delay can be reduced by 0.25 to 0.5 g/kg addition of glidants. After conducting technoeconomic due diligence, plant trials were conducted with two silica based glidants.

1.4 Development of Antimicrobial colour coated sheet: A coating formulation with Anti-bacterial and Anti COVID-19 functional properties was developed by dispersing functionalised nano additives in a paint system. The coated steel substrate qualifies the anti-bacterial and Anti-COVID-19 measurement tests as per standards JIS Z 2801; ISO 21702.

1.5 Development of Copper free MIG wire: Copper coating on MIFG wire possess peeling issues during welding and also, copper fumes are hazardous to operators. R&D has developed an environmental friendly coating, which can eliminate the copper coating on MIG wire. A plant trial has been conducted with the novel coating formulation – the novel coating formulation meets the desired welding criteria.

1.6 Pulse iron ore sintering: Tata Steel R&D has developed a new methodology in iron ore sintering called "Pulse Sintering". Unlike conventional sintering process where the suction is continuously downdraft, pulse sintering helps in to broaden the flame and, increases sinter heating index by improving heat transfer rate of flowing gas. This concept was successfully implemented in sinter plant at TSL and observed improved flame-front propagation and, lowers sinter return fines generation.

(B) Kalinganagar Raw Material Handling System and Logistics

(i) Robot Operation in wagon tippler: Elimination of MMI during coupling and decoupling activity.

(ii) Modification of CHP HMI mapping of all the piles in yard: By mapping of the Coal stockpiles in HMI resulted in elimination of mixing of different grades of material due to human error

(iii) Productivity enhancement of Conveyor through effective Braking: By measuring and setting up the conveyor stoppage time in sync with preceding and succeeding conveyor resulted in elimination of jamming in conveyor circuits.

(iv) Prevention of Dumper Movement during its Body raised condition: By setting a timer-based operation of body raised dumper movement helped resolve multiple serious incidents.

(v) Enhanced reliability of Moving equipment through installation of Drag Chain: This system is aimed at eliminating the failure of composite cable along with minimising the risk of electrocution.

(vi) Safety reliability improvement through smart fencing system in wagon tippler: This ensures elimination of unsafe condition arising due to MMI during rake unloading.

(vii) Preparation of Intelligent Ore and Flux Dispatcher (IOFD) decision making system: This will help in planning effective engagement of stacker reclaimer during day-to-day operation.

(viii) Setting up of Tyre washing facility: Reduction in fugitive dust emission caused by movement of vehicles on road.

(ix) Robot Operation in Wagon Door Opening and Closing in Outbound Logistics: This will help in elimination/ reduction of MMI during opening and closing of wagon doors for finished Good Despatch.

(C) Sinter Plant

(i) Digital Twin model for Sinter Plant: Integrated model with simulation and recommendations to improve Key KPIs of Sinter Plant.

(ii) Digital model for sinter size analysis: Improve mean size of sinter dispatch to BF.

Hindustan Zinc Ltd (HZL)

Specific areas in which R&D has been carried out by Hindustan Zine Ltd in 2021-22 are summarised below:

(i) Enhance grade and recovery of metals during mineral processing on various circuits

(ii) Improve recovery of metals from Cu dross and fume zinc-oxide generated in lead smelting process

(iii) Improve recovery of metals in existing ancillary processes for waste generated in zinc leaching process

(iv) Development of value-added products

(v) Improvement of current efficiency in electrowinning of Zinc

(vi) New process development for treating waste generated in zinc leaching process

(vii) Sintering challenges in ISF with Pb-Zn concentrate

(viii) Alternative utilisation of jarosite and jarofix to reduce environmental footprint

(xi) Utilisation of mixed salt generated in Zero Liquid Discharge process

(x) Geo-Metallurgical performance like ore hardness, minerology and flotation performance for individual ore types across HZL mines.

(xi) Automated Minerology equipment (FESEM with Minerologic software) installation and initiate use for characterisation of ore and in process samples.

(xii) Feasibility tests to address graphite challenge in ores by evaluating various reagents performance, gravity separation, flotation and de-sliming techniques.

(xiii) Technical support to mills for operational issues like high rejects from grinding mills, increased misplacements and poor concentrate quality.

(xiv) Silver recovery improvement by testing of alternate reagents and enhanced gravity separation.

(xv) Utilisation of ground blast furnace slag as a binder in paste fill plant

(xvi) Chloride-based leaching bench-scale testwork conducted to enhance Zn recovery and reduce the waste footprint in Zn Hydro process

Hindustan Copper Ltd (HCL)

HCL has undertaken the following R&D projects in 2021-22.

(i) Study on Feasibility of Changing mining method from Track to trackless at Khetri Mine, Rajasthan and Cost Benefit analysis in order to achieve enhanced production & productivity.

(ii) Study of requirement and selection of suitable Mine Communication System in Underground mine of MCP.

(iii) Geotechnical Study and Numerical Modeling by Stability analysis of open-pit and underground mine of MCP, Risk assessment for optimisation of support system design.

(vi) Developing software-based 3D Geological ore body modeling and mine planning system for MCP underground mines with real-time updating incorporating geological and mining data for short- and long-term production planning.

(v) Study for debottlenecking and capacity enhancement provision for concentrator plant, Khetri.

(vi) Numerical modeling and 3D Subsidence analysis for Mine lease areas of ICC unit.

(vii) Around 1,70,000 MT of old lean ore from mines was treated in two phases exclusively and metal recovered was 708 CMT.