Indian Minerals Yearbook 2018

(Part- I : GENERAL REVIEWS)

57th Edition

RESEARCH & DEVELOPMENT

(FINAL RELEASE)

GOVERNMENT OF INDIA
MINISTRY OF MINES
INDIAN BUREAU OF MINES

Indira Bhavan, Civil Lines,
NAGPUR – 440 102

PHONE/FAX NO. +91712 – 2565471,2562216
PBX : +91712 - 2562649, 2560544, 2560648
E-MAIL : cme@ibm.gov.in
Website: www.ibm.gov.in

June, 2019

5 Research & Development

The Science and Technology (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. S&T 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.

As per minutes of 48th meeting of SSAG held on 20.11.2017 at Shastri Bhawan, New Delhi, a total of 116 project proposals was received for the year 2017-18. The first stage comprised of preliminary screening of the proposals done by a team of experts constituted by Ministry of Mines (MoM), which recommended 27 project proposals for the next stage i.e. Project Evaluation and Review Committee (PERC). These project proposals covering five areas, namely (i) Geo-sciences 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. Total 27 project proposals were presented by the respective PIs and evaluated by the committee during the 16th PERC meeting held on 06.09.2017 at JNARDDC, Nagpur. The PERC recommended 9 Project proposals comprising (i) One from Geosciences and Exploration (ii) Two from Mining (iii) Two from Mineral Processing & recovery from waste (iv) One from Metal Extraction (Metallurgical processes) and (v) Three in the area of Alloys, specialty materials and product, to SSAG for the third/final stage review. After detailed evaluation by the SSAG, nine projects were approved and summary of the same is given in Table-1.

During the 16th PERC, it was proposed that JNARDDC may be asked to submit a complete proposal to MoM on the status paper on the work carried out nationally and internationally on red mud to benchmark future investigation in the country for Rs. 25 lakh. The above proposal submitted by JNARDDC was examined and approved by SSAG. Besides, nine projects for which PERC had already recommended the extensions without any cost overruns were considered for review and extension of time. After detail evaluation, the SSAG approved the proposed time extension to all the nine projects and the details are furnished in Table-2.

Further, during 49th meeting of SSAG held on 31st July 2018 at Shastri Bhavan, New Delhi, the SSAG considered projects which were reviewed and recommended by the PERC. A total of 100 project proposals was received under S & T programme scheme of MoM for the year 2018-19. The new project proposals and 6 proposals recommended by the 16th PERC for resubmission were considered and evaluated in the 17th PERC meeting held on 19-20th July 2018 at JNARDDC, Nagpur. The PERC recommended 12 Project proposals, 7 on-going projects for extension of duration, acceptance of final reports of 10 completed projects, 1 ongoing project for foreclosure and 1 ongoing project for transfer from one to another institution for consideration and approved SSAG..

After detailed deliberation, SSAG approved 10 project proposals (Table-3) and time extention for 7 projects (Table-4) for which PERC had already recommended time extensions without any cost overruns. Besides, the SSAG accepted the final reports of the ten projects and approved closure of projects (Table-5). The SSAG was of the view that the project proposal "Postural risk analysis of mining equipment operators and its relation to musculoskeletal disorder" by NIMH, Nagpur may be continued and granted 8 months extension up to 19.06.2019. The project will be reviewed in next PERC. Further, as requested by PI, SSAG approved the transfer of the project "Simulation of simultaneous rock fractures at multiple scales" from BITS Pilani, Goa Campus to IIT, Delhi subsequent to transfer of PI.

Table -1: Summary of Projects approved by SSAG for 2017-18

Category	Project Title	Implementing Institution	Cost & Duration of Project	Approval/Recommendation
Geosciences and Exploration	Critical Mineral (non-fuel) Resources Index of India – for effective policy decisions on mineral and manufacturing sector of India.	Council on Energy, Environment and Water (CEEW), Thapar House, Janpath,New Delhi	` 36.29115 lakh, duration = 3 yrs	The project is approved by SSAG with the condition that two officers each from IBM and GSI shall be included by CEEW as a part of the project with a view to assist and monitor the development of the statistical tool / data of critical index of mineral commodities.
Mining	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, West Bengal	` 68.46 lakh, duration = 3 yrs	The SSAG noted that mining/ exploration of friable rock mass of horizon still remains a challenging issue. The Member Secretary informed that Odisha Mining Corporation (OMC) has given a letter of support and provided site facility for undertaking the above project. The SSAG approved the project.
-do-	Processed Sea sand for construction and other purposes.	Civil Engineering Department, Saveetha Engineering College, Thandalam, Chennai	` 40 lakh, duration = 2 yrs	The SSAG noted that use of offshore sand for construction is a challenge for the country in near future. The SSAG approved the project with the above cost and duration. However, the PI will also include physical characterization of the offshore sand as a part of project objectives.
Mineral Processing & recovery from waste	Estimation of Morphodynamicity and its remedial action using Red mud based concrete at coastal zone of Eastern Odisha	1. Jawaharlal Nehru Aluminium Research Development & Design Centre, Nagpur 2. IIT, Bhubaneswar, Odisha	Total cost: ` 30 lakh, (JNARDDC- ` 15 lakh, IIT - ` 15 lakh) duration= 6 months	The total Budget of the Project i.e. Part A and Part B is Rs. 143.4162 lakh. In line with the recommendation with the PERC, the SSAG approved the initial feasibility study in Part-A as above. Based on the results obtained in Part-A the full scale project may be considered in Part-B.
-do-	Nano Processing of Industrial Rejects for Use as Additives in Mix-designs for Improved Pozzolanic Reaction Efficiency.	1. Jawaharlal Nehru Aluminium Research Development and Design Centre, Nagpur 2. Visvesvaraya National Institute of Technology, Nagpur, Maharashtra	` 49.77170 lakh, (JNARDDC - ` 37.69670 lakh & VNIT- ` 12.07500 lakh) duration = 2 yrs	The SSAG noted that the project outcome would result in reduced used of binder (cement) which shall be substituted by the above nano-materials. SSAG also took note of the consent letter submitted from Industry with regards to utilization of the R&D outcome for economic and efficient building and construction work. The SSAG approved the project.
Metal Extraction (Metallur-gical processes)	Urban Li Battery Mining: Physio-Chemical Separation of Used Li ion Batteries for Recovery of Li, Co, Ni active materials and Cu, Al metals	Nonferrous Materials Technology Development Centre, Hyderabad, Telangana	` 94.82 lakh (MoM- ` 83.82 lakh and Central Electronics Ltd & NFTDC: ` 11 lakh) duration = 2 yrs	The SSAG observed that the project deliverable would result in pilot plant (TRL-7) level and technology could be transferred to a large no. of SMEs & MSMEs. The SSAG advised that the PI should take care of the issues relating to framework for regulatory mechanism for institutionalizing collection and recovery of the Li Battery. The project is approved by SSAG.

Contd.

Concld. (Table-1)

Category	Project Title	Implementing Institution	Cost & Duration of Project	Approval/Recommendation
Alloys, speciality materials and products	Development of Metal-Graphene Alloys	Department of Materials Engineering, Indian Institute of Science, Bengaluru, Karnataka	` 20 lakh, duration = 2 yrs	The SSAG approved the project with the above cost and duration.
-do-	Fabrication of Advanced Ceramic Nanocoatings for Automotive Applications	1. Christ University, Bengaluru, Karnataka 2. Jawaharlal Nehru Aluminium Research Development and Design Centre, Nagpur, Maharashtra	` 43.75920 lakh (Christ University– ` 21.81250 Lakh and JNARDDC- ` 21.94670 Lakh), duration = 2 yrs	The SSAG noted that outcome of the project could lead to overall import substitution in the field of automotive sector applications. In line with PERC recommendation, the SSAG approved the above project for a reduced period of 2 years.
-do-	Value added Electro-chemical Devices from Zircon obtained from Beach Sands of Odisha	IIT, Bhubaneswar, Odisha	` 36.04 Lakh duration = 2 yrs	The SSAG approved the project for a reduced duration of 2 years.

Source: *Minutes of meeting of 48th SSAG held at MoM, New Delhi.*

Table -2: Details of project for which time extension approved by SSAG for 2017-18 during 48th meeting

Sl. No.	Project Title	Implementing Institution	Remark
1.	Development of viable technique for assessment of reclaimed land and for safety of structures under settling environment	NIRM, Karnataka	Extension granted upto 31.03.2018
2.	Estimation of seismic hazard in and around the mines out areas of Kolar Gold Fields	NIRM, Karnataka	Extension granted upto 30.06.2018
3.	Development of Super Thermal Aluminium (STAL) conductor for Indian Power Sector	NFTDC, Hyderabad & JNARDDC, Nagpur	Extension granted upto 30.09.2017
4.	Development of process for making value added materials from ilmenite mineral	IMMT, Bhubaneswar	Extension granted upto 30.09.2017
5.	Integrated approach for development of process models and production of aluminium alloy extrudates using porthole dies	JNARDDC, Nagpur	Extension granted upto 31.03.2018
6.	Development of low density emulsion explosives for energy efficient blasting in environmentally sensitive areas	Indian School of Mines, Dhanbad	Extension granted upto 31.03.2018
7.	Development of Nickel containing steel from chromite overburden	IIT, KGP and IMMT, Bhubaneswar	Extension granted upto 31.03.2018
8.	Development of TDR based wireless system for slope stability monitoring in opencast mines	NIT Rourkela	Extension granted upto 31.12.2017
9.	Physico-chemical processing of low grade chromite ore for beneficiation and agglomeration of fines for recovery of metal values	Jadavpur University, Kolkata	Extension granted upto 31.12.2018

Source: *Minutes of meeting of 48th SSAG held at MoM, New Delhi.*

Table -3: Details of projects approved by SSAG for 2018-19

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 mineral approval of DST also for the proposal.
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 mineralization (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 -4: Details of project for which time extension approved by SSAG during 49th meeting

Sl. No.	Project Title	Implementing Institution	Decision/Result
1.	Technology Development (TRL-7) for calico- thermic reduction of rate earth metal oxides and establishment of pilot plant for extraction and purification of samarium.	Non-ferrous Materials Technology Development Centre, Hyderabad.	Extension upto 31.03.2019 without any cost escalation
2.	Recyclability strategy or value-added utilization of iron/ manganese ore tailing/low grade ore: evaluation of energy storage capacities.	IMMT, Bhubaneswar.	Extension upto 30.04.2019 without any cost escalation
3.	Developing downstream application of strip cast aluminium alloys (AA8011 & AA3004).	JNARDDC, Nagpur, VNIT, Nagpur and NALCO, Bhubaneswar.	Extension upto 31.03.2019 without any cost escalation
4.	Development of Nickel containing steel from chromite over burden.	IIT, Kharagpur and IMMT, Bhubaneswar.	Extension upto 31.03.2019 without any cost escalation
5.	Prospecting/Exploration of Platinum group of metals within Nega Hills ophiolite at Thengahu Ridge-Moke area, Phek District, Nagaland.	DGM, Govt of Nagaland, Dimapur.	Extension till 31.03.2019 without any cost implication. project progress may be reviewed by MoM.
6.	Novel synthesis routes for high purity kesterites (CZTS:Cu-Zm-Sn-S; Cu-Zn-Sn-Se) and development of cost kesiterite based solar PV cells and modules.	Non-ferrous Materials Technology Development Centre, Hyderabad.	Extension till 31.03.2019
7.	Study of alkaline-carbonatite complexes as potential resource for REEs, NBTA and U-TH.	IIT, Roorkee.	Extension upto 31.12.2018 without any cost escalation

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

Table -5: Details of completed project for which final reports accepted and closure approved by SSAG during 49th meeting

Sl. No.	Project Title	Implementing Institution
1.	Physico-chemical processing of low grade chromite ore for beneficiation and agglomeration of fines for recovery of metal values.	Jadavpur University, Kolkata.
2.	Study of toxic fumes and development of Carbon nanotubes based sensing Device.	CIMFR and Amity University.
3.	Development of copper bio-leaching methodology/technique from tailing waste at Hindustan Copper Ltd, Khetri.	Birla Institute of Technology & Science, Pilani.
4.	Development of hard and high temperature refractory material/aggregate from saprolite.	JNARDDC, Nagpur .
5.	Development of TDR based wireless system for slope stability monitoring in opencast mines.	National Institute of Technology, Rourkela.
6.	Recoverable reserve estimation using non-gaussian copula-based ore body simulation along with open pit and stope optimisation techniques.	National Institute of Technology, Rourkela, Odisha and IIT, Kharagpur.
7.	Feasibility and application of Bio-fuel as well as low cost and diluted ANFO.	CIMFR, Dhanbad.
8.	Development of state-of-art facilities for in-situ stress measurement by hydrofracture in porous and fractured rocks.	NIRM, Karnataka.
9.	Evaluation of Biomarkers for early detection of noise induced hearing loss.	NIMH, Nagpur (Pilot project may be undertaken by NALCO and HCL based on the project findings).
10.	Development of Standard Framework and Guidelines for Noise Mapping in Mines and Surrounding Community.	NIMH, Nagpur (Pilot project may be undertaken by NALCO and HCL based on the project findings).

Source: *Minutes of 49th 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, 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 2017-18 are furnished below:

Indian Bureau of Mines (IBM)

R&D activities regarding Ore Preparation & Process carried out by Mineral Processing Division, IBM during the year 2017-18 are summarised below:

1. BASE METAL

1.1 Bench Scale Beneficiation Studies on a Base Metal Mineralisation Sample from Jangaldheri Block, Betul Belt, Chhindwara district, Madhya Pradesh (G-2 Stage Investigation): A base metal mineralisation sample from Jangaldheri Block, Betul belt, Chhindwara district, Madhya Pradesh (G-2 Stage investigation) was received from Geological Survey of India, Madhya Pradesh. The objective of the investigation was to study the amenability of the sample for beneficiation to produce a suitable concentrate for metallurgical use.

The as received sample assayed 105 ppm Cu, 150 ppm Pb, 0.46% Zn, 69.05% SiO_2, 12.45% Al_2O_3, 4.60% Fe(T), 0.85% CaO, 2.45% MgO, 1.00% S.

By flotation process, a zinc concentrate could be achieved, which assayed 49.27% Zn, 2.59% SiO_2, 1.23% Al_2O_3, 1.11% Cu, 1.56% Pb, 9.62% Fe(T), 29.79% S with 89.5% Zinc recovery (Weight % yield being 0.85).

By adopting flotation process method, up-gradation of the zinc assayed 49.27% Zn from 0.46% Zn which may be utilised for metallurgical applications.

1.2 Bench Scale Beneficiation Studies on a Base Metal Mineralisation Sample from Biskhan Block, Betul Belt, Betul district, Madhya Pradesh (G-2 Stage Investigation): A base metal mineralisation sample from Biskhan Block, Betul belt, Betul district, Madhya Pradesh (G-2 Stage investigation) was received from Geological Survey of India, Madhya Pradesh at the Modern Mineral Processing Laboratory and Pilot Plant, Indian Bureau of Mines, Nagpur. The objective of this investigation was to study the amenability of the sample to beneficiation and produce a concentrate suitable for end industrial use.

The as received sample assayed 52 ppm Cu, 1.12% Zn, 64.02% SiO_2, 10.57% Al_2O_3, 4.72% Fe(T), 1.70% CaO, 0.79% MgO, 2.92% S. Mineralogical studies on the as received sample show that the sample consists major amounts of quartz and mica (muscovite, biotite) with minor amounts of felspar (microcline, plagioclase) and garnet. Amphibole, chlorite, pyroxene and tourmaline are the other transparent minerals noticed in a very minor amount. Sphalerite, pyrite, pyrrhotite, galena, goethite/limonite chalcopyrite, arsenopyrite, ilmenite and magnetite are the opaque minerals noticed in a very minor to traces.

By flotation process, a zinc concentrate could be achieved, which assayed 57.08% Zn, 2.99% SiO_2, 0.34% Cu, 10.90% Fe(T), 32.71% S with 90.7% Zinc recovery (Weight % yield being 1.72). This zinc concentrate may find use for metallurgical applications.

2. COPPER ORE

2.1 Bench Scale Beneficiation Studies on Copper Ore Sample from South of Gangutana, Mahendragarh district, Haryana: A Copper ore sample from South of Gangutana, Mahendragarh District, Haryana received from GSI, Northern Region, Faridabad, as a part of G-2 exploration at RMPL, IBM, Ajmer. 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 sample assayed 0.34% Cu; 41.38% SiO_2, 11.31% Al_2O_3, 0.19% S(T), 5.51% Fe(T), 16.87% CaO; 4.30% MgO; 0.46% Na_2O, 3.17% K_2O; 0.06% TiO_2, 13.45% LOI with 49.09% Acid Insoluble. Chalcopyrite, bornite and covellite and chalcocite are the copper bearing minerals present in trace in the sample. Carbonate (dolomite and calcite) and mica (muscovite and biotite) are major gangue minerals.

By employing froth flotation technique the sample assaying 0.34% Cu has been successfully up-graded to 19.39% Cu with recovery of 84.2% (Wt % yield 1.5) which is suitable for use in copper

smelter. Efforts were also made for collecting calcite concentrate 43.59% CaO with recovery of 70.9% (Wt % yield 27.6) as a by-product.

2.2 Bench Scale Beneficiation Studies on Copper ore sample from Toda-Ramliyas Block, Sikar district, Rajasthan: A Copper ore sample from Toda-Ramliyas, District-Sikar, Rajasthan collected by GSI, Western Region, Jaipur as a part of G-2 exploration was received at Regional Mineral Processing Laboratory, IBM, Ajmer for bench scale beneficiation studies to find the amenability of producing copper concentrate. 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 sample assayed 0.39% Cu; 40.54% SiO_2, 10.12% Al_2O_3, 0.22% S(T), 4.48% Fe(T), 8.40% Fe_2O_3,11.76% CaO; 1.53% Na_2O, 2.67% K_2O; 12.83% LOI with 52.47% Acid insoluble, 39 ppm Co, 64 ppm Ni, 64 ppm Pb, 155 ppm Zn. Bornite, covellite, chalcocite and chalcopyrite are the copper bearing minerals present in trace in the sample. Quartz, carbonate (calcite and dolomite) and mica (muscovite, biotite and chlorite) are major gangue minerals.

By adopting flotation process, yielded a copper concentrate assaying 20.1% Cu with a Cu recovery of 72.72% (Wt % yield 1.4) which finds suitable for use in copper smelter. Efforts were also made for collecting calcite concentrate 33.15% CaO with recovery of 64.8% (Wt % yield 24.1) as a by-product.

3. COPPER BEARING CALC-SILICATE ROCK

Bench Scale Beneficiation Studies on Copper bearing Calc-silicate Rock sample from Kamalpura Block, Bhilwara district, Rajasthan: A copper ore bearing calc-silicate rock sample from Kamalpura Block, district Bhilwara collected by GSI, Western Region, Jaipur as a part of G-2 exploration was sent to Regional Mineral Processing Laboratory, IBM, Ajmer. 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 sample assayed 0.37% Cu; 50.44% SiO_2, 10.98% Al_2O_3, 0.66% S(T), 14.06% Fe(T), 14.8% Fe_2O_3, 5.63% CaO; 3.22% Na_2O, 0.10% K_2O; 0.73% TiO_2, 0.40% SnO_2 0.86% LOI with 77.12% Acid insoluble. Chalcopyrite and bornite are the copper bearing minerals present in traces in the sample. Quartz, Pyroxene and Amphibole are major gangue minerals.

By employing flotation a copper concentrate could be achieved which assayed 20.12% Cu with a Cu recovery of 81.1% (Wt. % yield was 1.5).

The bench scale beneficiations results indicate that a low grade copper sample assaying 0.37% Cu, it could be upgraded and produce a Copper concentrate suitable for Copper smelter.

4. COPPER BEARING GARNETIFEROUS MICA SCHIST ROCK

Bench Scale Beneficiation Studies on Copper bearing Garnetiferous Mica Schist Rock sample from Kamalpura Block, Bhilwara district, Rajasthan: A Copper bearing Garnetiferous Mica Schist sample from Kamalpura block, district-Bhilwara, collected by GSI, Western Region, Jaipur as a part of G-2 exploration was sent to Regional Mineral Processing Laboratory, Indian Bureau of Mines, Ajmer for bench scale beneficiation studies. The aim of bench scale beneficiation study was to evolve a process flow sheet producing a copper concentrate assaying more than 18% Cu with maximum possible recovery.

The sample assayed 0.27% Cu, 13.95% Fe(T),3.62% FeO, 51.96% SiO_2, 9.90% Al_2O_3, 83.10% AI, 1.88% CaO, 9.99% MgO, 0.89% S(T), 0.29% TiO_2, 0.37% Na_2O, 0.44% K_2O, 0.04% Mn, 0.35% Graphitic carbon and traces of Sn. Chalcopyrite is the only copper bearing mineral. Garnet is major gangue mineral present in the sample.

By employing flotation test, produced a copper concentrate assaying 22.18% Cu, with 81.26% copper recovery (Wt % yield 1.0). The final result confirms that although the garnetiferous copper bearing sample from Kamalpura Block, Bhilwara (Rajasthan) deposit is a very low grade but it has potential to produce a metallurgical grade concentrate. However, weight percent yield is around 1% only.

A final concentrate under optimum conditions assayed 23.05% Cu with 79.73% Cu recovery.

5. GLAUCONITE

Bench Scale Beneficiation of Glauconite from the rock sample (OB-1) of Vindhyan Super Group in Bihar for Geological Survey of India, Patna, Bihar: A glauconite rock sample from the rock samples (OB-1) of Vindhyan Super group, village Adia Chutia, Bihar was received at the Modern Mineral Processing Laboratory and Pilot Plant, I.B.M., Nagpur through Geological Survey of India for conducting bench scale beneficiation studies. The objective of the study was to enrich glauconite content present in the sample for its use as potash fertilizer.

The as received sample assayed 3.12% K_2O, 2.52% Fe_2O_3, 7.4% Al_2O_3, 83.14% SiO_2, 0.25% CaO, 0.72% MgO, 0.27% Na_2O, 0.23% TiO_2 and 1.81% LOI. Mineralogical studies reveal that the sample mainly consists of quartz with minor amount of glauconite, mica (muscovite, biotite) felspar very minor and subordinate to minor amounts of goethite and limonite and hematite. Glauconite content of 7–10%.

By adopting Wet High Intensity Magnetic Separation process, obtained the concentrate which assayed 4.86% K_2O, 10.1% Fe_2O_3, 18.1% Al_2O_3, 56.9% SiO_2 and 5.2% LOI and the glauconite content of 75 – 80% which can be suitable for use as potash fertilizer.

6. GOLD ORE

6.1 Heap Leaching Studies on a Gold ore sample from Jonnagiri, Andhra Pradesh: A gold ore sample from Jonnagiri, Andhra Pradesh was received from M/s Geo-Mysore Services (India) Pvt. Ltd, Bengaluru for seven days bottle roll cyanidation to simulate heap leaching at the Regional Mineral Processing Laboratory, Indian Bureau of Mines, Bengaluru.

The as received sample assayed 1.10 g/t Au, 70.57% SiO_2, 11.53% Al_2O_3, 3.74% Fe_2O_3, 2.89% CaO, 1.87% MgO, 0.15% K_2O, 0.21% Na_2O, 1.46% LOI, 0.06%Zn, 0.14% Mn, 0.04% Ni and traces amount of S(T).

The objectives of the investigation were (i) to carry out bottle roll cyanidation by crushing the sample to 1, ½ and ¼ inch of the as received sample and

(ii) to simulate heap leaching.

The as received sample was crushed to 1, ½ and ¼ inch and subjected to bottle roll cyanidation for seven days.

The as received sample was crushed to minus ½ inch size and subjected to seven days bottle roll cyanidation, resulted in a recovery of 65.9% Au in the solution. Leach residue assayed 0.30 g/t Au gave the best result.

6.2 Beneficiation Studies on a Gold ore sample from Tanzania: A gold ore sample from Tanzania was received from M/s Shiva Analyticals (India) Private Limited, Bengaluru for beneficiation studies at the Regional Mineral Processing Laboratory, Indian Bureau of Mines, Bengaluru.

The as received sample assayed 1.0 g/t Au, 91.26% SiO_2, 3.33% Al_2O_3, 1.85% Fe_2O_3, 0.91% CaO, 0.19% MgO, 0.94% K_2O, 0.29% Na_2O, 0.14% TiO_2, 1.46% LOI, 53 ppm Pb, 89 ppm Cu, 53 ppm Zn, 230 ppm Mn, 18 ppm As, 528 ppm S(T) and traces amount of Ni.

The objectives of the investigation were to recover gold with maximum recovery. Direct cyanide leaching, adopting bottle roll procedure of ore at minus 200 mesh size, resulted in a recovery of 90.1% Au in the solution. Leach residue assayed 0.08 g/t Au.

6.3 Beneficiation Studies on a Gold ore sample from Ajjanahalli Block- C, Sira Taluk, Tumakuru dist., Karnataka: A Gold ore sample was received from Geological Survey of India, Bengaluru for gold recovery studies at RMPL, IBM, Bengaluru.

The as received sample assayed 0.7 ppm Au, 47.55% SiO_2, 10.93% Fe(T), 1.86% Al_2O_3, 15.03% CaO, 1.29% MgO, 1.50% Na_2O, 0.59% K_2O, 0.07% Cu, 0.02% Zn, <0.1% As, 15.42% LOI and Traces of Pb. Mineralogical analysis of the sample reveals that quartz+felspar and carbonates (calcite+dolomite) are major minerals in the sample. Martitized magnetite, magnetite/ilmenite, goethite+limonite, mica+amphibole+chlorite, pyrite/pyrrhotite, clay, arsenopyrite, chalcopyrite and serpentine/talc are present in very minor to trace amount.

The objectives of the investigation were to determine the process parameters for the recovery of gold to achieve maximum recovery. Direct cyanide leaching on the ore (minus 150 mesh size) adopting bottle roll procedure for 30 hours

leaching time gave a gold recovery of 84.3% Au in the solution with residue assaying 0.11 ppm Au.

7. IRON ORE

7.1 Beneficiation Studies on an Iron ore sample from MSPL Limited, Hospet: An iron ore sample was received from M/s. M.S.P.L. Ltd, Hospet for bench scale beneficiation studies at Regional Mineral Processing Laboratory, Indian Bureau of Mines, Bengaluru. The objectives of the test work are to develop a process flow sheet to produce pellet grade concentrate. The Fe(T) grade is >63.5% with ~2% Al_2O_3, ~ 5% (Al_2O_3+ SiO_2).

The as received sample assayed 53.52% Fe (T), 14.15% SiO_2, 4.71% Al_2O_3, 0.04% CaO, 0.04% MgO, 0.08% Na_2O, 0.025% K_2O, 0.04% Mn, 0.99% TiO_2, 0.06% P_2O_5 and 3.30% LOI. Mineralogical analysis indicates that the sample consisted of mainly hematite with subordinate amounts of goethite/limonite, quartz and clay. Martitised magnetite, ilmenite/rutile and mica are observed in minor to trace amounts. The process adopted was gravity followed by magnetic separation could yield a concentrate which assayed 65.90% Fe(T), 3.14% SiO_2, 1.04% Al_2O_3 and 1.26% LOI with weight percent yield of 53.0% and Fe(T) recovery of 65.8%.

The concentrate meets the specification stipulated by the party.

7.2 Beneficiation Studies on a low grade Iron ore sample from Huldool Dongor Bimbol Mine: A low grade iron ore sample of Huldool Dongor Bimbol Mine was received from M/s Eyestar Finance and Leasing Private Limited, Goa for beneficiation studies at the Regional Mineral Processing Laboratory, Indian Bureau of Mines, Bengaluru. The objectives of the investigation were to characterise the sample through chemical analysis and mineralogical studies and upgrade the iron content >63% with maximum possible iron recovery and reduce the SiO_2 content as much as possible.

The as received sample assayed 25.4% Fe(T), 43.83% SiO_2, 2.41% Al_2O_3, 36.32% Fe_2O_3, 3.58% FeO, 0.75% Mn, 0.07% P, 0.08% Na_2O, 0.11% K_2O, 2.87% CaO, 1.65% MgO, 6.28% LOI and traces amount of TiO_2. The Specific gravity of the as received sample is 3.20.

The sample mainly consists of quartz+ felspar, magnetite + martitised magnetite as major along with minor amount of clay+gibbsite, goethite/ limonite, carbonates (dolomite+calcite) and very minor to trace amount of mica, hematite, amphibole, pyrite, tourmaline, serpentine, pyrolusite/ psilomelane minerals.

The concentrates obtained by desliming followed by gravity separation meet the desired specifications of the party.

7.3 Bench Scale Beneficiation Studies on an iron ore sample (BMQ-2, OBS-3, 4, 5) from Yerabali Block, Karimnagar district, Telangana: An iron ore sample designated as (BMQ-2, OBS-3, 4, 5) from Yerabali block, Karimnagar district, Telangana was received from Geological Survey of India, Southern Region at the Modern Mineral Processing Laboratory and Pilot Plant, Indian Bureau of Mines, Nagpur for bench scale beneficiation studies with an objective to produce an iron concentrate suitable for end industrial use.

The as received sample assayed, 43.54% Fe(T), 7.23% FeO, 33.70% SiO_2, 0.74% Al_2O_3, 0.066% TiO_2, 0.066% CaO, 0.50% MgO, 0.57% Na_2O, 0.09% K_2O, 0.022% P, 0.097% Mn and 0.45% LOI.

Tabling on as received sample ground to all 100 mesh size followed by Multi-Gravity Separation on T. Tails could yield a composite concentrate assaying 65.71% Fe(T), 10.76% FeO, 2.48% SiO_2 and 0.46% Al_2O_3 with Fe(T) recovery of 93.6% and weight percent yield of 62.

By simple gravity separation beneficiation process flow sheet could yield a concentrate with high grade and recovery that may find suitable industrial use.

8. LIMESTONE

8.1 Limited studies on a Limestone sample (-40 mm screen fraction) from Emami Cements: A -40 mm screen fraction reject Limestone sample from M/s Emami Cements Pvt. Ltd, Chhattisgarh state was received for conducting limited studies for upgrading CaO% with maximum recovery.

The as received sample assayed 41.78% CaO, 1.04% MgO, 15.12% SiO_2, 3.81% Al_2O_3, 5.71 % Fe_2O_3 and 31.64% LOI. Mineralogical studies on the as received sample show that the sample consist predominantly of carbonates (calcite >>

dolomite) followed by subordinate amount of quartz, minor to very minor amount of clay, minor amount of goethite/ limonite, very minor amount of hematite, pyrite, mica (muscovite & biotite) and trace amount of feldspar, pyroxene, amphibole and garnet.

By simple scrubbing and screening tests, a composite concentrate assayed 48.54% CaO, 1.04% MgO, 8.77% SiO_2, 2.09% Al_2O_3, 2.30 % Fe_2O_3 and 36.51% LOI with 68.8% CaO recovery (Weight % yield being 59.3) could be upgraded as saleable product.

8.2 Limited studies on a Limestone sample - 2 (-40 mm screen fraction) from Emami Cements: A -40 mm screen fraction reject Limestone sample-2 from M/s Emami Cements Pvt. Ltd, Chhattisgarh state was received for conducting limited studies for upgrading CaO% with maximum recovery.

The as received sample assayed 39.88% CaO, 1.95% MgO, 14.39% SiO_2, 4.48% Al_2O_3, 7.46% Fe_2O_3 and 31.34% LOI. Mineralogical studies on the as received sample show that the sample consists predominantly of carbonates (calcite >> dolomite) followed by subordinate amount of quartz, minor amount of clay, very minor amount of mica (muscovite & biotite), goethite/limonite, feldspar, very minor to trace amount of hematite and trace amount of pyroxene, amphibole, garnet, tourmaline and pyrite.

By simple scrubbing and screening tests, a composite concentrate assayed 46.25% CaO, 2.65% MgO, 8.35% SiO_2, 2.19% Al_2O_3, 3.21% Fe_2O_3 and 36.78% LOI with 71.8% CaO recovery (Weight % yield being 61.6) could be upgraded as saleable product.

9. MANGANESE ORE

Bench Scale Beneficiation Study on a Manganese ore sample from Balaghat Mines, Madhya Pradesh for recovery of sand and manganese separately: A manganese ore sample from Balaghat Mines of M/s MOIL was received at Modern Mineral Processing Laboratory & Pilot Plant, Indian Bureau of Mines for carrying out bench scale beneficiation studies with an objective to recover sand from manganese ore fines.

The as received sample was in the form of sand and fines carrying a few coarser size lumps and assayed 22.19% Mn, 49.32% SiO_2, 4.93 % Fe, 4.46% Al_2O_3, 0.16% TiO_2, 0.86% CaO, 0.31% MgO and 1.52% BaO.

Braunite is the main manganese mineral in the sample with subordinate amount of pyrolusite. Hollandite, hausmanite, psilomelane, cryptomelane, jacobsite and rhodonite are the other manganese minerals noticed in minor to very minor amounts. Quartz is the main transparent gangue mineral with subordinate amounts of felspar (orthoclase, plagioclase and microcline). Minor to very minor amounts of pyroxene (diopside), mica (muscovite, biotite), amphibole (hornblende, tremolite), garnet and goethite were also observed. Traces of chlorite, epidote, tourmaline and pyrite are also noticed.

The final composite concentrates produced by desliming followed by gravity separation using spiral concentrator followed by MGS on slimes could yield -

(i) A composite Mn concentrate (Spiral Conc +MGS Conc) assaying 40.82% Mn and 16.39% SiO_2 with a Mn and SiO_2 distribution of 49.6% and 9.2%, respectively (Wt. % yield 27.6).

(ii) A composite sand conc. (Spiral Midd.+Spiral Tails) assaying 15.46% Mn and 63.0% SiO_2 with a Mn and SiO_2 distribution of 46.1% and 84.5% respectively (Wt% yield 66.7).

10. PLATINUM GROUP MINERALS

Bench Scale Beneficiation Studies on a Low Grade Platinum Group Minerals Sample (G2 Stage) from T2 Sector, Tasampalayam Block in Sittampundi Anorthite Complex in Tamil Nadu: A Platinum group minerals sample (G2-stage) from T2 sector, Tasampalayam block in Sittampundi Anorthite complex in Tamil Nadu for GSI, Chennai was received at the Modern Mineral Processing Laboratory and Pilot Plant, Indian Bureau of Mines, Nagpur for conducting bench scale beneficiation studies. The objective of the study was to assess the possibility of enriching platinum group mineral present in the sample and to evolve a suitable process flow sheet for recovery of PGM concentrate and chromite.

The composite original sample assayed 18.01% Al_2O_3, 22.10% SiO_2, 20.98% Fe_2O_3, 3.89% CaO, 11.10% MgO, 22.02 Cr_2O_3, 1.124% Na_2O, 0.032% K_2O, 0.323% TiO_2, 0.144% V_2O_5, 0.102% MnO_2, 0.021% Co_3O_4, 0.132% NiO, 0.031% SO_3,

0.005% P_2O_5, and 0.45% LOI. The sample assayed 195 ppb Ru, 91 ppb Rh, 1020 ppb Pd, 99 ppb Ir, and 1142 ppb Pt. Mineralogical studies reveal that the sample mainly consists of 45-50% amphibole (both lino & ortho varieties), 30-35% chromite, 10-15% mica (biotite),1-2% Ilmenite, 2-3% pyroxene, ~2% chlorite, ~2% rutile, <1% quartz and platinum group minerals, feldspar, pyrite, magnetite and chalcopyrite in traces.

Mozley concentration of rougher sulphide float yielded a heaviest concentrate assaying 839 ppb Ru with 34% Ru recovery, 350 ppb Rh with 30.9% Rh recovery, 6601 ppb Pd with 42.9% Pd recovery, 369 ppb Ir with 33.6% Ir recovery, 5230 ppb Pt with 34.9% Pt recovery (Wt% yield: 6.6%).

The preliminary studies indicate that the sample is amenable to beneficiation to produce a platinum group minerals.

CSIR-National Metallurgical Laboratory (CSIR-NML), Jamshedpur

Mineral Processing Division at CSIR-NML, Jamshedpur has state-of-the-art facility for Process mineralogical study, Beneficiation and Agglomeration at Bench scale and Pilot scale. Following Investigations were carried out in the area of Mineral Processing during the year 2017-18.

1. Studies on Recovery of Chromite Values from Tailings of Chromite ore Beneficiation Plant: With the advancement in beneficiation technology to maximise recovery, the low and lean grade chromite ore are to be exploited with a renewed resource management plan. In addition to exploiting the new resources, it is also important to maximize recovery of chromite values in the existing beneficiation plants. The process route for chromite ore beneficiation involves comminution, classification followed by gravity separation. The plants of present day technology operate to generate chromite concentrate assaying Cr_2O_3 more than 40% with the rejection of tailings assaying 18-20% Cr_2O_3. To meet the new guidelines of IBM on chromite tailing maintaining Cr_2O_3-content <10%, CSIR-NML had undertaken a study on characterization and bench scale beneficiation of chromite tailing from eastern part of India and developed process technology for recovery of chromite value. Chromite ore with an assay of 20% Cr_2O_3, 35% Fe_2O_3, 16% SiO_2 and 10% Al_2O_3 is beneficiated through desliming, gravity separation and enhanced gravity separation techniques to generate a concentrate with an assay of ~ 42% Cr_2O_3 wherein 65% recovery was achieved.

2. Beneficiation Study on Recovery of Iron Values from Iron ore Slimes: CSIR-NML had undertaken study on characterization and beneficiation of iron ore slime from Iron Ore Washing Plant from eastern part of India and developed process technology for recovering of iron values from slimes. The beneficiation process developed based on the bench scale study basically involved desliming, wet high intensity magnetic separation followed by dewatering of products. The process developed through bench scale study was validated by pilot scale operation. The product is suitable for use in iron making through pelletisation.

3. Pilot Scale Flotation Studies of Iron Ore Slime: Hematitic iron ore from northern part of India is subjected to washing and the fines released as slime is disposed in the slime pond, which subsequently leads to environmental threat besides the losses of iron values. The slime is observed to be comprised of fine grained ore minerals of hematite, goethite as well as gangue minerals of quartz and kaolinite. Beneficiation process involving froth flotation and through development of suitable novel reagents to recover iron values from slimes was undertaken as collaborative research of Tata Steel and CSIR-NML. Bench scale trials were conducted at 0.5 kg, and the performance of the flotation reagents was studied at pilot scale. The study reveals higher selectivity of the novel reagents and achieved an iron-concentrate with 82% yield assaying 64.5% Fe, 2.4% Al_2O_3 through reverse flotation rejecting a tailings with <45% Fe.

4. Briquetting of Chrome Concentrate Micro-fines for Ferro-alloy Production: In Industrial raw material preparation through agglomeration of chromite ores is carried out by sintering, pelletisation and briquetting but the latter is preferred because the other two are highly energy intensive with high infrastructural cost and addition of gangue components as binders. In view of this an attempt was made to convert the

chrome micro-fines to briquette for use as raw material in ferro-alloy making. The briquettes developed under optimised conditions attained a CCS of with 126 kgf and 25 drop number.

5. Development of Stationary Bed Pellet Induration Furnace: In pelletisation plant, the induration is carried out in straight travelling grate and grate-kiln, which occupies large space. Travelling grate facilitates both up draft and down draft facility. To simulate the firing zone of pellet induration, CSIR-NML in collaboration with Tata Steel designed and developed a gas based stationary grate induration strand with down draft facility.

6. Desliming Hydrocyclone Simulation Studies: In iron ore beneficiation, desliming is a very common operation in which very fine particles are separate. Typically, low diameter hydrocyclones such as 50 mm (2") are preferred for this kind of operation to classify particles smaller than 10 micron. But due to lower capacity and small orifice in such very small hydrocyclones, the operational problems are significant with average amount of tramp over size. A study was carried out to achieve a cut size between 5-10 micron with a 4" hydrocyclone through pilot scale test at varied combination of parameters such as vortex finder, apex followed by development of steady state model and simulation analysis. The product was generated with D_{50} of 4.4 micron and solid recovery of more than 91% in underflow at optimum condition, as guided by simulation result.

7. Modelling and Simulation Analysis of Comminution Circuit: Size reduction operation in mineral beneficiation circuit is an extremely energy intensive process. The process of developing a model for crushing circuit and simulating it regularly will optimize the parameters affecting the circuit performance. Simulation studies will be useful in predicting the optimum operating conditions of the circuit and therefore retrofitting the circuit. Objective of the present study was to predict the maximum throughput of the crushing circuit along with the optimum parameter to achieve that throughput. The study includes a steady state model development using the actual plant data followed by validation and prediction of the process effects through off-line simulation. Simulation analysis proved helpful in achieving an improvement (~40%) in the circuit throughput with change in crusher closed side setting (CSS).

8. Beneficiation of Siliceous Limestone for Cement Industries: Limestone of various grades are extensively used in cement, metallurgical, glass industries, food processing, paper making, leather, wastewater treatment, polymers as well as adhesives. The specification of limestone required by Cement Industry is 42% (min.) CaO, 11-14% SiO_2, 1-1.5% (max.) Fe (T). CSIR-NML has taken up a research project on beneficiation of argillaceous limestone containing 39% CaO, 19% SiO_2, 23% total insoluble and 0.8% Fe(T) and minerals with fine texture. Based on the process mineralogical information, the ore was subjected to comminution followed by flotation in bench scale and a limestone concentrate of cement grade with 11% SiO_2 was generated.

9. Development of Process Flowsheet for Beneficiation and Extraction of Tungsten Metal from Mines Waste: Tungsten is an elastic, ductile metal with high tensile strength, low thermal expansion, highest melting point and boiling point of all metals and has significance as alloying element for defence, space and nuclear applications. Due to increasing domestic demand of tungsten and export restrictions from the major producers, indigenous production to meet a part of the domestic demand is inevitable. CSIR-National Metallurgical Laboratory is working on development of indigenous technologies for production of tungsten metal from domestically available resources such as lean grade ores and mines waste. The study involved mineral characterisation, process mineralogical study, beneficiation followed by extraction of metal from concentrate/pre-concentrate produced from scheelite bearing gold ore tailings sample. The scheelite bearing mines waste with very low WO_3 content was subjected to innovative processing exploiting the differences in specific gravity, magnetic susceptibility and surface properties of minerals. The tungsten concentrate is further processed by hydrometallurgical route for production of highly pure ammonium paratungstate (APT). The pilot scale study is under progress.

10. Dry Beneficiation of High Ash Non-coking coal for Application in Thermal Power Plants and DRI Making: CSIR-NML has developed an expertise and pilot scale facility for dry beneficiation of non-coking coal. Pilot scale dry beneficiation process flow sheets were developed for three different high-ash non-coking coal with ash-content of 49%, 43% and 32% from three different regions, namely, South Eastern coalfield, Central Coalfield and Eastern Coalfield respectively. Products with ash of 34% and 25% were generated for utilization in thermal power plant and DRI (Directly Reduced Iron) making respectively. The rejects from the dry beneficiation circuit can be utilized in FBC plant. The developed dry beneficiation technology will be helpful in eliminating process water requirement, generation of effluent/slime and production of clean coal with no additional moisture.

CSIR-Central Glass & Ceramic Research Institute (CGCRI)

1. R&D for recovery and utilization of wastes, marginal materials and byproducts, substitution of one mineral by other or of mineral by other commodities, etc: Large amount of Industrial Solid Wastes (ISW) are generated from steel plants, thermal power plants, mining activities etc. The main cause of concern associated with the ISW is their proper disposal. CSIR-CGCRI is working for the proper utilization of these materials for value added product development like pavement tiles, blocks etc. Pavement blocks have been developed using an optimized combination of steel slag, fly ash along with other ceramics raw materials. The properties achieved are at par with the Indian Specification. Presently, performance evaluation in actual condition is going on.

2. R&D (Coal, Hydrocarbons & Energy): Solid Oxide Fuel Cell (SOFC) is an "all solid-state" energy conversion device that converts the chemical energy of a fuel directly into electricity through its electrochemical combination with an oxidant. Due to the direct electrochemical reaction, they offer very high conversion efficiency (>50%) and low level of pollutant gas (e.g., NOx, SOx etc) emissions. CSIR-CGCRI has developed process technology for making solid oxide fuel cell (SOFC) stack using indigenously developed planar anode-supported SOFC single cells (10 cm x 10 cm x 1.5 mm), glass-based high temperature thermally cyclable sealant and ferritic stainless steel based bipolar plates and current collection plates having a novel flow field for the reactant gases (both fuel and oxidant) to produce electrical power through electrochemical reaction of the fuel gas (e.g. hydrogen) with the oxidant (e.g. oxygen/air). The stack is operated at a temperature in the range 700 – 850 ^{0}C. Depending upon the number of cells in the stack, an electrical power output upto 1 kW can be achieved and several such working SOFC stacks have been demonstrated for the first time in the country.

3. R&D for development of ceramics, refractories and glass based on minerals or mineral-substitutes: Over the years the CSIR-CGCRI has developed expertise in new generation bioceramics, glass, metal and composite materials for variety of biomedical applications. Specifically, the division dedicated to the R&D of bioceramics in CSIR-CGCRI has commercialized ceramic-on-PE hip joint prosthesis, plasma spray grade hydroxyapatite granules, hydroxyapatite-based bone fillers/scaffolds/granules and integrated ocular implants, which have received different international certifications. Other areas of expertise include bioceramics based drug delivery system, glass and glass-ceramics, wear resistant coatings, additive manufacturing of patient specific implants as well as tissue engineering and regenerative medicine research pertinent to biomedical and other focused societal applications.

Two major Magnesite sources of India (viz. Salem in Tamil Nadu and Almora in 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, without any ore beneficiation, by judicious selection of additives to reduce the low melting phase formation.

CGCRI is working in collaboration with another sister laboratory, CSIR-IMMT, Bhubaneswar for utilizing quartz, alumina and

other components extracted from fly ash generated by thermal power plants as mineral substitutes. Some of the glasses which are developed utilizing quartz, alumina and other components extracted from fly ash are Container glass, Float glass, Coloured glasses and Sealing glasses.

CGCRI is also working on development of speciality glasses for applied usage which require raw materials of high purity developed in association with indigenous manufacturer and those are metaphosphates of aluminum, barium and potassium as well as oxides of rare earths. These raw materials are being used in the preparation of speciality glasses.

Precision glass optics is witnessing an exponential growth in demand over the last couple of decades due to a variety of applications in precision high technology devices, strategic equipment and consumer electronic appliances, such as, mobile camera lenses, CD/DVD pickup lenses, head up displays for aircrafts and automobiles, microscope objectives, Fresnel lenses, F-theta lenses for laser optics, micro lens array, hologram optics, aspheric collimators for laser diodes and solar concentrators etc.

Conventional process chain for majority of these complex optical components involve multi-step lapping and grinding of glass preform with abrasives followed by polishing to minimize surface roughness levels to appreciably low levels and diamond turning. These processes necessitate inspection of the surface form accuracy and roughness accuracy at intermediate steps and leading to low productivity and high cost. An alternative process chain is thus being pursued in the laboratory involving a rapid, net shape, replicative technology of precision glass moulding using high-precision moulds with which glass components are deformed. The replicative high temperature precision glass forming technology stands out as a promising candidate for high volume production of optical components which is expected to lower the cost of these optics by an order of magnitude. In terms of R&D efforts for the strategic sector, Silicon Nitride based EM window has been developed where green processing and nitridation technique have been carried out.

CSIR – Institute of Minerals & Materials Technology, Bhubaneswar

A. R&D (Ore preparation & process)

1. Characterisation and Beneficiation Studies on Hematite iron ore for preparation of DRI Pellet Feed Material: Two iron ore fines samples from IP and Serajuddin mine from Odisha were collected to beneficiate the ore to produce super grade concentrates. The iron ore from IP mine contains 63.65% Fe having 2.88% SiO_2 and 2.88% Al_2O_3 and 2.56% LOI. As per heating cycle and XRD studies, it contains around 15-16% goethite and 7-8% kaolinite and other clay material. As per particle size distribution, it contains below 45-micron around 15-16% and around 53% Fe. The Bond work index of the bulk sample and screw scrubber underflow sample are 9.8 and 12.8 Kw hr/tonne, respectively. Once the sample is scrubbed in screw scrubber the screw scrubber underflow contains around 66.18% Fe with a yield of 80% whereas overflow contains 54.6% Fe. Hence, the underflow is considered as one of the products of the process. In general, goethetic hematite ore is fragile in nature, hence, the two stages classification units either by hydrocyclones or hydrocyclone and high frequency vibrating screen should be adopted in the grinding circuit to control the Blaine number. The overflow of screw scrubber is subjected to a high intensity magnetic separator to maximize the iron recovery. It is possible to produce around 89% yield with 66% Fe in the concentrate and simultaneously the tailings Fe will be around 45%.

Another sample was collected from Serajuddin mine. It contains a good amount of high grade blue dust. This iron ore fines sample contains itself 65.18% Fe. It contains around 26% of below 45 micron. This ultrafine contains more Fe than coarse particles. Hence, desliming is not possible. Ore was classified using screw scrubber and the underflow was ground to below 100-micron particles and mixed with an overflow of the screw scrubber to produce pellet feed materials. The screw scrubber is used to classify the iron ore samples so that ultrafine generation can be minimized during grinding of the ore. The bond work index of the bulk sample and screw scrubber underflow samples are 8.1 and 9.6 Kw hr/tonne respectively. The detail material balance based on 200TPH was carried out.

Both acidic and basic pellet tests were carried out on the iron concentrate generated from the two samples. In both cases, the metallurgical property of pellet could be achieved more than the desired level. It has been observed that in case of basic pellet, the metallurgical properties are better in comparison with an acidic pellet. Hence the basic pellet can be produced which can be used directly in the blast furnace for the production of iron.

2. Characterisation and beneficiation studies on hematite iron ore from Sagasahi Mine Odisha: The borehole samples were collected from the iron ore mine at Sagasahi, Odisha. The objective of the project was to provide appropriate process flow sheet for different Fe ranges of raw materials to maximize the iron recovery with high Fe content to utilize powdery and fragile types of hematite iron ores resources. A total of nine borehole samples consisting of 3 boreholes from each block are being investigated. The detail characterization study has been done. Beneficiation study of the samples was carried out in different ranges of Fe content to produce super grade and normal pellet. A process flowsheet has been developed with detail material balance and process basic engineering was prepared for the commercialisation of the process.

3. Process development for the recovery and extraction of Nb and Ta from carbonatites of Sevattur deposit, Tamil Nadu: A typical beneficiation flowsheet of niobium ore consists of size reduction, classification, magnetic separation, flotation and leaching of the final concentrate. The specific gravity of Nb/Ta mineral is 4.4-4.8 which is associated with light minerals like quartz, calcite, dolomite and alumino silicates. Hence, gravity concentration techniques are used for pre-concentration of the ores. Very little literature is available on the flotation of niobium tantalum minerals since most of the plants use gravity separation for the beneficiation.

4. Characterisation and beneficiation study of low grade PGE ores from Boula mine: The characterisation of the feed material and comminution work were completed. The PGE analysis of the bulk feed shows wide variations in their composition from 1.1 to 4.0 ppm. The mineralogical investigations on the feed material revealed that the chromite and silicate gangue minerals are liberated around 150 micron particle size. It is anticipated that the PG mineral liberation occurs at much finer sizes. In view of this beneficiation experiments were carried out on finer particle sizes. Preliminary experiments were carried out on conventional gravity concentrators and advanced gravity concentrators to pre concentrate the feed material. The shaking table and spiral concentration experiments were carried out by varying all possible process parameters in batch and continuous mode.

Advanced gravity concentration studies on Falcon and Knelson concentrator were carried out by varying particle size and other process parameters. Preliminary studies on gravity concentration of fine feed material show that the PGE content in the concentrate has been enriched to 10-11 ppm.

5. A preliminary study of recovery of nickel value from chromite overburden and to optimize and undertake technology development in COB plant operation: IDCOL, Odisha has chromite beneficiation plant at Talangi Sukinda, Odisha. As the ore is degrading day to day, lean grade ore is to be beneficiated in the existing beneficiation plant. The low grade ore was collected and beneficiated at the lab and plant scale in the Institute. As per requirement of quality of concentrate, the modification of the plant was suggested. At present, the work is in progress. Apart from beneficiation, nickel recovery from chromite overburden work is also taken.

B. R& D activities in Building materials

1. Mineral cementation technology for cold setting building brick: CSIR – IMMT, Bhubaneswar has developed a non-fired process for utilization of industrial and mining wastes in the manufacture of building material named as mineral cementation technology. It is sustainable green process, where the binding matrix of hydrated layered silicates are formed by chemical reaction of oxides and hydroxides of silica, alumina, calcium magnesium, iron alkali, sulphate bearing minerals in atmospheric temperature and develop strength like Portland cement. Mineral cementation is flexible to use all kind of industrial solid wastes in the manufacture of building

materials. This process is flexible to use all type of mining and industrial wastes.

2. Cement free fly ash geopolymer technology: Geopolymer is a green chemistry of making cementitious binding materials like hydraulic cement through alkaline reaction of alumino-silicious minerals. The process is CO_2 negative and very effective for utilization of fly ash, metallurgical slag and other mining and industrial wastes. The technology on fly ash geoplymer concentrate has been developed and it is in the process of commercialization for construction of road.

3. Treatment and utilisation of jarosite a waste of Zn extraction plant in the manufacture of cold setting building brick: Jarosite is a toxic waste generates from Zn smelter plant during the extraction of Zn from Zn ore. As of today, the waste jarosite is stockpiled for storage. Presence of toxic water leachable elements like Pb, Cd, Zn, etc. in jarosite causes serious environmental problem. No such commercial process has been developed for suitable utilisation of jarosite in making value added application. Under the exploratory research programme, a successful innovative process has been developed for toxic leachable elements stabilisation and manufacture of cold setting building brick/block using jarosite. The work is to be carried out on pilot scale optimization and transfer of the process with the financial support of M/s HZL, Udaipur, Rajasthan.

4. Preparation of Calcium sulfo-aluminate cement: In context to the environmental point of view, Calcium sulfo-aluminate cement is an option to develop alternate low lime clinker to substitute Portland cement to reduce CO_2 emission. Calcium sulfo-aluminate is a compound having the similar cementing property and characteristics like hydraulic cement alternate to Portland cement, which can be prepared with low lime content and less emission of CO_2. The industrial waste by-products like low grade limes, gypsum and hydrated alumina are the major raw material in synthesis of calcium sulfo-aluminate cement. All these raw materials have been ground altogether into a fine powder in the presence of different accelerating, setting and blending materials to prepare cement.

National Mineral Development Corporation Ltd (NMDC)

NMDC operates a state-of-the-art R&D centre at Hyderabad, which undertakes various projects related to the operational problems of the units of NMDC and provide 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:

- Developing technologies for enhanced utilization of iron ore fines.
- Providing technical solutions to the problems related to quality and productivity of NMDC mines.
- Upgradation of processing technology of existing process plants for better productivity and meet the customer requirement.
- Development of technology for utilization of mine wastes.
- Development of Value Added process and product through innovation.
- Development of technology for dry processing of sub and lean grade iron ore.
- Development of technologies for enhanced recovery of iron values.

1. In-house Programmes

1.1 To improve the screening efficiency of secondary screens at existing plants at Kirandul.

1.2 Study on abrasive wear and frictional characteristics of liner materials used in Iron ore storage and handling.

1.3 Development of mathematical model to predict metallurgical characterisation of iron ore sinter (Phase 2) - it is a continuation project.

1.4 Development of cold bonded iron ore pellets.

1.5 Characterisation of Sub-grade/lean grade/ overburden/waste samples from Kirandul complex and Bacheli Complex.

1.6 Study on enhancing the separation efficiency of magnetic separation.

1.7 Process development for preparation of Silica Sol from Lean Grade Iron Ore Slimes.

1.8 Feasibility study of production of TiO_2 slag from Ilmenite using Hydrogen gas as reductant followed by smelting - it is a continuation project.

1.9 Pelletisation studies with magnetite concentrate on banded magnetite quartz sample of Ballari district (Karnataka).

1.10 Effect of excess quantity of ultra fines (less than 150 micron) in iron ore fines from Bailadila region on sinter properties.

2. Collaborative Programmes

List of Collaborative Institutes:

Sl. No.	Collaborating Institutes	Title and Nature of Work
1.	IIT, Bhubaneswar (started on 9th October 2017)	Optimisation of Silos, Bins and Hoppers design through modelling, primarily intended for Iron ore storage.
2.	IMMT, Bhubaneswar (started on 9th October 2017)	Modelling & Optimisation of high concentration Iron ore fines/concentrates slurry pipe line for Indian Iron Ore Processing Industry.
3.	CSIRO, Australia (started on 21st August 2016)	Characterisation and beneficiation studies on laterite/goethite iron ore. Development of dry beneficiation technology for processing of hydrated iron ore.
4.	ECT, Australia	Adoption of alternate iron making novel technology patented by M/s ECT, Australia.
5.	IIT Madras, IIT Kanpur, JSW	Develop a process for Iron Ore reduction through Microwave furnace. Micro-wave is alternate route of heating the minerals. Finalisation of MoU is under process.
6.	IMMT, Bhubaneswar	Development of an entrained flow gasification system using non-coking coal (F-grade) blended with dolo-char for thermal applications.
7.	IIT, Hyderabad	Improving the efficiency of dense medium cyclone separating the high NGM Coal samples using GPU based CPM and PERT methods.

2.1 Development of an entrained flow gasification system using non-coking coal (F-grade) blended with dolo-char for thermal applications (IMMT, Bhubaneswar): Gasification is an exothermic reaction between a high carbon fuel and a carefully controlled and limited supply of oxidizer, in which the fuel yields useful elemental and compound gases that can be made into other products. Fuel can be fed dry or wet (mixed with water) into the gasifier. The reactants (steam and oxygen) flow unidirectionally upwards through the gasifier, as the stages of gasification take place, until high temperature completed syngas exits the top of the reactor. Molten slag drops out at the bottom.

The project pertains to utilisation of dolochar generated during sponge iron production. It has been estimated that in near future, the utilisation and disposal of huge amount of waste in the form of dolochar is a major challenge. The dolochar invariably contains 15-30% fixed carbon which can be efficiently utilized through adoption of appropriate technology. The proposed research is an attempt to develop method for utilizing dolochar in entrained type gasifiers.

After incorporating air pre-heating system with the prototype entrained flow gasifier, experimental campaign was carried out. F-Grade coal, dolochar & lignite coal (Size: < 150 µm) were used as feedstock for gasification process. Mixing of dolochar with coal further reduces the quality of producer gas. The highest average reactor temperature 830 ^{0}C was achieved with lignite as feedstock due to presence of high volatile material. Steps will be taken to commercialize the result of ongoing studies.

2.2 Characterisation and beneficiation studies on laterite/goethite Iron ores, Development of dry beneficiation technologies for processing of hydrated iron ores: Agreement was signed between NMDC and CSIRO, Australia in Jan 2016. Test work is under progress. Stage 1 related to characterization and exploring options for dry

beneficiation has been completed and agreement for Stage 2 has been signed on 28th May 2018.

2.3 R&D for alternative Iron making Technology: A pilot plant for iron making by adoption of MATMOR technology is envisaged in Research Collaboration mode between NMDC, NLC and ECT. The MATMOR technology is a unique alternate iron making method for producing high-quality iron from inexpensive, abundant Lignite (brown coal) and high or low grade iron ore/ mill scale etc; technology patent is owned by M/s ECT, Australia. The MoU for Research Collaboration on COLDRYMATMOR Pilot plant project was signed on 30th May 2018 at Canberra, Australia. The MoU will set out the understanding of the Parties for the development of the Pilot Project and includes provisions with respect to formation and capitalization of the Project SPV, execution of several agreements at different stages of the implementation of the Pilot Project and licensing and sub-licensing of IP as contemplated for the Pilot Project followed by construction, commissioning and operation and maintenance of the Pilot Project.

2.4 Improving the efficiency of dense medium cyclone separating the high NGM coal samples using GPU based CPM and PERT methods (IIT, Hyderabad)

(i) To undertake a detailed literature review on the existing numerical models used for the performance prediction of Dense Medium Cyclone (DMC).

(ii) To conduct test work on thermal coal with Graphical processing unit CPU CFD codes. The test work has been completed and preparation of the final report is under progress.

Manganese Ore India Ltd (MOIL)

MOIL has carried out R&D activities to improve the safety, productivity and environmental standards in the mines by introducing newer technology in consultation with reputed academic and CSIR-R&D Institutions 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 Institute (NGRI), Hyderabad, (iv) CSIR -National Environmental and Engineering Research Institute (NEERI), Nagpur, (v) Indian Institute of Technology (IIT), Kharagpur, (vi) Indian Institute of Technology (IIT), (Formerly Indian School of Mines), Dhanbad, (vii) National Institute of Technology (NIT), Rourkela, (viii) Visvesvaraya National Institute of Technology (VNIT), Nagpur, (ix) National Institute of Rock Mechanics (NIRM), Kolar Gold Fields, (x) Indian Institute of Engineering Science and Technology (IIEST), Shibpur and (xi) National Remote Sensing Centre (NRSC), Hyderabad.

Significant R&D projects in MOIL are listed below:

1. **Mine Environment:** IIT, Kharagpur has conducted ventilation reorganisation studies for deeper levels at Munsar, Kandri and Ukwa Mines. Accordingly, new ventilation drifts are now being developed at Kandri and Chikla Mine for installation of large diameter ventilation fans.

2. Mines Safety: (a) **Mining Subsidence:** In-house scientific 3-D analysis of subsidence parameters has been carried out by Mine Planning and Design Department for Munsar Mine. With the analysis, it is confirmed that no noticeable movement of any orthogonal direction has been found at the Mine.

(b) **Stope Design:** Stope design for mechanised support system is going on by NIRM at Balaghat Mine for better safety and productivity.

3. Mineral conservation: R&D studies have been conducted at Munsar Mine by NIRM. The suggested stope design has incorporated placement of haulage drive in foot wall rock with roof bolts in haulage drive, x-cut and in stope. This has totally eliminated the *in situ* sill pillar 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 mines for exploitation by around 20%, thus conserving the valuable mineral resource.

4. Mining Technology: (a) **Decline:** R&D project for entry to the underground stoping area by decline has been prepared by CSIR-CIMFR, Nagpur for Gumgaon Mine. Feasibility studies are

going on for economic evaluation. This may help in improving production, safety and productivity by mechanisation of stoping operations.

(b) **Alternative to Cartage Explosives:** To reduce the ground vibrations, fly rock and noise, Site Mix Emulsion (SME) explosives have been used with shock tubes at Dongri Buzurg Opencast Mine. The post blast result of the SME is found satisfactory and it has reduced noise level, ground vibrations and fly rock substantially, besides increasing operational efficiency.

5. Collaborative work with Academic and Research Institutions: (a) MOIL is carrying out joint collaborative R&D project with NIRM, Bengaluru for installation of modern scientific rock mechanics instruments at Balaghat Mine.

(b) A collaborative research for slope stabilisation with National Institute of Technology, Raurkela for Modern Slope Monitoring Instruments – Time Domain Reflectometry (TDR) using Wireless Sensor Network is going on at Dongri Buzurg Mine for better safety.

6. In-house R&D works: (a) **Substitute of fill material:** Mine Planning and Design Department has conducted the in-house R&D study on overburden material to use as a fill material in underground by hydraulic transportation at Munsar Mine on experimental basis and filed a patent.

(b) **Pre-cast RCC Columns & Sections:** In-house developed pre-cast RCC columns and sections have been rapidly erected in drift development and thus improved the safety standard of drift development in underground.

7. Mineral Beneficiation: R&D studies of black dump manganese rejects of Balaghat Mine have been carried out by Modern Mineral Processing Laboratory and Pilot Plant, Indian Bureau of Mines for utilisation of mineral rejects.

8**. Metallurgical Studies:** For improvement of product quality of High Carbon Ferro Manganese (HCFeMn) alloy of Balaghat Mine process flow studies for de-phosphorisation of HCFeMn alloy has been carried out on bench scale at CSIR-National Metallurgical Laboratory (NML), Jamshedpur.

Steel Authority of India Ltd (SAIL)

Three projects are being pursued with assistance of Ministry of Steel: (a) Development of Pilot scale pelletisation technology for Indian Goethitic/hematite ore with varying degree of fineness (completed in September 2017); (b) Indigenous development of model based breakout prediction system for Continuous Casters; and (c) Development of automation system for optimum coal blending at coal handling plant of coke oven batteries.

Tata Steel Ltd

A. R & D (Ore beneficiation), Jamshedpur

(i) Established 'High Intensity Magnetic Separation' technology on a pilot scale at Noamundi iron ore processing plant to recover iron value from slimes.

(ii) 'Dry Magnetic Separation' technique for beneficiation of low grade manganese ore fines established on a pilot scale which will facilitate using of ore which is currently being dumped.

(iii) Comprehensive/deep beneficiation flow sheet developed for processing low grade iron ore at Noamundi & Khondbond to achieve higher yields at lower alumina.

(iv) Reduction in specific water consumption at Noamundi wash plant by optimising the scrubber performance.

B. R & D (Agglomeration, Ferro-alloys, Blast Furnace and Waste Utilisation)

Jamshedpur

(i) Development of carbon composite briquette using plant reverts as third agglomerate in Blast furnace. This will enable reduction in carbon rate of blast furnaces.

(ii) Implementation of lime excess framework for sinter chemistry control to optimise flux consumption in Iron making.

(iii) Physio chemical characterisation of Manganese ore done for the first time for better understanding of raw material characteristics. This will enable optimisation of furnace feed for Ferro Manganese production.

(iv) Metallurgical know-how for premium grade low Silicon Ferro Chrome production established.

(v) Lowest ever coke rate achieved through process improvement.

(vi) Controlling furnace hearth wear by suitable adjustment of casting practice and use of acoustic technology.

Kalinganagar:

(vii) Solid wastes from Blast Furnaces, Steel Melt Shop and Hot Strip Mill are mixed and processed in various proportions and are utilised as by-products in Sinter making at Kalinganagar. This not only reduces the Sinter cost but also helps prevent disposal cost and preserves natural resources thereby supporting sustainability of Steel Plant. Processed Solid Waste utilization started in Sinter-making from April 2017 and has reached the utilisation level of 80 kg/tonnes of Net Sinter in year 2017-18 which is equivalent to consumption of all the solid wastes that get generated at Kalinganagar Plant.

(viii) Tata Steel Kalinganagar is equipped with the most advanced Twin Wagon Tippler for handling different raw materials. This was designed for handling different types of wagons such as BOXN, BOXNHL, BOY, BOY-25 etc. This wagon tippler has been modified and made capable of handling BOST, BOBSN & BOBYN rakes as well. This has created flexibility in rake allocation with increased rake availability and faster turnaround time for raw material movement, thereby strengthening the Raw Material supply chain. It has also supplemented the dispatch of finished goods from TSK in wagons such as BOST types.

Hindalco Industries Ltd

A. R&D (Ore preparation & process)

1. Optimization of Bauxite Blending for Bayer Plants: Different types of bauxites available for the plants were characterized and blended suitably (based on the complete processability study) in order to optimize the production parameters of the Bayer process and obtain highest possible recovery. This study helped plants to use both low as well as normal grade bauxite, available in the mines, thus improving the mines life.

2. Improvement of Oxalate Productivity of Bayer Plant: Precipitation tests were conducted based on the Design of Experiment (DoE) of the process, prevailed in Belagavi plant. Outcome of the DoE resulted into an optimized process parameters of the plant and led to increase the productivity from 0.5 to 2.0 g/L. Presently plant is operating with this optimized process and getting the desired results.

3. Grinding Aids for Bauxite Milling Process: The present bauxites of Western Ghat has become harder than the earlier available resources which led to reduction of output of the bauxite milling process. Hence, studies were conducted to find out a suitable grinding aid for such type of bauxites. The evaluation of this grinding aid, both in laboratory and pilot, resulted in an increase of output by ~15%. Regular plant operation is being done with this grinding aid.

4. Utilisation of Bauxite Residue in different Applications: Collaborative works with different institutes, like IIT Mumbai, NML – Jamshedpur, etc, as well as studies at our own R&D facilities are conducted on the following areas.

- Geopolymer for reclamation of land area (for construction purpose)
- Preparation of paver block for construction purpose
- Neutralisation of residue for land as well as mine back filling.
- Use of this residue for cement making, which is a great success for some of our plant. Steps taken to replicate this in all our plants.

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

Separation of Unburnt Carbon from Fly Ash of Cogen plant: Studies were conducted to characterize fly ash and optimize froth flotation process with a right combination of frother and collector. Finally, a process route was established to recover ~80% unburnt carbon from the flay ash. The recovered product showed a calorific value of ~ 4200 Kcal/kg which is equivalent to the calorific value of standard Indian Coal. Pilot plant studies are being planned for scaling up of this process.

C. R&D (Development of ceramics, refractories, glass, etc.)

Development of Precipitated Super Fine Hydrate: Hindalco has developed a process for producing

precipitated SF hydrate both in lab and pilot facility. Based on the outcome of this, action has been initiated for setting up a plant for bulk production of this material. Presently, this type of Speciality hydrate is used as fire retardant filler in polymeric compound and presently it is imported to India. Indigenous production will surely help the industry to source this product from indigenous supplier.

Hindustan Zinc Ltd

A. R&D (Ore preparation & Process)

1. Pre-graphite flotation to remove graphitic carbon of SK-6 Ore: The sample has been taken from SK mines, actually a new ore body found named as SK 6 with peculiar metallurgical characteristics i.e. high graphitic carbon content and low Total Metal Content (TMC). High graphitic content adversely affects the flotation characteristics of Galena and Sphalerite and also, high content of graphite in lead concentrate adversely affects downstream smelting process. To address this problem, it was proposed to conduct pre-graphite flotation experiment to remove graphitic carbon in graphite concentrate. Number of flotation tests with different parameters are conducted to optimize metal grades and recoveries.

(i) Determination of Mesh of Grind (MoG): Batch flotation tests @ different grind size (80% passing 75 µ, 63 µ & 53 µ) was conducted to determine MoG.

(ii) Pyrite depressant Testing: It shows that at both MoG i.e. 75 & 53 µm, use of MBS reduces iron (Fe) values in Zinc Rough Concentrates by 5-6% when compared with that of NACN. But, use of MBS also leads to decrease in metal recoveries in both lead & Zinc as compared to that of NACN.

(iii) Pre-Graphite Roughing: Pre-Graphite Roughing stage flotation tests were conducted to recover graphite in pre-float rougher (PFR) concentrate and to observe its effect on other metal grade and recoveries. In pre-float only frother and zinc depressant were used. The results are as follows:

- At MoG 75 µm, there is decrease in Pb, Zn and Ag recoveries when Graphite pre-float is done as compared to graphite w/o pre-float.
- The decreases in metal recoveries approximately are Pb 5-6%, Ag 6-7% and Zn 5-6%
- However, graphitic carbon in Pb concentrate is decreased from 7.8 to 5.8%
- Mass pull of rougher graphite concentrate is 4%.

2. Grade & Recovery optimization of Zawar Ores: The experiment was performed on samples taken from various Zawar mines (Zawar mala, Baroi, Balaria and Mochia) ores to obtain the optimum grade and recovery of Zawar mines ores using differential flotation by varying parameters such as Grinding time, Reagent dosages and Blending of ores. It was observed that

- Pb and Ag grade in mochia ore has increased from 42.27% to 51.70% and 484 to 498 (ppm), respectively. Apart from this, the grade recovery of Ag also increased from 39.85 to 48.53%. The grade and recovery of Zn is almost same in both the dosage variation.
- For Balaria ore, increasing the dosages of SIPX for Pb from 40 gpt to 45 gpt results in recovery increment from 80% - 87% but Zn recovery decreases from 93% to 85%. The Ag recovery is optimum for higher gpt of Sipx (45gpt).
- For Zawarmala, less grinding is recommended as more fine size significantly affects the Pb grade (14.7%) which is difficult to optimize even with higher gpt of dosages.
- Pb and Ag grade shows a higher percentage as 53.57% and 855 ppm, respectively, with dosage variation. So dosages variation is advisable for Baroi ore.

Blended ores: The samples of ores have been collected from different mines of Zawarmala unit and the ores have been blended with the combination (i) Mochia + Zawarmala (50:50); (ii) Mochia + Balaria (50:50); (iii) Baroi + Balaria (50:50); and (iv) Baroi + Zawarmala (50:50) to get better grade and recovery of Zn, Pb & Ag by blending ore in different combinations. It was concluded that

- Blending of ores with Mochia is giving Pb grade 32-38% with a recovery of around 90% whereas Zn grade 24-27% with a recovery of 85%.
- Blending of ores with Baroi is giving Pb grade 35-40% with a recovery of around 85-88% whereas Zn recovery is low around 70% this is due to misplacement of Zinc in Pb concentrate which is around 25%.
- Silver recovery in blending is very poor less than 40% in combination with Mochia and less than 50% in combination with Baroi.

3. Paste Filling Test by using power plant waste: The sample (tailing) has been taken from SK mines and fly ash from power plant waste to reduce cost of cement used in filling by using ultra fly ash. In this process, Cement is mixed with fly ash in different ratio and allowed them to dry in cylinder for 7, 14, 28, 56 days to check increase in strength of the mixtures. After the desired time period their strength was checked using master loader equipment and observed that the ratio of 2:6 of fly ash and cement, respectively, dried for 56 days showed the strength comparable to the strength of the mixture containing total cement.

B. R&D (Product development)

1. Bismuth Oxy-chloride & Copper sulphate: Flow sheet developed for recovery of Copper & Bismuth from Cu-Bi slag generated from silver refinery. Copper is recovered as copper sulphate (Purity 90%) which is consumed internally at HZL mines and Bismuth is recovered as Bismuth Oxy Chloride (BiOCl) of purity >86%. The Cu-Bi lean residue generated after treatment gets enriched in Lead & Silver and consumed internally in Lead refinery. The flow sheet was successfully tested at CRDL pilot plant for 6 months and about 650 kg BiOCl and 30 m^3 Copper sulphate solution has been generated. Proposal for commercial scale plant set up has been initiated.

2. Antimony Tri oxide: Process flow sheet developed and successfully validated at pilot scale for recovery of Antimony as Antimony Tri-oxide from Lead refinery Antimony dross. The antimony lean residue is enriched in Lead and consumed internally at Lead Smelter. About 900 kg Antimony tri-oxide of purity >96% has been generated during pilot scale testing of flow sheet for two months. Proposal for commercial scale plant set up has been initiated.

3. Sodium Sulphate: The smelter effluent is treated in conventional Effluent Treatment Plant (ETP) to precipitate out heavy metals and generate waste water, which is fed to RO process followed by Multiple Effect Evaporator (MEE) process to recover water values. The MEE reject is a solid mass comprising of Sodium, Sulphates and Chloride in large quantity, which is dumped in SLF increasing solid waste liability at a cost. On the other hand, during iron precipitation in zinc hydro smelting, a chemical named as Sodium sulphate is added in the process to convert iron into jarosite, a stable iron waste. An innovative idea was captured to recover sodium sulphate values from this MEE reject and convert it into a usable chemical for zinc plant. The ideas was translated and tested at laboratory scale and was found feasible with more than 80% Sodium recovery as sulphate with controlled chlorides and COD. Also, some sodium chloride rich salt will be generated form MEE after Sodium sulphate precipitation. Thus, the above resulted in achieving zero liquid & zero solid waste from effluent water.

Other ongoing major R&D projects are (i) Generation of cobalt carbonate from purification cake; (ii) Graphene from graphite concentrate; (iii) Electrolytic Manganese Dioxide from Zinc Electro-winning Anode mud; and (iv) Aggregates from waste rock.

C. R&D (Waste Utilisation)

1. Utilisation of HZL wastes in construction sector: The objective was utilisation of HZL wastes like jarosite, slag and flyash in paver blocks. Central R&D Laboratory (CRDL) of Hindustan Zinc has worked with the waste generated from Pyro-smelting, Hydro-smelting and Captive Power Plant and established a suitable raw mix design to cast paver blocks using these waste materials. Cement paving blocks are precast solid products made out of cement concrete. The conventional raw materials required for the manufacturing of paver blocks are Ordinary Portland Cement, Aggregates and Stone Dust. Replacement of conventional raw materials has been validated for different grades of paver blocks from M-25 to M-40 grade. Typically 70-80% waste utilization was observed for the M-25 to M-30

grade paver blocks, which are preferably used for Pathways/Pedestrian paths. Paver blocks of M-25 grade paver blocks have been produced and test patches laid at various HZL locations to confirm the durability & performance. The benefits of above are sustainable usages of waste in pavement blocks and low cost of manufacturing as conventional raw material consumption is reduced.

Indian Rare Earths Ltd (IREL)

R&D (Ore preparation & process)

1. Development of process flow sheet using OSCOM raw sand to separate Very Heavy Minerals, Light Heavy Minerals & Light Minerals with HM content in tails <1% at IREL, OSCOM, Chatrapur, Odisha: The developed flow sheet could achieve the objectives, improve the recovery of valuable minerals, reduce loss of minerals in tailings, better efficiency in separation of garnet.

2. Test works on Separation of minerals using REDMS, RERMS & Floatex within various process samples at IREL, Chavara, Kerala: R&D studies (Ilmenite circuit Primary HTS Cond & Mids REDMS test works, Ilmenite circuit recirculating feed test on REDMS, Wet circuit feed) for improvement of grade and recovery conducted at IREL Chavara. Based on studies REDMS procured & installed in plant.

3. Feed to Garnet section test on Coronastat HTS, Feed to Ilmenite circuit test on Coronastat HTS and HUS output test on Coronastat HTS, REDMS, IRMS at IREL, OSCOM, Chatrapur, Odisha: R&D studies carried out for improvement of grade & recovery at IREL, OSCOM.

NALCO

R&D Projects

1. Extraction of Alumina from Partially Lateritized Khondalite (PLK) at laboratory scale" has been completed and the basic flow sheet for the process has been developed by CSIRO, Australia.

2. NALCO & IIT, Bhubaneswar have jointly developed a process for "Synthesis, Characterisation and Development of Red mud-Fly ash based Geopolymer concrete" which has a potential for application in civil activities.

Hindustan Copper Ltd (HCL)

R&D Projects

1. Recovery of Copper through leaching from ESP dust of flash smelter has been successfully carried out.

2. Experiments on bismuth removal from electrolyte were carried out at GCP using barium carbonate at different dosage and temperature. Optimum dosage of Barium Carbonate has been established at lab scale. Further the same experiment has been scaled up and done in refinery using commercial grade in existing operational conditions, it is observed that removal of Bi upto 58.5% was observed at 6 kg/m^3 dose.