Indian Minerals Yearbook 2019

(Part- I : GENERAL REVIEWS)

58th 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 top priority to R&D programmes. For fructification of principles as enunciated in the NMP and for the promotion of R & D in the mining sector, Ministry of Mines has launched a comprehensive Science & Technology Programme.

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.

The S&T programmes of the Ministry of Mines, Government of India cover the disciplines of Geology, Exploration, Mining, Beneficiation and Mineral Processing, Rock Mechanics, Ground Control and Non-ferrous Metallurgy and Environmental issues related to Mining and Metallurgy. These projects are funded through grant-in-aid by the Ministry of Mines through the process of project evaluation by Project Evaluation and Review Committee (PERC) and recommended projects are approved by the Standing Scientific Advisory Group (SSAG) constituted by the Ministry.

Based on scrutiny which passes through different stages of evaluation including presentation of shortlisted projects before the PERC and final approval of an inter-ministerial SSAG, grants are given to the projects submitted by R&D institutions. During the financial year 2018-19, a total of 19 projects have been approved by SSAG for grant-in-aid under S & T programme of the Ministry.

During 17th PERC meeting held on 19-20th July 2018 at JNARDDC, Nagpur, the new project proposals and 6 proposals recommended by the 16th PERC for resubmission were considered and evaluated. The projects recommended by the PERC were further considered during 49th meeting of the SSAG held on 31st July 2018 at Shastri Bhavan, New Delhi. After detailed deliberation, SSAG approved 10 project proposals for the year 2018-19 (Table-1).

As per minutes of the 18th PERC meeting held on 24th October 2018 at JNARDDC, Nagpur, a total of 48 project proposals were received in the second phase for the year 2018-19. Out of 48 proposals, 16 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 short listed for further review in the second stage. These 16 project proposals were presented by the respective PIs and evaluated by the PERC. Further, 4 (Four) projects as recommended by 17th PERC were included in presentation. In addition to the above, 6 (six) ongoing/completed projects were reviewed by the committee.

Based on the detailed review and evaluation, PERC recommended 9 (Nine) project proposals with or without changes to next level of SSAG, 3 (three) project proposals to be revised and resubmitted in next PERC and 8 (eight) project proposals not recommended. Besides, PERC recommended 1 (one) ongoing project for extension of duration, acceptance of final report of 1 (one) completed project for consideration and approval of SSAG.

During 50th meeting of SSAG held on 2nd November 2018, the projects which were reviewed and recommended by PERC were considered. After detailed deliberations, SSAG approved 9 (nine) project proposals which are summarised in Table-2.

One project was considered by the SSAG for review and extension of time. After detail deliberation, the SSAG approved the proposed time extension to the following project -

Project Title: Mineralogical and geochemical characterisation of Indian glauconites for alternative potassium fertilizers (Ongoing)

Implementing Institution: Indian Institute of Technology, Bombay and CSIR National Geophysical Research Institute, Hyderabad, Telangana.

Extension: up to 31st Dec 2019 without any cost escalation.

The final report of one project was considered by the SSAG. After deliberation, the SSAG accepted the final report of the following project and approved closure of project-

Project Title: Purification of commercial rare earth oxides, e.g. Ceria, by molten salt fusion and recrystallisation

Implementing Institution: Non ferrous Materials Technology Development Centre, Hyderabad

Action: Accepted final report and approved closure of project.

Table -1: Details of Projects Approved for 2018-19 during 49th Meeting of SSAG

Sl. No.	Project Title	Implementing Institution	Cost & Duration of Project	Remarks
1.	Development of a Low-cost Portable Optical Reflectance Spectrometer for Mining and Mineralogy	IIT, Madras	Total Cost: ` 10 lakh (Capital: ` 3 lakh, Recurring: ` 7 lakh) Duration : 1 year	-
2.	Novel Approach to Recover Individual Valuable Heavy Minerals from Pyribole-ferrous Beach and Dune Sand Deposits	CSIR-IMMT, Bhubaneswar	Total Cost : ` 15 lakh (Recurring) Duration : 1 year	-
3.	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-NIIST, Industrial Estate, P.O. Thiruv-ananthapuram	Total cost: ` 60 lakh, [MoM's share subject to 50% contribution towards capital expenditure by DST] Duration: 2 years	Subject to approval by DST. NIIST to obtain approval of DST also for the pro-posal.
4.	Use of Overburden Clay as alternate for aggregate	IIT, Madras & NLC Ltd	Total cost: MoM's share: ` 70 lakh, NLC contribution: ` 103 lakh. Duration: 3 years	-
5.	Texturally controlled micro-chronological and extraction protocol studies on Pt-Chromite mineralisation (Preliminary studies)	Centre for Earth Sciences IISc, Bengaluru & IBM	Total cost: MoM's contribution: ` 8 lakh to IISc Bengaluru (Recurring), IBM to meet expenditure of balance ` 8 lakh from its sanctioned budget Duration: 1 year	-
6.	Development of Ready-To-Use Assorted Sand for Construction Activities from Zinc Refining Wastes and Marble Powder	Manipal University, Dehmi Kalan, Jaipur	Total cost: ` 20 lakh (Capital: ` 9.60 lakh, Recurring: ` 10.4 lakh) Duration: 1 year	-
7.	To study the fire retardancy of nano-ATH in polymers	JNARDDC, Wadi, Nagpur & CIPET	Total cost: ` 56.98 lakh (JNARDDC- ` 31.30 lakh & CIPET - ` 25.68 lakh) Duration: 2 years	-
8.	Techno-economic Survey of Aluminium Scrap Recycling in India	JNARDDC, Wadi, Nagpur & Metal Recycling Association of India	Total Cost: JNARDDC - ` 53.55 lakh (Recurring) Duration: 1 year	The report should include an analysis of the survey and recommendations for developing the ecosystem
9.	High performance of rare earth metal as Electrode material for super-capaciter application and fuel cell	Velammal Institute of Technology, Chennai	Total Cost: ` 30.96944 lakh Duration: 2 years	-
10.	Development of open cell aluminium foams for heat sink and EMI shielding Applications	AMPRI, Bhopal	Total Cost: ` 30 lakh [MoM's share- ` 21 lakh CSIR's share- ` 9 lakh] Duration: 2 years	-

Source: *Minutes of 49th meeting of SSAG held at MoM, New Delhi.*

Table -2: Details of Projects Approved for 2018-19 during 50th Meeting of SSAG

Sl. No.	Project Title	Implementing Institution	Cost & Duration of Project	Remarks
1.	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	Total Cost: ` 24.9225 lakh (Capital: ` 3 lakh, Recurring: ` 21.9225 lakh) Duration : 2 year	-
2.	Bench scale study on extraction of pure Silica and smelter grade Aluminium Fluoride from Coal Fly Ash (CFA)	JNARDDC, Nagpur	Total Cost: ` 63.026 lakh (Capital: 16.5 lakh, Recurring: 46.526 lakh) Duration : 18 month	-
3.	Characterisation and Beneficiation of Lithium-bearing Minerals from Indian deposits	CSIR-Institute of Minerals & Materials Technology, Bhubaneswar	Total cost: ` 15 lakh, (Capital: Nil, Recurring: 15 lakh) Duration : 1 year	-
4.	Development of capacitive deionisation technology for the extraction of germanium and selenium	IIT, Madras Chennai	Total cost: ` 29.61 lakh, (Capital: Nil, Recurring: 29.61 lakh) Duration:1 years (phase-1)	-
5.	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 Geo-physical Research Institute, Hyderabad, Telangana & Indian Institute of Science, Bengaluru	Total cost: ` 60 lakh, [NGRI – 30 lakh, (Capital: Nil, Recurring: 30 lakh); IISc – 30 lakh (Capital: Nil, Recurring: 30 lakh)] Duration: 2 year	-
6.	Treatment of Acid Mine Drainage for Heavy Metal Removal	Indian Institute of Technology, Mandi, Himachal Pradesh	Total cost: ` 19.8397 lakh (phase-I) (Capital: 12.47 lakh, Recurring: 7.3697 lakh) Duration: 1 year	-
7.	Development of graphene-based membranes from graphite ore for desalination	CSIR-National Institute for Inter-disciplinary Science and Technology (NIIST), Thiru-vananthapuram & CSIR –NML, Madras Centre, Chennai	Total cost: ` 60 lakh [NIIST – 42.27 lakh (Capital: 15 lakh, Recurring: 27.27 lakh); NML – 17.73 lakh (Capital: Nil, Recurring: 17.73 lakh)] Duration: 2 years	-
8.	Recovery of scandium metal from acid leach liquor from titanium mineral industries	CSIR-National Institute for Inter-disciplinary Science and Technology (NIIST), Thiru-vananthapuram	Total Cost: 32.92 lakh (Capital: Nil, Recurring: 32.92 lakh) Duration: 2 years	-
9.	Improving fracture resistance of rocks through adhesive bonding for underground mining application	Indian Institute of Technology (ISM) Dhanbad	Total Cost: ` 14.73467 lakh (Capital: 13.7571 lakh, Recurring: 0.97757 lakh) Duration: 15 month	-

Source: *Minutes of 50th meeting of SSAG held at MoM, New Delhi.*

RESEARCH & DEVELOPMENT

The Research & Development (R&D) work in the field of Ores & Minerals is being carried out by IBM, JNARDDC, CSIR & allied laboratories, other research organisations relating to mineral/metal and various mining & mineral-based industries. As per available information, details of some of the R&D work conducted or completed by various organisations during 2018-19 are furnished below:

Indian Bureau of Mines (IBM)

Important R&D activities regarding ore dressing carried out by Mineral Processing Division, IBM during the year 2018-19 are summarised below-

A) Research & Development - Ore Preparation & Processes

1. Bauxite

1.1 Beneficiation Studies on a Medium-grade Bauxite Sample, Jamnagar, Gujarat: A medium-grade bauxite sample, Jamnagar, Gujarat assaying 44.38% Al_2O_3, 8.08% SiO_2 (T), 7.63% reactive silica, 16.99% Fe_2O_3, 24.80% LOI, 2.15% TiO_2 was received for beneficiation studies. Gibbsite is the main aluminium bearing mineral in the sample with minor amounts of boehmite and diaspore. Clay (kaolinite) was noticed in subordinate amount. Haematite and goethite/limonite were the iron minerals also present in subordinate amount.

By adopting simple cost-effective technique like attrition scrubbing followed by screening could yield a composite concentrate which assayed 49.85% Al_2O_3, 2.27% SiO_2(T), 17.36% Fe_2O_3 and 27.48% LOI with 54.9% Al_2O_3 recovery (wt% yield 49.2). The concentrate produced may be suitable for industrial use where the silica content is less than 3%.

1.2 Bench-scale Beneficiation Studies on a Low-grade Clayey Bauxite Sample, Jamnagar, Gujarat: A low-grade clayey bauxite ore sample assaying 38.42% Al_2O_3, 26.05% Fe_2O_3, 8.81% SiO_2, 7.69% reactive silica, 2.32% TiO_2 & 21.76% LOI were received for beneficiation studies. Gibbsite was the main aluminium-bearing mineral in the sample with minor amounts of boehmite. Clay (kaolinite) was present in subordinate amount. Goethite and limonite were iron-bearing minerals present in subordinate amounts. Haematite was also found in the sample and was present in minor amount.

By adopting scrubbing on -6 mm size yielded a composite concentrate which assayed 44.26% Al_2O_3, 2.84% SiO_2, 24.57% Fe_2O_3 and 23.56% LOI with 42.4% alumina recovery (wt % yield 37.0). The concentrate did meet the desired stipulations of silica content less than 3% and Al_2O_3 values could be upgraded.

2. Copper Ore

2.1 Bench-scale Beneficiation Studies on a Low-grade Copper Ore Sample from North of Golwa, Mahendragarh Distt., Chandigarh, Haryana: A very low-grade copper exploratory drill core sample was received from North of Golwa, Mahendragarh Distt., Chandigarh, Haryana through Geological Survey of India, Chandigarh, Haryana. The objective of the investigation was to study the amenability of the sample for beneficiation and to produce a copper concentrate suitable for metallurgical purposes.

The as received sample assayed 0.29% Cu, 42.25% SiO_2, 9.98% Al_2O_3, 18.47% CaO, 4.87% MgO, 0.25% C and 10.55% LOI. The mineralogical studies on the as received sample indicated that the sample consisted of copper-bearing phases chalcopyrite, bornite, and chalcocite/covellite were present in traces. The sample also consisted of major amounts of carbonates (dolomite, calcite) with subordinate amounts of mica (muscovite, biotite), chlorite, quartz and minor amounts of amphibole and very minor to traces of tourmaline, haematite and zircon.

The beneficiation route employed flotation process yielded a final concentrate that assayed 21.75% Cu, 14.85% SiO_2, 2.38% Al_2O_3, with 86.8% Cu recovery with 1.16 weight percent yield.

The as received sample also had about 18.47% CaO. A tentative flotation test was carried out on the rejects of the copper flotation process. After recovering the copper concentrate, the reject was used as feed for carbonate flotation and the final concentrate produced assaying 45.75% CaO, 3.57% MgO, 6.09% SiO_2, 1.31 Al_2O_3 and 38.11% LOI with 49.1% CaO recovery with 19.8 weight percent yield. The concentrate produced as a by-product of carbonate concentrate was found suitable for Cement-making Industry.

2.*2 Bench-scale Beneficiation Studies on a Low-grade Copper Ore Sample from South of Gangutana Extension, Unit TS No. 54 A/1 Mahendragarh Distt., Haryana:* A very low-grade copper exploratory drill core sample of South of Gangutana extension, Unit TS No. 54A/1, Mahendragarh Distt, Chandigarh, Haryana was received from Geological Survey of India, Chandigarh, Haryana.

The as received sample assayed 0.19% Cu, 44.17% SiO_2, 10.08% Al_2O_3, 19.98% CaO, 3.66% MgO, 0.124% organic carbon and 8.38% LOI. The mineralogical studies on the as received sample indicated that the sample consisted of major amounts of mica (biotite & muscovite), quartz, amphibole and carbonates (dolomite & calcite) with minor amounts of chlorite and feldspar. Presence of chalcopyrite, covellite/chalcocite, bornite, pyrite, arsenopyrite, and tourmaline were noticed in very minor to trace amounts in the sample.

By employing flotation process the sample yielded a final copper concentrate assaying 21.93% Cu, 18.06% SiO_2, 20.02% Fe_2O_3, 6.48% Al_2O_3 with 66.3% Cu recovery (weight percent yield being 0.55). The copper concentrate produced was found suitable for industrial use.

The as received sample also contained about 19.98% CaO and so efforts were made to assess the possibility to produce a by-product of carbonate concentrate which is suitable for industrial applications. A preliminary flotation test was carried out on the rejects of the copper flotation process. After recovering the copper concentrate, the reject was used as a feed for carbonate flotation and the final concentrate produced assayed 43.82% CaO, 5.54% MgO, 7.09% SiO_2, 1.31% Al_2O_3 and 39.81% LOI with 39.3% CaO recovery (weight percent yield 17.9)

Besides copper concentrate production, carbonate concentrate for making cement as a by- product showed capability for production of value addition product from these mines.

2.3 Bench-scale Beneficiation Studies on a Copper-bearing Ore Sample (G-2 stage) of Dariba, North Block, Distt Sikar, Rajasthan: A low-grade copper-bearing ore sample (G-2 Stage) was received from GSI, Western Region, Jaipur for bench-scale beneficiation studies.

The as received sample assayed 0.23% Cu, 331 ppm Pb, 822 ppm Zn, 34.52% SiO_2, 25.22% CaO, 8.063% Al_2O_3, 4.179% MgO, 10.1% Fe_2O_3, 2.10% K_2O, 1.38% Na_2O, 0.708% TiO_2, 0.444% MnO_2, 0.259% SO_3, 0.091% P_2O_5 and 16.40% LOI. Mineralogical studies of the as received sample indicated that the sample consisted of chalcopyrite, covellite and chalcocite as the copper-bearing minerals in minor to very minor amounts. On the other hand, major amounts of carbonates (calcite, dolomite) and mica (biotite > muscovite) with subordinate amounts of quartz were indicated. Minor to very minor amounts of chlorite, haematite, amphibole (tremolite, actinolite), magnetite, ilmenite, goethite/limonite, pyrite and traces of galena, bornite, sphalerite and tourmaline were also noticed in the sample.

By adopting froth flotation beneficiation process, the sample yielded a copper concentrate assaying 21.16% Cu, 3.20% Pb, 6.20% Zn with respect to metal recoveries of 70.01% Cu, 57.17% Pb and 64.47% Zn with wt% yield of 0.8.

Attempts at employing a preliminary flotation test on Rougher Tails obtained after rougher sulphide flotation for by-product recovery yielded a carbonate concentrate assaying 46.20% CaO, 2.58% MgO, 5.41% SiO_2, 2.21% Al_2O_3, 4.06% Fe_2O_3, 37.73% LOI with CaO recovery of 28.94% and wt% yield of 13.1.

The carbonate concentrate obtained may find its use in cement- making industries.

2.4 Bench-scale Beneficiation Studies on Copper-bearing Sample from Khera SE Block, Distt Alwar, Rajasthan: A low-grade copper ore-bearing sample from Khera SE Block, Distt Alwar, Rajasthan collected by Geological Survey of India, Western Region, Jaipur as a part of G-2 exploration was received at Regional Mineral Processing Laboratory, IBM, Ajmer for bench-scale beneficiation studies. The objective of the investigation was to evolve a process flow sheet for producing a copper concentrate assaying more than 18% Cu with maximum possible recovery.

The as received sample assayed 0.22% Cu, 52.82% SiO_2, 6.43% Al_2O_3, 0.67% S(T), 3.64% Fe(T), 2.34% FeO, 11.39% CaO, 4.85% MgO, 0.21% Na_2O, 2.38% K_2O, 0.40% TiO_2, 11.87% LOI with 56.01% acid insoluble. Mineralogically, chalcopyrite was present in traces. Quartz was present in predominant amount, whereas carbonates (calcite and dolomite) occured in major amounts. Mica (muscovite and biotite) present in subordinate amounts. Feldspar and iron oxides (haematite, magnetite & goethite) were present in minor amounts, whereas arsenopyrite, pyrrhotite, pyrite, fluorite, rutile and amphibole occured in very minor to trace amount.

By employing flotation test, a composite copper concentrate was obtained that assayed 21.2% Cu with recovery 68.7% (wt% yield 0.71) which is suitable for metallurgical applications.

The bench-scale beneficiation results indicate that, although the "as received sample" was a low-grade (0.22% Cu), it is amenable for upgradation and it is possible to produce a copper concentrate suitable for copper smelter.

3. Iron ore

3.1 Beneficiation Studies on a Low-grade Iron Ore Sample from Huldool Dongor Bimbol Mine: A low-grade iron ore sample from Huldool Dongor Bimbol Mine assaying 32.93% Fe(T), 44.17% SiO_2, 2.90% Al_2O_3, 47.09% Fe_2O_3, 3.10% FeO, 1.05% Mn & 3.90% LOI was received for beneficiation studies. The sample predominantly consisted of magnetite + martitised magnetite and quartz + feldspar minerals. Goethite/ limonite and clay were present in minor amounts.

De-sliming followed by tabling and magnetic separation of table middling yielded a composite concentrate which assayed 65.01% Fe(T), 4.74% SiO_2, 0.45% Al_2O_3 with Fe(T) recovery of 53.3%. (wt % yield 27.4). The concentrate obtained could be used as pellet-grade concentrate.

3.2 Reduction of Alkali Content from an Iron Ore Sample (No.2): An iron ore sample (No.2) containing high alkali content assaying 61.79% Fe(T), 0.06% FeO, 5.39% SiO_2, 3.42% Al_2O_3, 0.28% CaO, 0.20% MgO, 2.23% LOI and with 0.179% K_2O was received. Haematite was present as a major iron-bearing mineral whereas clay, quartz, gibbsite, goethite, limonite, mica, and feldspar were present in minor amounts. Mica and feldspars were the main alkali (K_2O) contributing minerals in the sample. The objective of the study was to reduce the alkali content (K_2O) to less than 0.1% so that iron ore could be used for end metallurgical use.

By adopting screening, gravity separation and Multi-gravity separation (MGS), the sample yielded a composite concentrate which assayed 64.66% Fe (T), 3.05% SiO_2, 1.80% Al_2O_3, 1.91% LOI and with 0.078% K_2O with 77.5% Fe Recovery with 73.9 weight percent yield.

By employing simple beneficiation techniques, the alkali content (K_2O) was reduced to less than 0.1%. The process indicates that high alkali iron ore after processing can be used for end metallurgical purpose.

3.3 Beneficiation Studies on a Low-grade Iron Ore Sample from Gandhalpada, South Block, Keonjhar distt., Odisha: A low-grade iron ore sample assaying 59.50% Fe (T), 0.07% FeO, 5.42% SiO_2, 4.70% Al_2O_3, 0.28% CaO, 0.24% MgO, 3.94% LOI was received for beneficiation studies. The sample consisted predominantly of haematite with subordinate amounts of goethite/limonite, minor amounts of clay and very minor amounts of gibbsite quartz and mica (muscovite, biotite).

By adopting the Gravity Separation, Multi Gravity Separation Test (MGS) and Wet High Intensity Magnetic Separation (WHIMS), the sample yielded a composite concentrate assaying 63.13% Fe (T), 2.20% SiO_2, 3.03% Al_2O_3 and 3.15% LOI with 72.4% Fe recovery with 68.5% weight percent yield. The composite concentrate produced by adopting the above flow sheet may be suitable for industrial use.

3.4 Bench-scale Beneficiation Studies on Iron Ore Bulk Sample (Drill core) from Gandhalpada South-East, Part-B Block, Kendujhar distt, Odisha: Bench-scale beneficiation studies on an iron ore sample from Gandhalpada South-East Part-B Block,Kendujhar District, Odisha were carried out at Modern Mineral Processing Laboratory and Pilot Plant, IBM, Nagpur for Geological Survey of India, Bhubaneswar, Odisha. The objective of the investigation was to obtain an iron concentrate suitable for end industrial use.

The as received sample assayed 58.84% Fe(T), 4.40% SiO_2, 4.90% Al_2O_3, 0.15% CaO, 0.14% MgO, 0.059% Na_2O, 0.053% K_2O, 0.118% TiO_2, 0.15% P_2O_5, 0.095% Mn, 0.85% S and 4.30% LOI. The mineralogy of the sample revealed that haematite was present in major amount with subordinate amounts of goethite/limonite in the sample. Minor to very minor amounts of clay, gibbsite, quartz and traces of pyroxene, feldspar, tourmaline, carbonate (calcite) and mica (muscovite, biotite) were also noticed in the sample.

By adopting beneficiation process Elutriation followed by Tabling and Multi Gravity Separation (MGS), the sample yielded a composite concentrate assaying 62.64% Fe(T), 3.18% Al_2O_3, 2.81% SiO_2 and 3.59% LOI with Fe(T) recovery of 71.3 (wt. % yield 66.9). This concentrate could be utilised for industrial purpose.

4. Limestone

4.1 Beneficiation Studies on a Limestone from Chhattisgarh: A limestone sample from Chhattisgarh assaying 73.28% Total Carbonates (TC), 37.72% CaO, 16.51% SiO_2, 3.61% Al_2O_3, 2.82% MgO, 3.30% Fe_2O_3 & 33.47% LOI was received for beneficiation studies. The sample consisted of predominant amounts of calcite with sub-ordinate to minor amounts of dolomite, mica (muscovite, illite) and quartz.

The beneficiation process adopted consisted of grinding, screening followed by froth flotation which yielded a composite concentrate assaying 84.37% TC, 43.69% CaO, 9.12% SiO_2, 1.35% Al_2O_3, 2.41% MgO, 2.05 % Fe_2O_3 & 34.58% LOI with a TCO_3 recovery of 91.3%

and 79.8 wt% yield. The concentrate did meet the stipulated specifications required for Cement-making industries.

B) Research & Development for Recovery and Utilisation of Wastes

1. Limestone Reject

1.1 Bench-scale Beneficiation Studies on a Siliceous Limestone Reject Sample from Village Bilakalaguduru, Gadivemula Mandal, Kurnool Distt, Andhra Pradesh: A siliceous limestone reject sample from Village Bilakalaguduru, Gadivemula Mandal, Kurnool Distict of M/s JSW Cement Limited was received at Regional Mineral Processing Laboratory, IBM, Bengaluru for preliminary characterisation and detailed bench-scale beneficiation studies with an objective to reduce silica content in the limestone concentrate so as to meet the Cement Industry requirement.

The as received sample assayed 36.90% CaO, 0.73% MgO, 24.24% SiO_2, 3.95% Fe_2O_3, 2.3% Al_2O_3, 0.14% TiO_2, 28.50% A.I., 12.46% Free Silica, 67.72% Total Carbonates and 29.75% LOI. Specific gravity of the as received sample was 2.72.

Mineralogical analysis of the sample revealed that the sample mainly consisted of carbonate (calcite) as major mineral and quartz+ feldspar as sub-ordinate mineral. Clay, goethite/ limonite, pyrite/pyrrhotite, pyroxene/amphibole**,** dolomite and mica were present in very minor to trace amount. Microscopic examination studies revealed that the carbonate (calcite) occurred in cryptocrystalline to fine-sized grain. Most of the carbonate grains are interlocked with quartz + feldspar, goethite/limonite, pyrite+ pyrrhotite and clay minerals.

Attempts were made for dry processing but the results were not encouraging as calcite & other gangue minerals were intermixed. Flotation test at a grind of 95.4% passing 75 μm, with 0.5 kg/t sodium silicate, with 0.7 kg/t sodium oleate, at a low pulp density of solids (~20%) yielded a three stage cleaner float concentrate assaying 47.21% CaO equivalent to 84.03% $CaCO_3$, 12.42% SiO_2, 36.16% LOI with a CaO recovery of 68.1%. The wt % yield of the product was 55.6.

The studies suggested that the limestone reject dump sample is amenable for beneficiation by flotation to reduce silica content to the desired specification of Cement Industry i.e., < 13% SiO_2.

2. Lime Mud (Aragonite) from Gujarat Offshore

2.1 Beneficiation and Agglomeration Studies on a Lime Mud (Aragonite) Sample from Gujarat Offshore: A Lime mud (Aragonite) sample from Gujarat offshore assaying 48.62% CaO, 4.08% SiO_2, 0.71% MgO, 0.52% Fe_2O_3, 0.74% Al_2O_3 and 42.99% LOI was received for beneficiation studies. Aragonite and calcite were the major minerals present in the sample, with subordinate amount of quartz/feldspar. Kaolinite, illite and albite were also present in minor amounts.

By adopting wet screening and flotation yielded a rougher float concentrate assaying 52.16% CaO, 2.20 % SiO_2, 0.28% Fe_2O_3, 0.45% Al_2O_3, 0.29% MgO, and 42.16% LOI with CaO distribution of 77.6% (wt% yield of 74.8). This rougher float concentrate meets the requirement of the Filler Industry applications.

Thus, the lime mud sample subjected to screening followed by flotation yielded a concentrate suitable for Filler Industry applications, while the +500 mesh size fraction obtained by screening and non-float (combined reject) could find utilisation in Cement Industry. Thus, this process generated "ZERO WASTE". The entire lime mud material would be useful for different industrial applications.

3. Lime Sand (Aragonite) from Gujarat Offshore

3.1 Beneficiation and Agglomeration Studies on a Lime Sand (Aragonite) Sample from Gujarat Offshore: A lime sand (aragonite) sample from Gujarat sea coastal area assayed 49.73% CaO, 3.76% SiO_2, 0.70% MgO, 0.34% Fe_2O_3, 0.55% Al_2O_3, 0.34% TiO_2 and 42.41% LOI was received for beneficiation studies. The aragonite and calcite are the major minerals present in the sample, with subordinate amounts of quartz/dolomite and illite were also present in minor amounts.

By adopting screening, attrition scrubbing and flotation yielded a composite (filler-grade concentrate) that assayed 51.57% CaO, 2.27% SiO_2, 0.43% Fe_2O_3 and 42.58% LOI with CaO recovery of 96.2% (wt % yield of 95.0). The lime sand sample is amenable to (i) simple beneficiation methods, such as, wet screening to obtain filler-grade concentrate assaying 51.15% CaO, 2.95% SiO_2, 0.5% MgO, 0.35% Fe_2O_3, 0.47% Al_2O_3 and 41.64% LOI with CaO recovery of 77.0% (wt % yield of 76.4) and (ii) wet screening, grinding and flotation to obtain a composite concentrate with still lower SiO_2 content assaying 52.27% CaO, 1.76% SiO_2, 0.29% Fe_2O_3 and 42.92% LOI with CaO recovery of 64.4% (wt % yield of 62.8). The concentrate produced did meet the

requirement of the Filler Industry. The reject material of the process was also found to meet the requirement of Cement Industry. Both the processes suggested here generate 'ZERO WASTE', which may lead to the utilisation of entire material of lime sand from off-shore.

A maximum recovery of lime sand was obtained by multistage screening and flotation which yielded a composite concentrate assaying 51.97% CaO, 2.13% SiO_2, 0.42% Fe_2O_3 and 41.91% LOI with CaO recovery of 93.0% (wt % yield 91.2).

Jawaharlal Nehru Alumnium Research Development & Design Center (JNARDDC)

1. Completed R&D Projects

1.1 Studies on Trace Liquor Impurities, its Behaviour and Control in Bayer's Process with respect to Reduction in Product Hydrate (Joint Project with NALCO): This joint project with NALCO was aimed at conducting studies for reduction/control of trace impurities from Bayer's liquor to improve the quality of the product. The samples were collected from different unit operations at NALCO Alumina Refinery, Damanjodi, Odisha. The complete profiles of impurities were studied from feed bauxite to final product to assess the behaviour and movement in different unit operations and its control at refinery. The equilibrium solubility was studied with available salts in the market to analyse the saturation concentration of trace impurities in plant liquor as well as synthetic liquor. Digestion of bauxite was also carried out using plant liquor and pure caustic to study the dissolution behaviour and movement of impurities during the process. Lime causticisation was tried in washer overflow at 3rd stage based on soda concentration and C/S ratio and this showed significant reduction in impurities.

The outcome of this study revealed that the impurities can be reduced by chemical routes, i.e. addition of some reagents, such as, sodium diethyl-dithiocarbamate trihydrate, sodium sulphide, sodium dodecyl sulphate and extra in liquor. The trace impurities can also be reduced in washer overflow 3rd stage by increasing the dose of lime.

1.2 Development of Instrument for Instantaneous Onsite Measurement of Bath Parameters (Joint Project with HINDALCO, Hirakud): JNARDDC has successfully designed, developed, delivered and demonstrated the robust and easy to operate equipment suitable for instantaneous measurement of bath parameters (operating temperature, liquidus temperature, superheat, aluminium fluoride, free alumina and bath ratio) to HINDALCO Industries for their Hirakud Smelter Plant. The equipment has been tailor made to suit the plant conditions prevailing in Hirakud Smelter and incorporates unique features like Wi-Fi enabled Data Acquisition System and Electromagnetic Compatible Tablet for ease of operation.

1.3 Characterisation & Technical Assessment of Hazardous/Other Wastes from Process Industry (Joint Project with High Tech Metaflux, Raipur): JNARDDC as part of this project collected products (fluxes, such as, Metric Super, Slag Treat Powder, Teeming Powder, Laddle Covering Compound, Synthetic Slag, Carbon Additives and Tundish Powder/Casting Powder) manufactured by Hi-Tech Fluxes from its premises. Synthetic samples were prepared from the waste/ process rejects (such as dross, waste carbon dust, shot blast dust & carbon bath/skimmed bath and other non-hazardous raw materials like lime, soda, rice husk, mill scale, graphite powder etc.). Raw materials, manufactured products as well as synthetically prepared product samples were extensively characterised. Mass balance studies carried out with raw materials and manufactured product as well as raw materials with synthetically produced product samples indicated close resemblance with calculated ones.

Toxicity Characteristics Leaching Process (TCLP) was carried out for raw materials and finished products for the leachable hazardous level chemical entity. Values obtained for TCLP test for finished products were found to be matching with those obtained for raw materials.

1.4 Effect of Modified Seed Properties in Precipitation of Aluminium Hydroxide from Bayer Liquor (Sponsored by S & T, Ministry of Mines, Government of India): The successful completion of this project whose main objective was to evaluate output from precipitation process in terms of liquor productivity by altering or modifying seed surface properties has led to development of new products and processes. Precipitation process route parameters were established which successfully produced-

- fine hydrate (10-12 μm)
- high surface area alumina hydrate (BET SA 150- 250 m2/g)
- boehmite product hydrate

Also produced alumina from boehmite hydrate (having properties close to smelter-grade alumina) and coarse & fine high surface area gamma alumina.

1.5 Large-scale Digital Database Creation of Bauxite and Laterite Deposits of Maharashtra State using Geo-informatics Technology (Joint Project with MRSAC & GSI): JNARDDC has successfully completed this project using GIS and remote sensing technology which has led to creation of exhaustive and comprehensive digital database related to geology, geomorphology & technological characteristics of Bauxite and Laterite deposits of Maharashtra in geospatial domain. The Master Plans & Resource Plan Atlas prepared provide at a glance scenario of deposits, data on geology, geomorphology, LULC, soil, slope, extensive information on cadastral, GIS, technological data, etc. Prospective entrepreneurs, with limited efforts, can get plethora of information related to environment, economic, accessibility, habitation, available manpower, etc. which will be very useful while mining. The app-based utility - GeoPDF files derived is another unique deliverable of this project.

JNARDDC is fully committed for creating similar digital databases for bauxite and laterite deposits in rest of the States in the country in the coming years.

1.6 Synergistic Utilisation of Aluminium Industrial Wastes for Development of Geopolymeric Building Materials (Joint Project with M/S Swarnalata Holdings, Raipur): In the latest studies, components in mix designs studied earlier were altered to verify synergy among the components. The corresponding impact on water absorption, efflorescence and crushing strength of geopolymerised products has been studied. It is observed that the input of lime sludge in geopolymer mix designs deteriorate physical properties such as enhanced water absorption (from 15 to above 20), efflorescence (slight to moderate) and reduced crushing strength (12 to 8 MPa). Paver blocks (1 x 1 sq. foot size with ~ 40 MPa crushing strength generated with mix fly ash and Granulated Blast Furnace Slag in 40:60 w/w) were laid on footpath and flooring of car parking to study the impact of weathering and durability. The cost of geopolymer paver block is calculated as Rs 18 which is cheaper than traditionally used cement-based paver blocks. The project activities are nearing completion stage and report preparation is in progress.

1.7 Developing Downstream Applications of Strip Cast Aluminium Alloys AA8011 and AA3004 (Joint Project with NALCO & VNIT, Nagpur): Strip cast & cold rolled samples of AA8011 alloy collected from NALCO were tested for their forming characteristics using Deep Drawing/Cupping Test equipment under varying clamping force and cupping speed. Samples of cast strips were rolled at IISc, Bengaluru and are being extensively characterised (mechanical, texture, forming). Set up anodisation laboratory where anodising characteristics of the thermo mechanically treated sheets will be optimised shortly.

1.8 Estimation of Morphodynamicity and its Remedial Action Using Red-Mud Based Concrete at Coastal Zone of Eastern Odisha (Joint Project with IIT, Bhubaneswar): Developed red mud based fired stabilised hard blocks prepared using 70% red mud, 25 % high siliceous plastic clay and 5% Talc with compressive strength comparable to class 20.0 of fired clay bricks. Also developed geopolymer blocks which were prepared by IIT, Bhubaneswar using 35% red mud, 65% fly ash (keeping Na_2SiO_3/NaOH ratio of 1.5 and alkaline solution to binder solids ratio of 0.5) with strength of about 18 N/mm^2. The blocks prepared will be placed along Kendraparha coastal area of Odisha which is facing severe erosion problems. In consultation with relevant authorities in Odisha, site (Dudhia River Muhana mouth, near Puri) was identified for flying UAV Drone jointly with Maharashtra Remote Sensing Application Centre, Nagpur (MRSAC). The timeline data of 10 years of the site starting from 2006 indicates gradual change of course of River Muhana and formation of bund in 2015. The orthophoto pictures captured from UAV drone has helped in identifying sites where the blocks will be placed in the second phase of the project to study the erosion patterns.

1.9 Status Report on Work Carried Out Nationally and Internationally on Red Mud to Benchmark Future Investigation in the Country: The objective of the project is to prepare a status report on work carried out nationally and internationally on red mud. Based on the data collected, detailed report covering various aspects of red mud, such as, generation, characteristics, disposal & storage practices, utilisation (in construction, infrastructure, vegetation, paints and pigments etc.) and recovery of valuables etc. is under preparation.

1.10 Mechanical Activation of Bauxite followed by Technological Studies. NALCO: Mechanical activation is a pretreatment process prior to the leaching of minerals. The process involves milling in a high energy mill to produce finely ground particles that exhibit enhanced dissolution rates in addition to the effects of increased specific surface area on dissolution. The objective is (i) to investigate the effect of mechanical

activation of bauxite on desilication, digestion and settling process steps; and (ii) Explore dissolution and digestion of both low silica (1.5-2.5% reactive silica) and high silica (5-6% reactive silica) bauxites in an attrition mill and study its effect in terms of acceptable silica level in the liquor, digestion efficiency and caustic soda losses in the mud.

The project work was undertaken to evaluate the use of mechanical activation technique for achieving better digestion efficiency. The experimental results are encouraging and have shown that pre-desilication is an essential step to be carried out prior to digestion to achieve an acceptable silica level in the liquor.

2. Ongoing Projects

2.1 Nano Processing of Industrial Rejects for Use as Additives in Mix-Designs for Improved Pozzolanic Reaction Efficiency (Joint Project with VNIT, Nagpur): Procured and installed High Energy planetary ball mill (Maximum power of 2.2 kW and higher acceleration of 64g) for milling of individual as well as mixed compositions of different aluminium and steel industrial wastes. This mill not only grinds material to nano level but is extremely fast compared to conventional ball mill.

Based on the results conducted and provided by VNIT (conductivity tests for evaluating pozzolanic property of grounded materials) some mixed compositions are identified for further tests which will fully assure the pozzolanic nature of the same.

2.2 Utilisation and Development of Process for Recovery of Strategic Rare-Earths from Industrial Waste-Bauxite Residue at Lab-scale (Joint Project with HINDALCO and IREL): The physical beneficiation was attempted to concentrate the REE-grade and reduce the iron content present in bauxite residue prior to leaching process. Hydrocyclone test was carried out to study the effect of the variables, namely, pressure, apex diameter and diameter of vortex finder. It was observed that there is significant enhancement of REE content in overflow than underflow with varied conditions. Optimum operating conditions (Pressure 20 psi, Apex dia - 6.4 mm, and Vortex dia - 8 mm) established showed good REE grade-recovery. Multi-gravity Separation technique was also tried which indicated enrichment of REE content (Sc - 55.0 mg/kg, La - 77.6 mg/kg & Ce - 129.5 mg/kg) in tailing fraction. More trials are underway for achieving maximum enrichment of REEs in lighter fraction. Bench-scale leach tests were carried out using both the raw and upgraded feed which confirmed that reduction of iron levels prior to leaching has positive effect on rare earth leaching efficiency. More trials are underway for optimising parameters for maximum leaching efficiency. Sieving, hydrocyclone and multi-gravity separation appear to be viable options for enrichment of REE's in bauxite residue.

2.3 Fabrication of Advanced Ceramic Nano-Coatings for Automotive Applications (Joint Project with Christ University, Bengaluru): Installed Spin Coating Machine procured for deposition of alumina coatings. Optimisation of process parameters (rpm, deposition time, acceleration) for deposition is in progress. Another technique of deposition (plasma spray method) is being studied by project partner (Christ University, Bengaluru).

2.4 Development of Ceramic Proppant from Low-grade Materials (Partially Lateritised Khondalite - PLK, Fly Ash, etc.) (Phase-II –Scale up Studies) : Objective of the project is to set scale up facility for the production of proppants from Partially Lateritised Khondalite (PLK), fly ash, additives etc. and optimisation at bench scale (10-15 kg/day processing). Established procedure for producing high strength ceramic proppant (on laboratory scale) from PLK by using various additives such as sillimanite, pyrophylite etc.

2.5 Development of Inline Automated Anode Butt Monitoring System to Measure Anode Butt Parameters (Joint Project with NALCO): Objective of the project is to develop an Automated Anode Butt Inspection System which will provide vital information and various defects in the anode butt, which will be useful in optimising anode fabrication process and improved pot control.

Visited Angul Smelter for selecting the suitable place for installation of cameras and other hardware parts. Sensors, cameras and relevant hardware are being studied. Synchronisation of 'n' number of cameras on the basis of the output of the sensor/camera and development of image analysis software is underway.

2.6 Utilisation of PLK (Partially Laterised Khondalite) as a Potential and Value-Added Filler Material with Specific Reference to White Ceramics and Pigments (Joint Project with C V Raman College of Engineering & NALCO): Iron oxide (Fe_2O_3) content in Partially Laterite Khondalite (PLK) was brought down substantially with a great amount of sucess. Physical methods of separation viz. Wet High Intensity Magnetic

Separator (WHIMS), Spiral Concentration and Hydrocylcone etc. were attempted but were not found effective in reducing iron oxide content to the targeted range of 1-2%. Subsequent attempts to produce PLK (with low Fe_2O_3 and high Al_2O_3 & SiO_2) in bulk quantity using acid leaching route are in progress. Once successful, trials to validate the use of PLK as binder for ceramics and pigments will be attempted.

2.7 Development of a Wi-Fi enabled Sensor Arrangement for Online Measurement of Anode Current Distribution of Aluminium Electrolysis Cell (Joint Project with NALCO): Objective of the project is to develop a Wi-Fi enabled sensor arrangement for online measurement of anode current distribution of aluminium electrolysis cell which will result in reducing cell instabilities and improved pot control & efficiency. Finalised the direct contact type of sensor and acquisition system and initiated the process for procuring the same. Plant will be visited shortly to identify suitable location for mounting the sensor and for subsequent trials.

2.8 To Study the Fire Retardancy of Nano-ATH in Polymers: The objectives of the project are to investigate the effect of nano-ATH as fire retardant filler in polymers, to examine the mechanical and flame-retardant properties of polymer/ ATH composites obtained using ATH fillers with different particle size and new process and product development using aluminium trihydroxide and polymer matrix.

2.9 Bench-scale Study on extraction of* pure Silica and Aluminium fluoride *from Coal Fly Ash: Aim of the project recently cleared by PERC, MoM, is to develop bench-scale process for the extraction of pure silica and aluminium fluoride from abundantly available Coal Fly Ash (CFA) solid waste being generated in thermal power plants around the country which typically contains 27-31% alumina (Al_2O_3), 56-60% silica (SiO_2) and 9-13% oxides of elements (Ca, Mg, Na, Fe, Ti etc.). CFA will be treated with mineral acid for extracting pure silica (which is used in structural materials, microelectronics, food & pharmaceutical) and aluminium fluoride (which is heavily consumed by primary aluminium industries 15 to 20 kg/t of Al). Results from preliminary in-house studies prompted taking up this challenging R & D programme, which has potential to address not only national but internationally burning issue and whose success shall be a big boost in improving global environment.

2.10 Techno-economic Survey of Aluminium Scrap Recycling in India (Joint project with MRAI): Compared with the production of primary aluminium, recycling of aluminium products needs only 5% of the energy and emits only 5% of the greenhouse gases. Recycling is a major facet of continued aluminium use, as more than a third of all the aluminium currently produced globally originates from recycling routes. Indian Aluminium Recycling Industry is currently un-organised and is represented by around 5,000 MSMEs. Current recycling rate in India is only 25% as compared to the world average of 45%. Presently, key concern areas of aluminium recycling in the country are complete lack of structure for aluminium scrap handling and secondary metal recovery. On the basis of this background, this project has been awarded jointly with Metal Recycling Association of India (MRAI) and the outcome of which would help 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.

2.11 Technological Characterization of Bauxite Sample for establishing the Mass Balance of the process design of the expansion study at Vedanta Ltd, Lanjigarh, Kalahandi, Odisha: The expansion study at Lanjigarh, Kalahandi, Odisha by Vedanta is being technically supported by JNARDDC. The Centre is undertaking technological characterisation of bauxite samples for establishing the mass balance of the process design.

2.12 Technical Feasibility Study for extraction of Alumina as Al F3 from Low-grade Bauxite (International Bauxite, Alumina and Aluminium Society IBAAS, Nagpur): A lab-scale study has been undertaken for extraction of alumina as aluminium fluoride from low-grade bauxite.

2.13 Development of a Process Technology (at lab-scale) for Low-cost production of 3N (99.9%) Pure Alumina (Dept of Science and Technology): Objective of the project is to develop the process know how for the low-cost production of 3N pure alumina suitable for LED (Light Emitting Diode) and Semiconductor applications. Challenge is to get the required product at much low temperature. Study of cost economics for 3N pure alumina synthesis process will also be evolved.

National Institute of Rock Mechanics (NIRM)

National Institute of Rock Mechanics carries out a number of investigations in the area of rock engineering

and rock mechanics. The Institute extends R&D support and expertise to the Mining Sector (underground, opencast and quarries), Energy Sector (hydel, thermal and nuclear power) and Infrastructure Sector (rail, road, metro, irrigation, urban construction, etc.). Of late it has expanded its activities to the Oil Sector (specialised testing), Defence Sector (onshore and offshore) and other miscellaneous sector (archaeology, environment, etc.). Key area of activities of the Institute involves site characterisation which includes geological, geophysical and geotechnical investigations, excavation engineering, controlled blasting, numerical modelling, engineering seismology, mine design, slope stability, laboratory testing of rock samples and wire ropes and insitu testing of various mining accessories using NDT technique. During the year 2018-19, the Institute has completed over 78 industry projects worth `15.43 crore which included three government funded R&D projects.

Some of the major projects executed by the Institute during this year include:

- Insitu stress measurements at a depth of 600 m at mine of SCCL in Telangana for optimising the orientation of workings of upcoming underground mines for maximising production at greater depth;
- Safe excavation of about 3.5 lakh m^3 of hard rock for the Darlipalli STPP (Stage-I) of NTPC;
- Design modification from underground structure to creation of circular shaft from surface leading to substantial reduction in construction time and cost of Devadulla lift Irrigation scheme, Warangal, Telangana;
- 3D-Modelling (incorporating Shear Zone and large cavity) for planning remedial measures for long-term stability of caverns of Powerhouse Complex of PHPA-II, Bhutan;
- 3D GPR tomography for locating buried archaeological monastery structure at Vadnagar, Gujarat;
- Active fault studies conducted through trenching for seismotectonic evaluation at Jaitapur (Maharashtra); and
- Planning and Design of Instrumentation layout with the help of 3D Model for Powerhouse Complex of Phunatsangchu-II project, Bhutan.

National Institute of Miners' Health (NIMH)

National Institute of Miners' Health conducts applied research in the field of occupational health and hygiene among persons employed in mining and mineral-based Industry with the vision of "Safe Mines and Healthy Miners" and the mission "Indian Mining and Mineral Industry sans occupational Diseases". The Institute has completed following two S&T projects:

(i) Multi-centric Study of Dust-related Diseases in Stone Mines and Development of Sustainable Preventive Programme (In collaboration with Ministry of Labour & Employment).

(ii) Possible implications of bioavailable iron in coal mines dust on coal workers' - lung disease. This project is in collaboration with National Institute of Miners' Health and Priyadarshani Institute of Engineering & Technology, Central India Institute of Medical Research & Western Coal Fields Ltd. (Sanctioned by Central Mine Planning and Design Institute, Govt of India).

The Institute is also implementing following two projects (Sponsored by Ministry of Mines):

(i) Development of standard protocol of field Audiometry for notifying noise induced hearing loss.

(ii) Postural risk analysis of Mining equipment operators and its relation to Musculoskeletal Disorders.

CSIR-Central Glass & Ceramic Research Institute (CGCRI)

1. R & D for Development of Ceramics, Refractories and glass-based on Minerals or mineral substitutes

1.1 R & D on Magnesite for Refractory application: Two major magnesite sources of India (viz. Salem, Tamil Nadu and Almora, Uttarakhand) are unsuitable for high temperature refractory application due to presence of silica, lime and iron oxide as impurities. These impurities form low melting phases during refractory application and hence Indian refractory industries largely depend on imported good quality magnesite. CSIR-CGCRI is working on improvement of high temperature properties of impure Salem magnesite by beneficiation or by judicious selection of additives to reduce the low melting phase formation. Reduction in the silica content of the magnesite was achieved by reverse froth flotation technique. Addition of zirconia and tailoring of the lime/silica ratio improved the thermo-mechanical properties of the sintered magnesia aggregates. Magnesium aluminate spinel was also developed using Salem magnesite through thermal plasma processing route.

2. R & D on clays, zeolites and beach sand minerals

2.1 R & D on Sillimanite Beach Sand for Refractory Application: Alumina-based refractories are widely used in several high temperature structural applications. Sillimanite beach sand is an industrial by-product

generated during rare earth extraction from beach sand. This sand is a pure form of aluminosilicate. Synthetic alumina-silicate aggregates with good thermo-mechanical properties were developed by reaction sintering sillimanite beach sand and calcined alumina. Application of these aggregates in shaped and castable products and their performance evaluation is under progress.

CSIR-National Metallurgical Laboratory (NML)

Studies carried out in the area of Mineral Processing at CSIR-National Metallurgical Laboratory during 2018-19 are as given below:

1. Recovery of Chromite Values from tailings of Chromite Ore Beneficiation Plant: Chromium is important raw material for production of special steel and ferrochrome alloys. About 90% of the mined chromite ore is converted into different grades of ferrochrome and out of which 80% is consumed by stainless steel industry. At present, chromite ore is beneficiated with a release of tailings having 18-20% Cr_2O_3. For resource conservation in compliance to IBM guidelines of 10% Cr_2O_3 in tailing, CSIR-National Metallurgical Laboratory carried out bench-scale and pilot scale beneficiation of Chromite Ore Beneficiation (COB) Plant tailings with 20% Cr_2O_3. A process flowsheet was developed for generating a product with 40% Cr_2O_3, 60-67% recovery and reject tailing with <10 % Cr_2O_3.

2. Optimization of Lead-zinc Ore Beneficiation Plant Comminution Circuit: 1.5 MTPA Lead-zinc concentrator consists of crushing circuit to reduce size from 300 mm to 12-14 mm in two stages and milling closed circuit with hydrocyclone to generate a product with P_{80} =106 micron. The crushed and milled ore is subjected to differential flotation for separation of lead and zinc sulphides. The comminution circuit was not achieving rated capacity due to generation of rejects in ball mill during the plant operation. CSIR-National Metallurgical Laboratory carried out modeling and simulation analysis of the circuit to predict the optimum parameters for comminution. Detailed survey was carried out and samples were collected at various points in comminution circuit to get ample data needed for the development of steady state model. From the plant data, mass balancing and model fitting suitable mathematical model of the comminution circuit was developed. This helped in prediction of optimum process parameters for achieving desired throughput.

3. De-ashing by Dry Beneficiation of Thermal coal: Thermal coal in India with high ash content is attributed to its inherent lithological association, intercalated shale of varied thickness and out of seam dilution through open pit mining and has effect in low combustion efficiency, low thermal efficiency, high operating & maintenance cost, erosion problem, difficulty in pulverization and excessive generation of fly ash. It requires beneficiation to control the ash content to 34% in compliance to regulation of Ministry of Environment & Forests, Govt of India. Out of the total non-coking coal used for thermal power, presently only about 20% is beneficiated coal through wet beneficiation by washery, but wet beneficiation of coal has several disadvantages. CSIR-National Metallurgical Laboratory has developed technology for dry beneficiation of Indian non-coking coal and is working on dry beneficiation of non-coking coal of Talcher coalfields. Dry beneficiation of coal with 41% ash from Talcher coalfields results in a product of 34% ash with 75% yield, 87% recovery of combustibles and organic efficiency more than 90%.

4. Prediction of Process parameters for De-sliming Hydrocyclone in Iron ore beneficiation plant: A Wet Iron Ore Beneficiation Plant of 1000 TPH involves crushing, scrubbing/washing, classification followed by desliming to recover iron values of accepted metallurgical grade. A significant quantity of iron values is reported to be lost during desliming operation. CSIR-National Metallurgical Laboratory conducted optimization study of desliming hydrocyclone. The study included sampling campaign, collection of plant data, mass balancing, identification of debottleneck in the existing circuit. Based on the simulation and modeling to develop a steady-state model and optimum process parameters were predicted to minimize loss in the plant.

5. Technology for Beneficiation and Extraction of Tungsten from Gold ore tailings: Tungsten is a metal of high strength and high melting point and has application in tools, defence applications and is of strategic significance. Gold tailings occurring as mines waste in India is reported to contain tungsten in the form of scheelite. Detailed characterization, beneficiation and metal extraction at bench followed by pilot scale were carried out on 100 tonnes of gold ore tailings sample received at CSIR-National Metallurgical Laboratory. Based on the studies undertaken, technological process flow-sheets were developed for beneficiation of gold ore tailings sample

and hydrometallurgical extraction of tungsten metal powder of 99.9% purity from bulk pre-concentrate produced.

6. Lowering of Water Consumption in Wet Beneficiation of Coking Coal: Beneficiation of coking coal is carried out by wet beneficiation method by using heavy media bath, heavy media cyclone, jig and froth flotation so as to lower ash content for production of coke for use in iron making. This processing route consumes water and industrial interest is to lower water consumption. Studies have been carried out at CSIR-National Metallurgical Laboratory on reducing water consumption by developing process route combining dry and wet processes. Based on the studies, conceptual process flowsheet was developed towards viability of processing of high ash coking coal by the combination of dry and wet of processing of Indian coking coal with 32.5% ash.

7. Beneficiation of Siliceous Limestone for Cement Industry: Cement Industry requires limestone with less than 12% silica and hence, high silica limestone does not meet the specification of cement-grade limestone. Characterisation and beneficiation studies were carried out on a low grade limestone sample from Rajasthan. The sample analysed 40.1% CaO, 19.9% SiO_2 and 2.2% Al_2O_3. Based on the studies, CSIR-National Metallurgical Laboratory developed the flotation based process for beneficiation of low-grade limestone to meet the industrial need. The product assayed with 46% CaO with 10.9% SiO_2 with CaO recovery of 88%.

8. Pilot Scale Flotation Studies of Iron Ore: In northern part of India, iron ore deposits comprise of haematite, goethite minerals with gangue of alumina and silica. Washing of iron ore produces slimes which is discarded in talings pond. The slimes contain substantial iron values and cause environmental pollution problems. Beneficiation process involving froth flotation to recover iron values from slimes is undertaken at CSIR-National Metallurgical Laboratory.

In this context, under the collaborative project with Tata Steel, CSIR-NML is working on the development of novel reagents to process the iron ore slimes through pilot scale study. Pilot scale study was conducted towards validation of bench scale results. Results indicated high selectivity than conventional reagents and achieved a concentrate of 2.46% Al_2O_3 with 82% yield. The tailings with iron content <45% is rejected during the reverse flotation of iron ore slimes.

Hindustan Copper Ltd (HCL)

HCL has undertaken following R&D projects:

1. Recovery of copper through leaching from Electrostatic Precipitator (ESP) dust of flash smelter has been successfully carried out.

2. Experiments on bismuth removal from electrolyte were carried out at Gujarat Copper Project using barium carbonate at different dosage and temperature. Optimum dosage of barium carbonate has been established at lab-scale. Further the same experiment was scaled up and done in refinery using commercial grade in existing operational conditions. It was inferred that removal of bismuth up to 58.5% was observed at 6 kg/m^3 dose.

Manganese Ore India Ltd (MOIL)

MOIL's R & D activities to improve the safety, productivity and environmental standards in the mines by introducing newer technology in collaberation with CSIR R & D Laboratory, reputed Academic and R & D Institution of the country. MOIL has engaged and has been associated with following institutions for various R&D projects; (i) CSIR – Central Institute of Mining & Fuel Research (CIMFR), Nagpur and Dhanbad, (ii) CSIR-National Metallurgical Laboratory (NML), Jamshedpur, (iii) CSIR- National Geophysical Research Institution (NGRI), Hyderabad, (iv) CSIR-National Environmental and Engineering Research Institute (NEERI), Nagpur, (v) CSIR-Centre for Materials for Electronics (C-Met), Pune (vi) CSIR-IMMT, Bhubaneswar (vii) Indian Institute of Technology (IIT), Kharagpur, (viii) Indian Institute of Technology (IIT), (Formerly Indian School of Mines), Dhanbad, (ix) National Institute of Technology (NIT), Rourkela, (x) Visvesvaraya National Institute of Technology (VNIT), Nagpur, (xi) National Institute of Rock Mechanics (NIRM), Kolar Gold Fields and (xii) Indian Institute of Engineering Science and Technology (IIEST), Shibpur.

Significant R & D projects in MOIL are listed below:

1. ***Mine Environment:*** Ventilation reorganization studies for deeper levels have been conducted at Gumgaon and Chikla Mines by IIT, Kharagpur. Accordingly, large diameter ventilation fan has been installed at Gumgaon Mine and Chikla Mines with energy saving devices. It has improved the face ventilation and productivity of underground sections of the mines.

2. Mines Safety:

(a) Mining Subsidence: In-house scientific 3-D analysis of subsidence parameters has been carried out for Ukwa, Munsar and Balaghat Mines. IIT, Kharagpur and Geo Technical Department of Ramdeobaba College of Engineering & Management (RCOEM), Nagpur have vetted the report. They have confirmed that no noticeable movement of any orthogonal direction has been found in the mines. The subsidence monitoring by 7 pillars for micro-analysis has been designed by MOIL for better safety.

(b) Decline: CSIR-CIMFR, Nagpur centre has designed decline for faster evacuation of waste and ROM from underground at Gumgaon Mine. Techno-economical feasibility studies for implementation at Gumgaon Mine is going on.

3. Mineral conservation: R & D studies have been conducted at Munsar Mine by National Institute of Rock Mechanics (NIRM), KGF for stope design. It has incorporated placement of haulage drive in footwall. It has eliminated manganese ore locked in sill drive in the manganese ore body and thus saved the locked mineral in sill pillar. The modified stope design has increased the quantity of manganese ore in underground for exploitation at Munsar Mine.

4. Mining Technology: R&D project for mechanized stoping operation and support systems has been prepared by IIT, Dhanbad and implemented at Ukwa Mine. This helps for improvement in production, safety and productivity by mechanization of stoping operations.

5. Mineral Beneficiation: R&D studies of old mineral reject manganese dumps of Ukwa Mine have been carried out by Modern Mineral Processing Laboratory and Pilot Plant, Indian Bureau of Mines for utilization of mineral rejects. This has generated low grade manganese ore production of Ukwa Mine around 12%.

6. ***Metallurgical Studies:*** Project of upgradation of EMD quality has been taken up under R&D by setting up 500 MTPA pilot scale facilities with reduced impurity levels to be suitable for E.V. Battery. The main impurities of EMD, Lead reduced from 300 PPM to around 50 PPM and Iron reduced from 500 PPM to 150 PPM as against the requirement of less than 50 PPM and 150 PPM.

National Mineral Development Corporation Ltd (NMDC)

NMDC operates a state-of-the-art R&D centre at Hyderabad. It undertakes various projects related to the operational problems of the units of NMDC and provides solutions in terms of improvement in the system or change in technology to achieve continual improvement in its processes & operations. R&D centre also provides solutions to the external agencies.The thrust of R&D Centre is towards:

(i) Upgradation of processing technology of existing process plants for better productivity and meeting customer requirement.

(ii) Providing technical solutions to the problems related to quality and productivity of NMDC mines.

(iii) Development of technology for utilisation of mine wastes.

(iv) Development of Value Added process and product through innovation.

(v) Development of technology for dry processing of sub and lean-grade iron ore.

(vi) Developing technologies for enhanced utilisation of iron ore fines.

(vii)Development of technologies for enhanced recovery of iron values.

Projects undertaken by NMDC include:

1. Projects as per MOU system with Ministry of Steel

Improving recovery of Iron Values (Min 2%) from lean tailing of Donimalai Beneficiation and Pellet plant.

2. In-house Programmes completed

(i) Implementation of recommended modifications for improvement in screening efficiency (at SP-2 Kirandul).

(ii) Studies on abrasive wear of liner materials used in Iron ore storage and handling.

(iii) Effect of particle size, chemical constituents and solid concentration on iron ore slurry rheology.

(iv) Beneficiation studies on high silica blue dust sample of Kirandul complex with emphasis on feasibility studies of dry magnetic separation.

(v) Characterisation and beneficiation studies with slimes from Kirandul.

(vi) Study on reduction of Ammonium Para Tungstate (APT) by H_2 gas for tungsten production.

(vii) Development of value-added products from iron ore overburden of Kirandul (Dep-14).

3. Collaborative Programmes under progress

Sl. No.	Collaborating Institutes	Title and Nature of Work
i).	RDCIS-SAIL, Ranchi	To synergise the capabilities of RDCIS, SAIL and R&D Centre, NMDC so as to accelerate the developmental efforts towards meeting the emerging requirement of the Iron & Steel Industry.

ii).	IIT, Hyderabad	Improving the efficiency of dense medium cyclone separating the high NGM Coal samples using GPU based CPM and PERT methods.
iii).	IIT, Bhubaneswar	Optimisation of Silos, Bins and Hoppers design through modeling, primarily intended for iron ore storage.
iv).	IMMT, Bhubaneswar	Modelling & Optimisation of high concentration iron ore fines/concentrates slurry pipeline for Indian Iron Ore Processing Industry.
v).	CSIRO, Australia	Characterisation and beneficiation studies on laterite/ goethite iron ore. Development of dry beneficiation technology for processing of hydrated iron ore.
vi).	IIT Madras, IIT Kanpur, JSW	Develop a process for Iron Ore reduction through Microwave furnace as an alternate source of heating the minerals.

4. Sponsored Assignments

(i) Flowability studies on Fly ash to design ESP hoppers for M/s BHEL

(ii) Flowability studies on coal of MCL Bhubaneswari Mines for M/s L&T

(iii) Metallurgical characterisation test for M/s SIPC

(iv) Beneficiation study for M/s Benita Industries

(v) Beneficiation study for M/s MECL

(vi) Metallurgical characterisation for iron ore sample for M/s MSPL

(vii) Blaine No test for M/s Essar and M/s KIOCL

(viii)Cyclosizer test for M/s SGS

5. Investigation Assignments

(i) Chemical analysis of Dhura Iron Ore Prospective Block -100 Chip/Soil Samples received.

(ii) Chemical analysis of samples received from Sidhi-Singrauli Iron Ore Block in M.P.

(iii) Chemical analysis of Jabalpur Katni Block in M.P.

(iv) Chemical analysis & thin section study of sample received from Nandgaon-maheva Block at Chattarpur, Madhya Pradesh

Tata Steel Ltd

1. Mining

a) Establishing application of GPS-based advanced portable tool to measure haul road parameters (gradient, curve radius, super elevation & rolling resistance) at Quarry - AB, West Bokaro. This will help to identify haul road problems, determine severity and allocate maintenance resources accordingly to improve haul road conditions, thereby, reducing haul truck fuel consumption and increasing the tyre life.

b) Augmenting coal extraction ratio by increasing the backfilling rate at Bhelatand Colliery. Backfilling rate increased by ~24% by installing fish tale arrangement for homogenous mixing of water and sand.

c) Site selection & prefeasibility study for underground coal gasification at Jamadoba for unlocking value from remaining coal resource (~200MT) which is unviable through current method of mining. All related baseline information/data is collated, Test bore-hole drilling has been completed, hydro-geological & rock mechanics study is in progress.

2. Ore Beneficiation Technology

Recovery of Iron value from Slime using High Gradient Magnetic Separation (**'HGMS'**) Technique: In absence of adequate beneficiation facility at Noamundi, ~16% of wet Run of Mine is discarded as slime having ~8% Al_2O_3 and ~55% Fe. HGMS trials on pilot-scale indicated a potential to recover ~50% iron value from slime having ~3.3% Al_2O_3 and ~63% Fe.

3. Agglomeration

a) Usage of coke dust (generated during screening of dry quenched coke) at the rate of 10 kg/tonne started in pellet plant. This helped in the replacement of costlier conventional fuels such as coke breeze and anthracite in pelletising

b) Successful trial of carbon composite briquettes produced from plant reverts was carried out at C Blast Furnace resulting in reduction in coke rate by 25 kg/tHM

4. Blast Furnaces

a) Using extruded carbon-composite briquettes in the BF burden to reduce coke rate

b) Curbing of raw flux additions in blast furnaces by using a predictive model

5. Ferro Alloys

a) Successfully established new way of silicon reduction in ferrochrome at Bamnipal by addition of Chrome ore mines through a series of plant trials.

The concept is going to be operationalised in Financial Year 2019-20.

b) Metallurgical know-how for making carbon composite chrome ore briquette at Ferro Alloy Plant, Gopalpur to lower production cost & utilisation of plant waste is established and plant trial is on.

6. Characterisation & Specialty support

a) Identification and Development of Coal Tar Distillation Product: In a collaborative project with National Physical Laboratory (NPL), Delhi, all the coal tar samples generated in Tata Steel coke ovens have been characterised and its feasibility for manufacturing high-end distillation carbon product, such as, needle coke and carbon fibre has been assessed. The suitable collaboration agencies for carrying out the test work for producing high-end carbon product like needle coke/carbon fibre have been identified.

b) Establishing LD slag as one of the component in Portland Slag Cement. Tata Steel has significantly progressed in the endeavour of establishing LD slag as raw mix component in Portland Slag Cement. In a collaborative project with National Council of Cement and Building Material, Faridabad (NCCBM), LD slag samples have been characterised and subsequent study is in progress. In its constant interaction with BIS, it was possible to incorporate LD slag samples from other major steel plants in India like SAIL and JSW in the existing study with NCCBM. Successful completion of this project and its acceptance from Bureau of Indian Standards would lead to a complete evacuation of 0-6 mm fraction of LD slag.

NLC India Ltd (NLCIL)

1. R & D (Ore Preparation & Processes)

1.1 Pilot Plant Studies on Beneficiation of Iron Recovered from Bottom Slag: NLCIL's Power stations produces an average of 250–300 tonnes bottom slag every day. The iron content of bottom slag is in the range of 20-30%. Centre for Applied Research & Development (CARD) has successfully installed a Pilot Plant for separation of iron from bottom slag. The separated magnetic iron has 25-30% Fe content. To commercially exploit, the Fe content needs to more than 50%. Hence, in order to improve the quality of the separated iron, it is proposed to set up a pilot plant to enhance the quality of the separated iron particles using suitable technology. The equipment procurement for pilot plant and further Lab studies are in progress.

2. R & D in Mining Technology

2.1 Electronification of Ground Water Control and Conveyor System in Mines: NLCIL, Neyveli operates three mines with deployement of around 150 km of conveyors and around 300 Ground water control pumps. It is difficult to monitor the working borewell located in remote areas due to many problems and identify the fault avoid downtime. Conveyor system used for transporting the OB/Lignite require regular monitoring for smooth functioning of mines and to improve productivity, monitoring of these two systems are important. It is proposed to take up real time monitoring of borewell operations and the conveyor system are underway. This project involves real time automation of GWC & Conveyor systems wherein the major parameters would be monitored continuously. This is a Coal S&T funded R&D project started in collaboration with NIT-Trichy and NLCIL with an objective to put in place of real time monitoring of the system which will reduce the downtime with the help of fault detection system which would increase in effective working hours and help energy conservation.

2.2 OB to Sand (Extraction of Construction grade Sand from Overburden materials): The overburden that gets removed is dumped during excavation. The overburden mostly contains about 30 to 40% of sand materials. It is proposed to explore the possibilities for extraction of sand from the overburden materials which can replace the river sand and also could provide scope for additional revenue. A project proposal has been submitted to Ministry of Mines in association with IITM. MOM has approved the proposal. Purchase of pilot plant equipment is in progress. Preliminary laboratory testing of overburden is in progress at IITM.

3. R & D (Coal, Hydrocarbon, Energy)

3.1 Solar Drying of Lignite: R&D initiatives were taken up to conduct techno-economic feasibility for solar drying of lignite and to analyse the possibility to install Demonstration model for Solar Drying of Lignite. The benefits of the project are that it would decrease energy consumption, pollutants and greenhouse gas emissions of low rank coals during the utilisation process. Lab-scale solar drying system have been installed and demonstrated by IES, AU at CARD. As the above lab-scale study resulted in appreciable outcome, it is proposed to take up the Pilot Project (1 tonne/day capacity) on Solar drying with IES Anna University, Chennai to study the feasibility and behaviour of dried lignite in Pilot-scale operation. MOA has been signed between IES/AU and NLCIL for R&D project entitled "Pilot Project on Solar Drying of Lignite"

on 14.06.2018. Design for the Pilot plant with solar system and drying unit has been finalised. The equipment required for pilot plant has been identified. The tendering and supply of Pilot plant equipment and the installation are in progress.

3.2 R & D for Lignite to Diesel: Neyveli lignite has high moisture content (50-55%) thereby making transportation of lignite to longer distances difficult. Emergence of alternate renewable energy generation has led to lowering of demand for power. This has prompted the intent for taking up diversification studies on lignite to develop clean coal technology for value-added product. The main objective of the project is to explore the possibility of producing diesel from lignite and also to develop a suitable technology for alternate use of lignite from proven technologies. In this connection, a global EOI has been floated to identify the proven technology and sources. Tender evaluation is in progress.

3.3 R & D for Lignite to Methanol: Lignite is basically a low-rank coal presently used as a fuel in pit-head power stations in Neyveli. Lignite has high moisture content making transportation of lignite to longer distances difficult. Emergence of alternate renewable energy generation has led to lowering of demand for power consequently promoting studies for further diversification. The conversion of lignite to methanol will open a new avenues for better utilisation of lignite and value-addition for lignite and the output product methanol could be stored and blended wherever and whenever necessary. To explore the possibility of producing methanol from lignite and blending will help in reducing pollution/emission. Lignite methanol is one of the emerging need of India. It is proposed to take up a feasibility study to identify the sources.

4. R & D in Building Materials

4.1 Studies on Suitability of Sand Recovered from Bottom Slag, Bottom Ash for Utilisation: Thermal power station generates huge amounts of bottom ash, bed ash and bottom slag which contain more than 50% of sand. Due to scarcity of natural river sand for construction purposes, there is an imperative need to develop alternate material. R&D initiatives are underway to utilise this sand effectively in construction/other uses.

5. R & D on Development of Specialty and Fine Chemicals from Minerals/Mineral-based Product/ Mineral Substitutes

5.1 Studies on Aquaculture Development in Neyveli with Humic Products: The humic acid was developed mainly for agriculture as plant growth stimulant. To increase its usage, it is proposed to study the effects of humic acid on aquaculture viz. fish/prawn culture. It is a new area of application under preliminary research. MoA has been signed between NLC India Limited and Centre for Advanced Study in Marine Biology (CASMB), Annamalai University. Lab-scale studies to identify the fast growing microalgae by feeding humic acid were completed. Microalgae species exhibit maximum growth at a specific humic acid concentration. Field trials have been completed and further studies are in progress.

6. R & D on Clays, Zeolite and Beach Sand Minerals

6.1 Development of Alternative Materials for Pebbles using Waste Materials: Pebbles from natural material are scarce and difficult to procure. Scarcity of pebbles for borewell construction is a common problem faced in all mines. To find alternative material, this research initiative attempts at utilising clay obtained from overburden materials from Mines. MoU has been signed between NLC India Limited and IIT Madras, Chennai. IITM has developed different size of pebbles with overburden material and the properties have been tested in the lab. The project was completed on 31.03.2019.

6.2 Studies on Synthesis of Zeolites from Lignite Flyash and its efficiency in Cooling Water Treatment: Zeolite from lignite fly ash were optimised and the product was developed at NLCIL. A bench-scale production facility was developed at Center for Applied Research and Development (CARD) for the production of zeolite tablets using fly ash from thermal power stations. Compared to lab-scale trials, the calcium reduction efficiency of the zeolite bed at bench-scale showed much improvement. The zeolite tablets are stable during column trials. Based on the outcome of the bench-scale study, it is proposed to establish 1 M 3 / hour capacity pilot-scale zeolite based water softening plant at CARD. Patent has been awarded for the process that was developed in the study. Further scaling up of study is in progress.

6.3 Studies on Zeolite based Catalyst for Mitigation of Exhaust Gas Pollution. Air pollution has been a major concern caused by emmission of gases from vehicle exhaust. CARD has proposed to take up a collaborative project to utilise the zeolite to develop suitable catalyst for mitigating the exhaust gas from the vehicles. MoA in this regard was signed with Annamalai University. It is proposed to develop suitable zeolite for reduction of NOX from the exhaust emission. Fly ash and bottom ash samples, zeolite characterisation studies and purchase of equipment by Annamalai University and lab studies are in progress.

Hindustan Zinc Ltd (HZL)

1. R&D - Ore Preparation & Process: To improve metal recoveries, bulk flotation was started in December 2008 after in-house modification in existing flotation circuit. Lead, zinc minerals are floated to a single product concentrate instead of separate lead and zinc concentrates in bulk flotation. Mineralogical studies were carried out to optimise required mog for new process (Bulk flotation). It was established that recovery can be optimised at 66-67% of -200 mesh. Effective change in flotation process with optimizing mog resulted in increase in lead recovery from 85% to 90.52% and zinc from 89% to 90.60%.

2. R & D Projects conducted in FY 2019:

a) Feasibility study of new technologies like Stage Flotation Reactor (SFR), flash flotation, graphite pre-float and lead re-grinding for suitability in operations to address ore variability and improve recovery.

b) Modification in flotation circuit configuration for increase in metal recovery in mills.

c) Testing of new flotation reagents for improved metallurgical performance and cost benefits.

d) Plant surveys of grinding and flotation circuit across all mines for optimised plant performance.

e) Benchmarking of beneficiation plant performance and modelling and simulation studies to strengthen metallurgical accounting at Zawar.

f) Process development for tailing re-processing to recover metal from tailings.

g) Conversion of pre-graphite concentrate into saleable graphite product and to recover metal values from pre-graphite concentrate.

h) Pilot-scale testing for 18.75 MT antimony slag was successfully completed. About 3 MT of antimony trioxide of purity >96% and 17 MT of enriched lead residue suitable for internal consumption were generated.

i) Pilot-scale testing initiated for high-grade cobalt cake generation from purification waste cake. The operating parameters have been optimised at lab and bench-scale to generation purified cobalt cake of about 20% purity.

j) Process for recovery of vanadium as ammonium metavanadate from spent acid catalyst was validated at lab-scale. Replacement of sodium peroxide is being explored.

k) Cold bricks are being prepared with 3-5% cement and 80% of different wastes used in various composition. Enhancing of brick strength is in progress.

l) Process feasibility for magnesium bleeding through zinc dross treatment has been done. Bench-scale closed loop testing is in progress.