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Metal Extraction vis-à-vis Mineral Resources : Indian Perspective.

THE MINING, GEOLOGICAL AND METALLURGICAL INISTITUTE OF INDIA

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Metal Extraction Vis-à-Vis Mineral Resources : Indian Perspective

THOUSANDS OF INNOCENT SOULS HAVE FALLEN VICTIM OF COVID19 DURING THE CURRENT WAVE OF COVID19.
CITIES, TOWNS AND VILLAGES IN INDIA ARE COUNTING DEATHS IN EVERY HOUR.

MOST OF US HAVE LOST SOMEONE OR OTHERS WHOM WE KNEW, WHO MATTERED US MOST AND WHO WERE OUR RELATIVES, COLLEAGUE OR FRIENDS.

UNCERTAINTIES HAD NEVER SUCH PATHETIC REALITY.

HOWEVER, THE SHOW MUST GO ON, "DEEP IN OUR HEART WE DO BELIEVE WE SHALL OVERCOME!"

WE PRAY FOR THE DEPARTED SOULS TO REST IN PEACE.

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Vol. 46, No. 4, January - March 2021

President's Message **1**

From the Desk of Editor-in-Chief **3**

Guest Editor's Column **7**

Obituary **9**

News About Members **10**

Interview

Perspectives on Indian Science and Institution Building : – A Conversation with *Prof. Samir K. Brahmachari* **12**

Perspective Piece

Changing Face of Indian Steel Industry, as Seen Through Last 40 Years in Industry – *Satyakam Basu* **20**

Technical Notes

i Mineral Deposits & Extraction of Aluminum & Tungsten : Indian Perspective – *Bappaditya Roy and Saugata Rakshit* **26**

ii Coking Coal Dynamics in India – *Souvik Mukherjee* **38**

iii Upgradation of Low Grade Manganese Ore Using Different Beneficiation Techniques – *Sudhanshu Kumar Singh, Puja Gorai, Maharshi Ghosh Dastidar, Arghya Majumder and Rajib Dey* **44**

Down The Memory Lane

– *D. N. Bhargava* **52**

A letter to MGMI members from an honorable Senior member – *D. N. Bhargava* **55**

Upcoming Events **56**

Editorial Board

THEME

The next issue Vol. 47, No. 1
"Sustainable Pathways for India's Coal Sector"

President's Message

METAL EXTRACTION VIS-A-VIS MINERAL RESOURCES : INDIAN PERSPECTIVE

Natural resources play a crucial role in India's development helping accelerate expansion of services and manufacturing thereby contributing towards the objective of poverty reduction. Coal has been the critical backbone of India's energy infrastructure and will continue to be the major source of energy in the near future as well even as more renewable energy technologies are deployed. In addition to being the world's second largest producer and consumer of coal; India is also the world's largest producer of sheet mica, fourth largest producer of iron ore and fifth largest producer of bauxite in the world. The iron ore resources of high-grade are abundant in regions of Chhattisgarh, Karnataka, Jharkhand and Orissa. India has 3rd largest reserves of chromite ore after Kazakhstan and South Africa and about 2% reserves of copper ores.

Given the rich diversity of minerals available in India, it is imperative that we must first "Mine in India" for "Make in India" to succeed. A report from the McKinsey Global Institute suggests that development of the mining sector will be important if India has to achieve 7%- plus GDP growth. The report further highlights that the sector alone has the potential to create 6 million additional jobs by 2025. India must, therefore, take a leaf out of Australia's book which set an economic record, of not experiencing a recession for almost 30 years, the longest stretch of uninterrupted growth for a developed nation ever seen, powered by its natural resources export. While development in the mining sector is the need of the hour; it is critical to monitor unregulated mining activities releasing harmful substances into the soil, air, and water. Government should enforce regulations on companies and encourage the use of cutting-edge technologies to reduce the damage from mining-related sources including collapse of tailings dams due to poor construction, pipe leakages, waste-rock stockpiles exposed to rainwater feeding groundwater, surface water and soil contamination.

It is also interesting to note that the wastes generated from metal processing plants have high mineral values, which can be reused to reduce the burden of acquiring good quality raw materials to some extent. In the Indian scenario, approximately 1.2 tons of solid waste are generated in producing one ton of steel. With proper methods put in place to re-capture and reutilize the iron and carbon content in the waste, the cost of raw materials can be lowered considerably enabling a circular economy. Similarly, in case of copper sulfide ores, the tailings can be processed to extract other metals such as lead (from galena) and zinc (from sphalerite), should they exist.

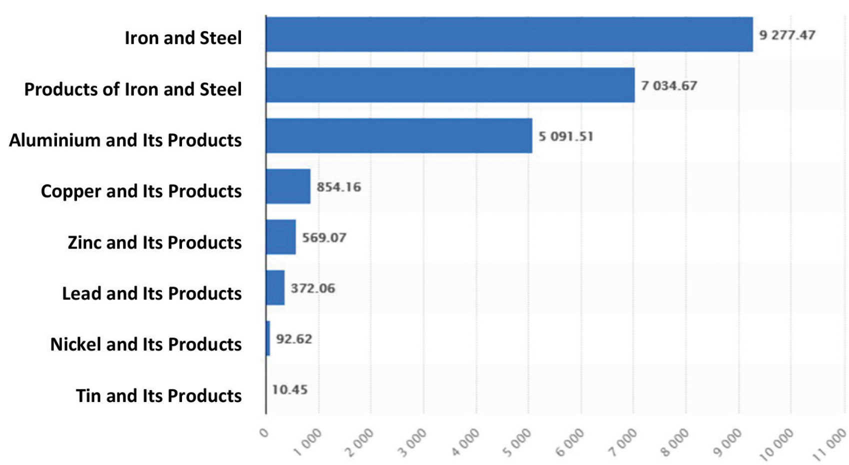
Another pertinent use of technology for waste management can be implemented in the case of e- waste. Management of e-waste, which is growing on par with municipal waste, is a challenge. E-waste contains many toxic elements like lead, mercury, cadmium, tin, bromide dioxins that leach into the earth. When dumped in a landfill or thrown into a water body, they cause inconceivable damage to soil and water resources and causing severe ailments like cancer, kidney problems, liver Damage etc. E-waste also contains precious metals like Gold, Silver, Platinum, Palladium, Selenium etc. Hydro metallurgical process, pyro metallurgical process and bioleaching can be used to successfully recover precious metals from e- wastes.

Despite the opportunities present in mining and metal extraction and several possible avenues of technological advancements, the post- liberalization phase in India has seen the dominance of the service sector led growth with the contribution of the manufacturing sector remaining mostly stagnant. Unfortunately, India has not been able to utilize its rich natural resource endowment (of iron, coal, mineral oil, manganese, bauxite, chromite, copper, tungsten, gypsum, limestone, and mica) to full potential to maximize growth and strengthen the economy. According to a study by Ernst & Young, India has explored only 7-9% of mineral resources in comparison to 100% geophysical and geochemical surveys in countries like Australia.

It therefore, is the responsibility of our mining, geological and metallurgical communityto come forward, seize this opportunity, drive innovations and the required policy changes. I am certain that with this purpose driven mission, our eclectic mix of ideas and our technological know-how; we will begin to see a paradigm shift in how minerals are utilized, conserved and re-used in our country leading to maximized and sustainable economic growth.

P. M. Prasad
President, MGMI

Value of base metals exported from India in financial year 2020 (April 2019-March 2020), by type *(Export values in in million U.S. dollars)*



(source: https://www.statista.com/statistics/652814/export-value-of-base-metals-by-type-india/)

From the desk of Editor-in-Chief

Metals and metalliferous Mining: Challenges and opportunities ahead in the global post COVID19 scenario

Minerals, which cannot be classified as coal or lignite, are termed as metalliferous minerals in India. The Mines and Minerals (Development and Regulation) Amendment Act, 2015 has created a new dynamism in exploration and development of mineral deposits for production of metalliferous minerals in the country. To facilitate metalliferous mining and large capital investment lease period is also extended to 50 years. For granting lease, system has been modernized to facilitate auction by a method of competitive bidding, including e-auction. Subsequent to this Amendment, a National Mineral Exploration Trust (NMET) has been formed in 2015 to support regional and detailed mineral exploration in the country and other activities to achieve its objectives. These objectives include special studies and projects to identify, explore, extract, beneficiate and refine deep seated and concealed mineral deposits. It also covers studies on mineral development, sustainable mining, mineral extraction and metallurgy adopting advanced scientific and technological practices, detailed and regional exploration for strategic and critical minerals, upgradation of mineral exploration status in an area, exploration leading to grant of mineral concessions, aerial and ground geophysical surveys, geochemical surveys, capacity building of personnel engaged in mineral exploration, etc. Metalliferous Mining sector includes both the surface and underground mining of iron ore, copper, tin, nickel, gold, silver and zinc. Metalliferous Mining also includes the mining of gemstone, uranium and mineral sands having rare earth minerals. In India underground metalliferous mining is limited to Uranium, Gold, Copper, Manganese and zinc.

India's Stature in the world

Mining in India is a vibrant sector. We have achieved the status of the third largest coal producer in the world with its 729.10 million tonnes (MT) production in FY20. In terms of iron ore production worldwide, in FY20 India produced 206.45 MT. India has about 8% of the world's iron ore deposits. It is a matter of our pride that India was world's second largest crude steel producer in 2019 with production at 111.2 MT. In the field of production of aluminium, India contributed 3.65 MT in FY20. Aluminium export from the country reached US$18.24 million in FY20 (till January 2020).

With the current boost by Government, budget allocation for augmenting the country's infrastructure to the tune of Rs 5.54 lakh crore as capital investment. Government is emphasizing creating institutional structures and giving a big thrust to monetising assets to achieve the goals of the National Infrastructure Pipeline (NIP). More activities and business are envisaged in metalliferous mining sector in the near future.

It may be noted here that there is positive move in the budgetary allocations for railways, metro services, India has plans for development of more airports, the Jal Jeevan Mission as well as the plan for urban and the rural infrastructure development would boost the demand for metalliferous minerals. It is expected that there will be generation of many direct and indirect job opportunities due to creation of new demands for steel, Cold Rolled Steel Manufacturers Association of India (CORSMA), which represents the secondary or non-integrated steel players in the country, also welcomed the recent budget as it announced reliefs to the steel sector. The exemption of the 2.5 per cent duty on iron and steel melting scrap, including stainless steel scrap, and raw materials used in the manufacture of CRGO (Cold Rolled Grain Oriented) steel will also boost the industry to have new dynamism in the steel sector.

Now, Indian metalliferous mining sector, mineral processing and metal trading need proper utilization of its strategic location for steel and alumina trades in the fast- developing Asian markets. As we all know, India produces 95 minerals ***4 fuel-related minerals, 10 metallic minerals, 23 non-metallic minerals, 3 atomic minerals and 55 minor minerals*** (including building and other minerals). How these are being utilized and monetized needs more institutional attention.

It is expected that world's hunger for metals and minerals in an attempt for economic recovery in the post COVID19 environment may accelerate the infrastructure development. Boost in automotive production can break the lethargy in growth in developing nations. Power and cement industries will have to grow side by side.

Towards an Atmanirbhar Bharat

India's aspirations for a newly defined rural quality of life and rurbanization or ruralisation of the city outskirts and outskirts of towns can accelerate the national plan for becoming 5 trillion economy. For the projected iron and steel demands, a boost in metal and mining sector in India with a holistic national approach is now a necessity for a healthy growth in the apparently mismatched developments in the mining industry of India.

The pandemic year has affected Indian overall export, during April-March 2020-21 it dipped by 7.4 per cent to $290.18 billion compared to $313.36 billion in 2019-20. However, a major jump in total export in March 2021 shows that return of post Covid-19 normalcy in the world would bring good prospect in Indian business including metal and mining Sector.

Indian Railways manage the world's 4th largest railway network with 92,000 km of tracks . Present government wants to overhaul the country's ageing tracks, but shortages of steel produced by state-run Steel Authority of India Ltd (SAIL) had slowed progress. Now, SAIL plans to start commercial production of ***head hardened*** (HH) rails on this fiscal at the new Universal Rail Mill (URM), a 1.2 million tonne every year capacity mill developed with an investment of about Rs 1,200 crore at its Bhilai Steel Plant (BSP) in Chhattisgarh. HH rails are particular rails utilized in high-speed freight corridors and metro rail tasks. Such rails are manufactured utilizing the pinnacle hardening expertise to bear about 50 per cent increased stress in comparison with regular rails.

In July 2020, SAIL-BSP dispatched the primary batch of R 260 grade vanadium alloyed grade prime rails for Indian Railways. BSP claims that it produces the cleanest rail steel in the world, with ***hydrogen content below 1.6 ppm*** at Tundish level. Equipped with secondary refining units, the steel melting shops at BSP have the capability to produce a wide variety of steel.

The Research Designs & Standards Organisation (RDSO), under the Ministry of Railways, has approved the newly developed 60E1 1175 heat-treated (HT) rails of Jindal Steel and Power (JSPL). JSPL is the first and only Indian manufacturer to develop 60E1 1175 HT rails suitable for high-speed and high axle load applications. JSPL manufactured 60E1 1080 HH rails are also approved for Metro Rail Corporations, High-Speed Corridors and Bullet Trains.

Iron ore mining sector has seen some good development during the last financial year. NMDC's Donimalai iron ore mine, which has total concession area of 597.54 hectare and estimated resource of 149 million tonnes shall now increase the annual Iron ore production in the country by 7 MTPA. The operationalization of the mine would contribute a total of ~Rs. 1,100 crore (US$ 150.59 million) to the State exchequer per annum.

A Hope in the Rare Mineral Market

Good days are looming there for the rare earth minerals also. There is an increasing demand for solar panels; subsequently this could be a huge traction for metals such as cadmium, gallium, germanium, indium, selenium, and tellurium, as they are important mineral materials used in photovoltaic cell technology.

Silver, which is typically laid down on the solar cell in what are called fingers, helping to deliver harvested energy. Amid growing installations of solar power, silver has benefited massively. In the early 2000s, silver demand from the solar sector barely registered, making up less than a percent of silver demand. In 2019, the photovoltaic sector accounted for 10% of total silver demand, comprising 98.7 million ounces within total demand of 991.8 million ounces, according to Metals Focus data. Silver demand is going to fluctuate between 70 to 80 Moz per year between 2024 and 2030. In solar panel preparation technology improvement silver demands is at downward trend. For the solar and wind power industry important metal demands globally is forcasted by Dutch researchs as given in Figure1.

So far as India is concerned Rare earth elements contribute a total value of nearly

$200 billion to the Indian economy. Currently, China controls nearly 90% of global rare earth production. Whereas, India has the world's fifth-largest reserves of rare earth elements, nearly twice as much as Australia, but it imports most of its rare earth needs in finished state from China.

In the new post-pandemic economic landscape, Rare earth elements (REEs) are crucial. They have uses in many fronts, from advanced ballistics systems to industrial machinery and TV screens, contributing a total value of nearly $200 billion to the Indian economy. They are also crucial to emerging technologies such as renewable energy and electric vehicles.

With adjustments to the existing policy, India could emerge as a rare earths supplier to the world and use these resources to power a high-end manufacturing economy geared to the needs of the 21 st century.

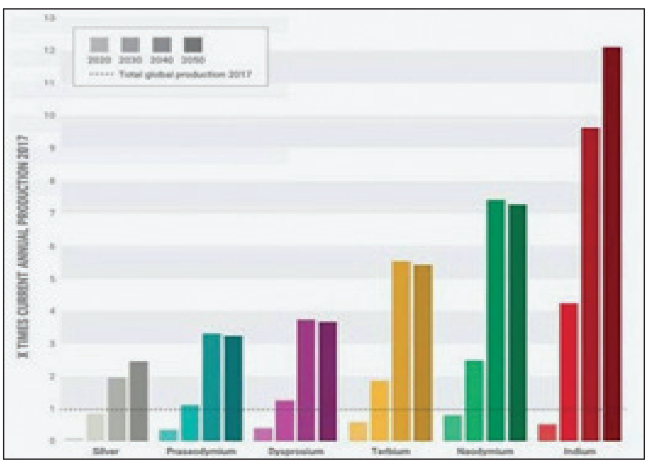


Figure 1: By 2040 the current demands of Silver will be doubled, for Praseodymium about 3.5times fr Dyasprosium about 4 times, Neodymium about 7 times and Indium about 10 times. These rare-earth elements needs more studies in India.

IREL's key to Rare Mineral Dominance

Indian Rare Earth Limited (IREL) produces rare earth oxides (low-cost, low- reward "upstream processes"), selling these to foreign firms that extract the metals and manufacture end products (high-cost, high- reward "downstream processes") elsewhere. IREL's focus is to provide thorium — extracted from monazite — to the Department of Atomic Energy. As such, REE production in India is conducted almost entirely by a government organisation, with little incentive to provide to global markets, IREL accounts for only a minuscule fraction of the world's production: only 2265 tonnes of REOs in 2016-17, providing almost no value to domestic manufacturers and consumers, who continued to import finished REE derivatives from China.

The key challenge for India today is to scale up upstream and downstream processes in the rare earths value chain. India must open its rare earth sector up to competition and innovation, and attract the large amounts of capital needed to set up facilities to compete with, and supply to, the world.

Anirudh Kanisetti, an Associate Fellow at the Takshashila Institution said "The best move forward might be to create a new Department for Rare Earths (DRE) under the Ministry of Petroleum & Natural Gas, drawing on its exploration, exploitation, refining, and regulation capabilities" . This DRE, he opined, should oversee policy formulation and focus on attracting investment and promoting R&D, with its first move being to allow private sector companies to process beach sand minerals within appropriate environmental safeguards. It should also create an autonomous regulator, the Rare Earths Regulatory Authority of India (RRAI), to resolve disputes between companies in this space and check compliance.

A Glimpse into Indian Mining Developments

Some of the important recent development in metal and mining sector in India include:

- In November 2020, Odisha-based Shiva Cement Ltd., a subsidiary of JSW Cement Ltd., announced plans to invest ~Rs. 1,500 crore (US$ 202.98 million) in a new 1.36 million tonne per annum (MTPA) clinker unit project in the state's Sundergarh district.

- State Bank of India (SBI) is planning to introduce a policy to lend loans to the coal miners
- On October 1, 2020, Directorate General of Foreign Trade (DGFT) announced that steel manufacturers in the country can avail duty drawback benefits on steel supplied through their service centres, distributors, dealers and stock yards.
- For FY20, JSW Steel set a target of supplying around 1.5 lakh tonne of TMT Rebars to metro rail projects across the country.
- In April 2020, the Government of Odisha granted the mining lease of Utkal-D coal block in Angul district to the National Aluminium Company (NALCO). The initial capacity of Utkal- D coal block is 2 million tonnes per year with a total mineable reserve of 101.68 million tonnes.
- In March 2020, IMR Metallurgical Resources AG, a Switzerland based company has proposed to set up a major steel plant in YSR Kadapa district, Andhra Pradesh with an annual production capacity of 10 million tonnes by investing more than Rs. 12,000 crore (US$ 1,630.89 million).
- In October 2019, Kamdhenu Ltd added new production capacity of 60,000 tonne per annum in Dadri, Uttar Pradesh to manufacture Kamdhenu Structural Steel.
- India's iron and steel export in FY20 stood at US$ 9.28 billion.
- From April 2000 to September 2020, FDI inflow in the metallurgical industry stood at US$ 14,244.26 million, followed by mining (US$ 2,789.44 million), diamond and gold ornaments (US$ 1,183.07 million) and coal production (US$ 27.73 million) industries.

As an achievement of the Government in the past year it may be noted that the index of mineral production improved to 132.7 in March 2020.Mining group under Index of Industrial Production (IIP) stood at 109.7 for FY20, witnessing a growth of 1.7% y-o-y. In June 2020, iron and steel recorded more than 100% growth in exports shipments of US$ 1.32 billion against US$ 653.52 million in June 2019.
There is a significant scope for new mining capacities in iron ore, bauxite and coal and considerable opportunities for future discoveries of sub-surface deposits. Infrastructure projects continue to provide lucrative business opportunities for steel, zinc, and aluminium producers. Iron and steel make up a core component for the real estate sector. Demand for these metals is set to continue given strong growth expectations for the residential and commercial building industry. With the commercial coal mining, if new mines are opened, demands of metal and minerals will increase many fold. A total revenue of Rs. 6,656 crore (US$ 900.59 million) annually from mines spread over the following five states—Madhya Pradesh, Chhattisgarh, Odisha, Jharkhand and Maharashtra are envisaged. This means boosts to the mining and metallurgical sector. In September 2020, Coal India Ltd. (CIL) announced plans to invest over Rs. 1.22 lakh crore (US$ 16.5 billion) on projects related to coal evacuation, exploration and clean coal technologies by 2023-24 to achieve 1 billion tonnes of the fuel output target. This will boost both steel, aluminium and cement industries.

Thus, it is can be safely interpreted that Indian metal mining and metallurgical sector has tremendous scope and the country needs boosting R&D and skill development for these sectors.

Dr. Khanindra Pathak
Prof. IIT, Kharagpur
Editor, MGMI

Guest Editor's Column

It is a privilege to edit the present issue of MGMI News Journal on Metal Extractionvis- à-vis Mineral Resources: Indian Perspective. This special issue throws light on the current knowledge base and research and development (R&D) in Indian metallurgical and mineral industries. An ore is a rock, which contains minerals with important elements such as metals. Regions rich with a particular ore are selected for mining from where the ores are collected. Every metal has a particular ore from which that metal can be extracted. Metals are extracted from their ores depending upon the feasibility and cost of the process. Few metals and their respective ores are given below:

Aluminium:
- Bauxite
- AlO_x $(OH)_{3-2x}$ [where $0 < x < 1$]
- Kaolinite (a form of clay)[Al_2 $(OH)_4Si_2O_5$]

Iron:
- Haematite(Fe_2O_3)
- Magnetite(Fe_3O_4)
- Siderite ($FeCO_3$)
- Iron pyrites (FeS_2)

Copper:
- Copper pyrites($CuFeS_2$)
- Malachite($CuCO_3.Cu(OH)_2$)
- Cuprite(Cu_2O)
- Copper glance(Cu_2S)

Zinc:
- Zinc blend/Sphalerite(ZnS)
- Calamine ($ZnCO_3$)
- Zincite(ZnO)

Depending upon the physical and chemical properties of the ores, the process of metal extraction is decided. The extraction of metals and its isolation occurs following few different steps:

- Concentration ofOre
- Isolation of metal from concentrated Ore
- Purification of themetal

India is self-sufficient in Bauxite, Iron Ore and Sillimanite. Magnesite, Rock Phosphate, Manganese and Copper concentrate are the ones, which are imported.The world's crude iron orereserve is around 170 billion tonnes as of 2019, comprising 81 billion tonnes of iron content. India's iron ore reserve is about 5.5 billion tonnes. India's leading state that produces ironore is Odisha. It accounts for more than 55% of the total production followed by Chhattisgarh producing almost 17%. This is followed by Karnataka and Jharkhand producing 14% and 11% respectively. In India, the value of metallic minerals in 2018-19 was at INR 64,044 crores. Among these the principal metallic minerals, iron ore contributed more than 45,000 crore rupees. This was equivalent to 70% of the contribution. The total reserves of bauxite have been placed at 3,896 million tonnes. These resources include 656 million tonnes Reserves and 3,240 million tonnes Remaining Resources. About 77% resources are of Metallurgical grade. There sources of Refractory and Chemical grades are limited and account for about 4%. Odisha alone accounts for 51% of country's resources of bauxite followed by Andhra Pradesh (16%), Gujarat(9%), Jharkhand(6%), Maharashtra(5%) and Madhya Pradesh & Chhattisgarh (4% each). Major bauxite resources are concentrated in the East Coast bauxite depositsin Odisha and Andhra Pradesh. The production of bauxite has increased rather out of proportion from a mere 68 thousand tonnes in 1950-51 to a staggering quantity of 9,777 thousand tonnes in 2002-03 recording an increase of over 140 times in a span of abouthalf a century. The total reserves/resources of copper or eason 1.04.2015 as per NMI database based on UNFC system are estimated at 1.51 billion tonnes. 77 million tonnes (13.74%) fall under 'Reserves category' and the balance 1.30 billion tonnes (86.25%) are 'Remaining resources' category. The total reserves/resources of manganese ore in the country as on 1.04.2015 have been placed at 495.87 million tonnes as per NMI database, based on UNFC system. 93.47 million tonnes are categorized as reserves and the other 402.40 million tonnes are in the remaining resources category. The total reserves/resources of chromitein the country havebeen estimated at 344 million tonnes with 102 million tonnes as "Reserves" (30%) and 241 million tonnes as "Remaining Resources" (70%). More than 96% resources of chromite are located in Odisha, mostly in Jajpur, Kendujhar and Dhenkanal districts. Minor deposits are scattered over Manipur, Nagaland, Karnataka, Jharkhand, Maharashtra, TamilNadu, Telangana and Andhra Pradesh.

Due to increasing demand in domestic market and depletion of high-grade ores day by day, industries as well as policy makers have started working on low-grade iron ores for different metal industries. There existshuges cope for low-grade ores. Most of the lean grade ores have not been tapped into. It is very important that we look for processes to extract metals from lean grade ores. We should look for different upgradation and beneficiation processes so that we are not bereft of high quality ores for the production of metals in the later ages. It is important that extraction of minerals from nature creates an imbalance, which drastically impacts the environment. The main impact is in wildlife and fishery habitats, the water balance, local climate changes and depletion of forests and the disruption of ecology. Today, globally every project is being designed keeping in mind the environmental factors. Many laws have been implemented in India also to reduce the impact that metal extraction has on the environment.

So, mineral exploration is quite widely followed in India due to the abundance of many ores rich with certain minerals from which a particular metal can be processed. This processing of metals requires a lot of good quality raw material from which the extraction is easier and cost effective. The good quality ores are now reducing at a higher rate due to the increased demand of high quality products. The attention should be turned towards the lean grade ores from which the metals can also be extracted. All this should be done keeping in mind the effect on the environment.

I am extremely grateful to the authors for contributing inspiring articles to this special issue. I shall fail in my duty if I do not express gratitude to the MGMI Council, Editor-in-Chief, Prof. Khanindra Pathak and the Editorial Board for giving me the opportunity to edit this special issue.

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Obituary

Late Prabir Narayan Chaudhuri (MMGI, LM – 7161, 1996-937) passed away on 6th March 2021. With heartfelt grief MGMI members wishes his soul to Rest in Peace in his heavenly abode. May God give strength to his surviving family members and friends to bear the loss.

Late Chaudhuri was a member of MGMI since 1996-97. A former Director (SG), Geological Survey of India, he obtained M.Sc. degree in Applied Geology from Jadavpur University in 1967. He joined GSI, WRO, Jaipur as Assistant Geologist in October 1969. During his stay there till 1975, he was associated with the base-metal investigations in the north-eastern part of Rajasthan. Some very potential copper prospects were located by him in Jaipur and Alwar districts, where detailed exploration were taken up later.

Late Chaudhuri was promoted to Geologist (Jr) in 1975 and transferred to Coal Wing in January 1976. His contribution in regional exploration in Ib-river and Talcher coalfields in Orissa, and also in Godavari Valley brought to light many workable coal deposits of the nation hitherto unknown. In recognition of his contribution in Talcher coalfield, he was awarded 'National Mineral Award' in 1996. He was promoted to Geologist (Sr) in 1985 and to Director in February 2000, when he was transferred to Operation (Orissa), Bhubaneswar. There he served a short stint as Director, Geodata & Geoinformatics. He was transferred back to Coal Wing in August, 2000 and took charge of 'Lgnite Operation'. During his tenure a number of potential as well as workable lignite sectors of Rajasthan, Gujarat and Tamilnadu were included in the lignite map of India. He was actively involved in preparation of the unique document 'Lignite Atlas of India' till his superannuation in February 2004.

An able scientist and administrator, Late Chaudhuri was universal 'PN' to one and all. His door was always open to anyone who wanted any help or advice. A genial personality, he seldom lost his cool and his smile.

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As on 31.03.2021

Prof. Lala Behari Sukla (LM- 10827) has been awarded Asian Education Awards 2021 by Asian Education Society in recognition of his continuing Excellence in Education on 10th April 2021. Prof. Sukla is at present Director in Biofuels and Bioprocessing Research Centre (BBRC), Siksha 'O' Anusandhan (Deemed to be University) , Bhubaneswar.

Interview

Perspectives On Indian Science And Institution Building
– A Conversation with Prof. Samir K. Brahmachari*

One of MGMI's key missions is to understand how fundamental science can be converted to cutting-edge application of technologies of societal relevance. While our membership comprises of the current who's who of the Indian mining industry, we also want to motivate future leaders in science and technology for earth sciences. With this intent, our Associate Editor, Dr. Ajay Kumar Singh interviewed one of India's leading biologists, Prof. Samir K. Brahmachari. Prof. Brahmachari received his PhD from the Indian Institute of Science and started his independent research career there. In 1997, he became the founding director of the CSIR-Institute of Genomics and Integrative Biology at New Delhi, where he demonstrated how basic science knowledge could be leveraged for high-impact industrial applications. During 2007-2013, he served as the Director General of the Council of Scientific and Industrial Research and during his tenure, the Academy of Scientific and Innovative Research was also established. For his contributions to R&D, he has been presented several awards, including SS Bhatnagar Prize, JC Bose National Fellowship, Banga Bibhushan Award (Highest Civilian Award of West Bengal), IISc's Distinguished Alumnus Award and honorary doctorates from five universities. But his major contribution is considered as the mentor of the Open-Source Drug Discovery Project, a first-of-a-kind initiative that transformed the genomics landscape of India. His full academic profile can be accessed at http://samirbrahmachari.rnabiology.org. Prof. Brahmachari also delivered MGMI's flagship oration, the Holland Memorial Lecture in 2013.

Please provide us a glimpse of your journey of practicing science in India. How did you enter the field of genomics and who were some of your key mentors?

I did my masters in physical chemistry from the University of Calcutta and came to the Indian Institute of Science (IISc) in 1974 to do my PhD in Molecular Biophysics. Here, I got to work with the tall scientists, Prof. G.N. Ramachandran, a great biophysicist, and Prof. V. Sasisekharan. I realized seeing them, that globally competitive science can be done sitting in India based on Prof. Ramachandran's work in Chennai and subsequently in Bangalore. So, I will say they were the first two mentors. Subsequently, I met Prof. C.N.R. Rao and I saw how fantastic science can be in India. Then of course at IISc, I completed my PhD in collagen structure.

After my doctoral work, I went to the University of Paris for a year to work in the area of chromatin. So, when I came back in 1980, I was interested to start my own laboratory and I was very lucky that within a short period I could publish many papers, so I was given a faculty position at IISc. When I started my independent science, I was very interested in repetitive DNA in the genome. The DNA structure, was what my passion was, and there I could see that 99% of the genome is repetitive and it didn't have any known biological function at that point. Orgel and Crick published a paper in Nature saying that this is 'junk' DNA and I knew in 1980 that the world will not work on it. However, I had an instinct that this will be important. Thus, I thought, if I work on it, and

* Samir Kumar Brahmachari, Former DG, CSIR and Former Secretary, Department of Scientific and Industrial Research, Government of India.

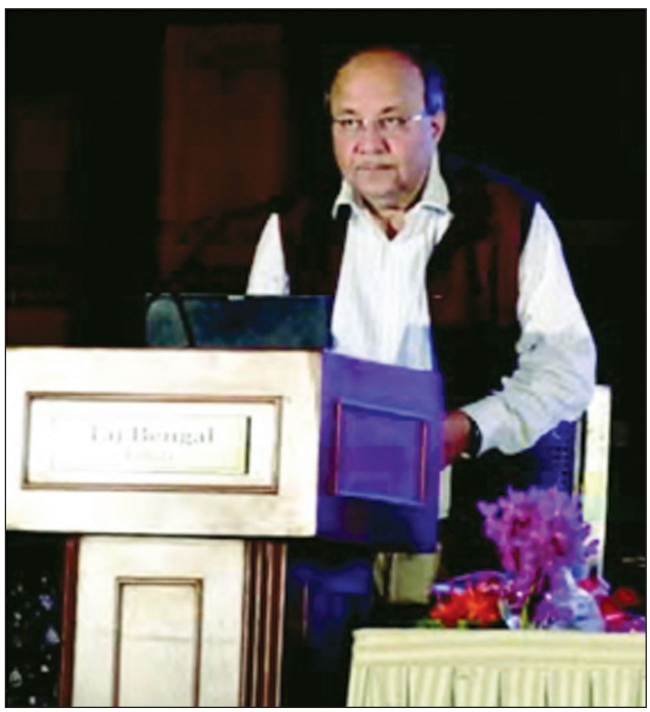
if it turns out to be right, it has a function, then, I have an advantage, because the western world will not have funding to do research. And since I got INSA Young Scientist Medal, I had some resources as a faculty member at a young age of 28. So, I started working on repetitive DNA structure function. And you know, 20 years down the road, as the human genome's biggest surprise was that these repetitive DNAs suddenly started showing some functional relevance. And now 20 years since the genome sequences were done; today, everything we talked about is on these repetitive sequences. So, I was very lucky that I got a break on a research problem that I have worked on from day zero as a faculty and that slowly brought me to the area of genomics.

My breakthrough in genomics came in the summer of 1985 when I went for a short visit to Columbia University, in the laboratory of Prof. Charles Cantor. And that's the time United States decided to do genome sequencing. So, I had a very early exposure. Then I interacted with scientists in the Soviet Union in 1988. I was impressed by these scientists who were imagining that there will be technology in the future, which would allow genome sequencing. As such, I was really lucky that I had such mentors and such visionaries to interact with and by 1990, I was elected to the Human Genome Organization (HUGO), which is the first of its kind, because of my work on repetitive DNA. So you can see, it starts with a curiosity and interest and asking a question and then, it eventually became a sunrise field during my scientific career.

You have long been a champion of open innovation. Kindly let our readers know what this means and how it accelerates innovative technologies and products, possibly in the energy and mineral sectors, and even other sectors.

I will tell you how it all began. By 1990, the way the genome project was considered, the rich oil merchants wanted to put $3 billion and get the genome sequence. But there was a fear, that it will become a proprietary knowledge of one person. You know in the backdrop of the fear of the atom bomb and the cold war, the human genome project was considered to be an open source. Therefore, a global community was created, to work together and share the data. By late 90s, unfortunately, India, did not realize its potential, but I was deep into it. Then, Craig Venter tried to privatize the genome sequence for his company. But there was a competition with open source versus private and eventually the HUGO published it, and it was open shared information.

By this time, I had moved to Delhi at the CSIR-Center for Biochemical Technology to build the genome Institute in 1997. We realized that the genome sequence will become open source, but how do we get to understand the genome function. I realized that one of the most important things that we should do is to focus on function, rather than collecting the sequencing data which will eventually become open. Today, that is the CSIR-Institute of Genomics and Integrative Biology (IGIB), one of the most famous institutes in the CSIR family. So, the presumption was data will be open. And it became open by 2003 which



Prof. Samir K. Brahmachari delivered the 56th Holland Memorial Lecture (2013) of MGMI on 'Open Innovation, Big data and Crowd Sourcing: The Next Frontier' has allowed enormous growth. There is a big discussion on the need for open-source. If you go back to discovery of penicillin where it was not patented. It was given during the Second World War which saved lives of so many people. But by 90s, some pharmaceutical companies decided to do extensive patenting and it accordingly led to increase in price of drugs. Today, you see a spinal muscular atrophy injection is sold at GBP 1.8 million – GBP 1.8 million! It is all proprietary. I realized that in India, 1000 tuberculosis patients die every day. TB genome was available in 1998 and we did the analysis to identify the new targets. We knew how to go about identifying the targets in a system biology approach by which the goal was to get new drug targets. But the pharmaceutical industry was not interested. As the Director of CSIR-IGIB, I even patented those targets, but I realized no big pharma company is interested because their intension is not to solve the problems of the poor, like tuberculosis with a 300m$ market. So, drugs for the neglected disease hardly had any interest in big pharma. I thought how do we change this. And that brought me to the idea of starting Open-Source Drug Discovery. Today, you can see over time, the whole world is discussing about open-source sharing of knowledge. You can see the COVID-19 vaccine has come in one year's time, which would not have happened if the sequence was not published. If the diagnostics were not open source, the people would not have had the access to the knowledge, if the protein sequence and structures were not published, we could not have made the vaccine in one year time. This is an example how an open-source sharing helps when the scientists/countries of the world find it impossible to solve a problem alone. You need large number of people to come together and that's how I believe open-source has thrived over these two decades. Although, in 2007 it was too novel, too audacious, people did not think it will work, but over a decade and a half we are there.

So, my point is how did this technology of open innovation be used by all industries. Since you are interested in metallurgy and mining, I will try to tell you how it has been successfully used. You know the knowledge of a mining engineer is limited to a company who they work for and it is not shared with another company. So, what do you do in open source, like Linux lots of people developed software together and therefore, you have very cheap android phones. You could not have smartphones if it was proprietary like iPhone, which is still expensive. Thus, the industry has understood that open source is an important component when you cannot solve it alone. Look at the mining industry today. In the sector of mining, I think that the gold corporations felt that they had exhausted the mining resources. So, they brought crowdsourcing. Geologists, engineers, all of them shared all the data. Today, by contributions from a large number of minds, they could actually create higher productivity of gold, Therefore, if you want to bring many minds together, it is very difficult to have an intellectual property protection. So, the question is where do we apply this. I think we are making our production most optimum. For all the knowledge of our mines, can we improve the productivity? How do we get all the data? I give an example; you are using machinery which goes and drills and cuts. We can have sensors which will actually collect data, we can have robots with cameras to provide you actual information, knowledge, and when you have it for a large number of points, you actually can start building a predictive model. You can find out whether your structure is stable or not, whether your machine is able to break rocks or not, whether there is a possibility of any gas leak, etc. Accordingly, I often say a strong intellectual property creates availability because investment comes but it reduces affordability. Just as an example, I can give you one today why the COVID-19 vaccine is affordable because it is open-access data. Whereas, I can give an example of genome sequencing was available at a million dollar but we could not afford. Today, it is at thousand dollar and so it is affordable. Thus, by sharing technology and knowledge, you actually can create affordability. That is where the power of open source comes in. Crowdsourcing brings in a collective intelligence and you need data, large data access.

So, I was just looking at what MGMI is interested in. How do you estimate your coal resources? There is pilferage, there is also wastage of minerals. Can you use drones and robots to actually take the images and these transferred images can be used to do analytics to actually know how much coal is there in each location? You don't have to spend time and money. You could have a project in the public domain that you want to use robots and drones to measure coal output. Your project could be open source and young people will come in, they will come up with new ideas if you provide thousands of images and then you will see the solution arriving. This is a very powerful approach when it comes to other energy sources. If you ask me, I will say we are very poor about digitization. We need to do extensive digitization of process, productivity and of maintenance. Preventive maintenance through digitization is a very big opportunity in the new industry that we're talking about.

How would the interests of inventors and investors be protected in an open innovation environment?

This is an important point. You know very well that inventors get very little money! Currently, the investors are protected. I say IPR doesn't stand for intellectual property protection, it rather stands for investors property protection. The question is, if you want collective good, investors should be government. If we wanted to have affordable drug discovery, the investor should be the public. if you want to create, say, OLED TVs, let there be private investment to make it proprietary. But if you want to make it affordable and accessible to all, public funding allows us to protect the interest of all because it is collective funding. Today the vaccine has become affordable because a lot of taxpayer money has gone into developing it. It is no longer an exploitatively profitable business. You can sell something to 10,000 people and make thousand-dollars profit each or you can sell it to ten million people making $1 profit. The total profitability remains the same. That is how I say, there should be a balance between open innovation and intellectual property. And even if you hold an intellectual property, you can make it available. It was just like you own a house and you want to give it for charity, you want to make it a *anath ashram*. How is it different that you own intellectual property and you share it?

As one of the initial mentors for OSDD project and India's open-source guru, we want to know your perspective on vaccine and the therapeutic development of COVID-19.

The COVID-19 pandemic is an unprecedented challenge for India and across the world. I have done a detailed study of this and I figured out that actually India has responded very well. One of the reasons we responded very well is that the knowledge was shared and we started open-source networks and international solidarity trials. Today, you have hundreds of vaccines on clinical trial with various funding support. COVID-19 has taught us that when something affects all of us and we do not invest in healthcare, the other industries suffer and the entire economy collapses. Accordingly, let healthcare be open-source. If we have a healthy nation and a healthy world, other businesses will thrive. This is a great example that if you want to make profitability on health care, the whole economy might collapse. This is why you are getting today a $3 vaccine in private clinics and it is being given free in government hospitals in India. Doing so will have an indirect and cascading effect on the economy. Therefore, open innovation is a very powerful tool for public good.

So, if you want to create energy at a lower affordable cost, it will immediately cascade profitability in other sectors. For example, you asked me this question what is the scope of open source in energy. Can we improve the design of our wind tunnels via open source? I don't know whether you know that the Sydney Opera House was an open-source architecture. Through an open call, a crowdsourced architecture was done. Can we do a crowdsourcing that we will create a material that could reduce the weight of batteries for vehicles? This will have a cascading effect on the car industry because it will reduce fuel consumption. Similarly, can we come up with a paint for a solar panel which will efficiently absorb energy? So, many ideas that a company cannot solve alone, can be crowdsourced and made open-source. Once that knowledge is available, then its subsequent effect on the industry is extraordinarily large.

As a developing economy, the impact of COVID-19 has been really large for our underserved communities who have had huge job losses, in addition to casualties and illnesses. What will it take for the country as a whole to have an affordable recovery from COVID-19 as well as other related complications? Does open innovation have a role to play?

Yes, this is where I believe that open innovation has a huge role. What has happened is that the people who are affluent, they did not take care of their employees during this pandemic. If they would have taken care of their employees, there would not have been such a migration of workers. It is very sad that even our famous temples which get crores in endowment did not take care of their employees to pay them salaries. I believe it is the upper middle class or the rich class that have led the nation down. Our job was to provide that basic support, whether it is to the person who provides me service or a driver. It is our duty, and we have failed. Now, the workers have gone back home and they realize that there is a rural industry required. Thus, the industry has to move where people are whereas earlier people were moving where industries were. This is a new norm.

Therefore, we have to go back to our village-centric development. Why should we not use the biowaste of the villages and convert it to energy? There is such a large surplus of rice in this country, we can feed the whole world. But why not do alternative cropping? Can we not use large number of geologists and chemists to look at the soil data record and then come up with alternate cropping patterns? So you can see the mission has to now change. Work from home has clearly demonstrated that you do not have to live in a big city to be an IT professional; you don't need these high-tech parks of Bangalore and Hyderabad. People have gone back so that the rents are falling, the properties are vacant and it is a drastic change in the system. But India has responded well, if you look at healthcare. Dharavi had 8 lakh people but only 3800 people got severely affected by COVID-19, which is a very small number. 57 to 60% people already had antibodies, and they had mild infection. It is people like you and me who live in sterile environments (especially those born post-1970) who are actually most vulnerable in India. This is different from the west where the old people are the most vulnerable. Whereas in India, we as children have played in dirt we have walked into the muddy waters and we did not drink bottled water, so therefore our immunity is different. COVID-19 has shown that the rich and wealthy are vulnerable. Poor people are actually more educated than us. When they went back to the villages, they were quarantined. In that sense, India has done better than anywhere in the world. And we should be proud of it, because I think open source has allowed us to come up with several diagnostics, a low-cost vaccine. Many treatments are shared across the world and everyone has used, such as Remdesivir. So, you can see alternate drugs and medicines have come, alternate protocols got developed. Therefore, it is the power of sharing knowledge and sharing data, and that has saved India and saving the world.

MGMI members are particularly interested in the energy sector. Could you provide us the big picture of how developments in the biosciences could further efficient energy production in the country?

If I told you, you would say that I am talking about a fantasy novel! But wait for 20 years, and we will be able do coal gasification using microbial technology. These microbes will be designed synthetically and those synthetic microbes will actually break down coal into syngas, and that would be the future energy resource. The future energy is in developing technology that will harness energy much better from small streams of water. There are lot of opportunities for solar energy. I will say biological application of designing algae to harvest energy in the seacoast is a key opportunity. There is also scope of producing energy from agricultural crop waste, and converting it to biofuels. We already see that ethanol production is taking place, though our demand is much higher. Can we convert other wastes such as rice husks or sugarcane bagasse into ethanol fuels?

These efforts need not be done on a mega-plant. This should be done on what I call using the model of micro-breweries. In Bangalore, you have breweries and many people prefer that to bottled drinks. Similarly, we should have micro energy generators using the local produce/wastes and that will get converted into energy. If you look at metal refining, the aluminum industry is among the biggest electricity consumers. Just imagine you come up with a bacterial redox system which will reduce aluminum oxide from bauxite. Will it be possible to use artificial photosynthesis as a way of capturing energy? I will say this will be synthetically developed algae cultivated on seabed, that will be used to do extensive photosynthesis to create energy and those will be used and eventually converted into biofuels.

We have heard from leading scientists such as Prof. C.N.R. Rao that a future energy source could be artificial photosynthesis. Could you enlighten about this process, and what potential do you see for it to complement existing conventional energy resources?

At this point of time, creating an artificial photosynthesis by chemical process is not very efficient – and I am sure Prof. Rao must have thought about it. Look at a plant – how many leaves does it utilize to capture energy. If you look at a coconut tree, it has an 18-degree angle at each of the leaves to catch the maximum sunlight. And we have agricultural land with borders running, which should enable us to capture energy like having solar trees. The question is what exactly is the biology by which sunlight capturing takes place. Carbon dioxide is captured to create energy. So, we will need a hybrid system according to me. That is why talked about algae - there are organisms in the sea such as blue and green algae which collect energy at a much efficient pace. Why do we need to reinvent! I will say synthetic biology is half chemistry and half biology. So, we should use the part of the system and improve the enzymes efficiency of converting and capturing the photons. That would be the engineering of tomorrow. For this synthetic biology is there knocking on the door. But it may take two more decades.

Can you share an example where you have seen an excellent application of industry-academia interaction, and how that could be replicated in the energy sector?

In 1997 August, when I came to CSIR, it was a dream to see that India will have a genomics revolution. It would not have happened only with some funding of Rs. 8 Crore (approx. $ 2.0 million at that time) from the Department of Biotechnology or support of CSIR. It happened because we first tied up with Nicholas Piramal in 2000 – which was one of the largest knowledge alliances in India and a multimillion dollar one. Subsequently, we had a collaboration with the Chatterjee Group, which is one of the most prominent petrochemical groups as part of Haldia Petrochemicals. They were able to see the future of genomics. Thus, that partnership, where the institutional knowledge and industries came together allowed us to first time do large-scale genome sequencing and mapping in India. It is on that foundation that CSIR-IGIB stands today. Today CSIR-IGIB has so many industrial collaborations and interactions. I will say we need to have industries, which are forward-looking and who believe that 20 years down the road, they will capture this innovation and use it. And they have a long-term investment interest and if they get into this, they will be able to do it.

That is the future of private-public partnerships if you really want to transform energy landscape of India. We also need do look for rural entrepreneurs who will actually participate in value addition and waste management of the entire productivity of the agriculture and converting it into energy. That is where I see the future of private-public partnership stands. It need not be a mega-industrial partnership coming in. Yes, such people may get funding from organizations such as the Gates Foundation. But it is the entrepreneur's energy of the 100,000+ agro-entrepreneurs who are really interested to make a transformation. They are the ones which an organization like MGMI should bring in together in a platform with financial support, both from government as well as from other large funds.

What are some challenges and opportunities in developing a team of young scientists to pursue R&D in some path-breaking areas?

I feel that I was lucky when I did science - because science was a priority in many parts of India. Science had respect. At least when I was growing up in Calcutta, a scientist in the family was far more respected than the people who make a lot of money. Unfortunately, post-90s most of the brilliant young people did not come to science. And they all jumped into IT and making quick money. Because of this, there is a depletion of talented young people who did not come to science from 1990 to 2005, until we built the IISERs (Indian Institutes of Science Education and Research) and many new IITs. But the leadership today is of leadership of 90s scientists, for whom it is very difficult to accept maverick talents below. We have to wait. You will get lots of young people (entrepreneurs) who actually made money and now want to do something different. They should have been scientists that time, but now they are in their 40's and I mentor many of those startups. They are the ones we should focus on in the next decade. By 2030, all our students who have gone to pursue science in the IISERs will then be faculty members and then they can be role models for younger generations. Young people want big challenging problems since they do not like some small incremental science. Therefore, when I got into open-source drug discovery, I had no difficulty in collecting 8700 young people. When we wanted to do the genetic landscape of India, we had 158 young co-authors in our paper. I think leaders have to provide a big vision and attract people. That is how ISRO was built. Satish Dhawan has been a great role model, M.M. Sharma is a great role model, and these are the role models that must be projected to the young people. Prof. M.M. Sharma is a great fundamental scientist, but also a great contributor to the industry and to the development of the nation. So, it is the responsibility of associations like yours to project great role models who have made massive contributions to Indian science. They may not be occupying Director General's or Director's position, but they have made massive contribution to the field. Prof G.N. Ramachandran was one such person and my way of motivating young people was to create a movie on him in 2004 (Immortal Coils) in which I projected his contributions. When young people see that a scientist of India is one who has done world-class research with limiting facilities, and that is projected again and again, I think young people will come to science.

In a difficult economy, due to the pandemic, what tips do you have for youngsters who wish to pursue careers in the fundamental science?

You know the adage 'when the going gets tough, the tough gets going'. If you look at the outcome of FELUDA, novel COVID-19 diagnostics of CSIR-IGIB, it is based on fundamental science of CRISPR/Cas9 – a very complex knowledge. But it was immediately diverted into the development of diagnostics overnight. It got clearance, it went to the industry, something I do not think ever got done at this speed in CSIR. The Tata Group created a company based on this knowledge called Tata Medical & Diagnostics. All this happened in 200 days but before these 200 days, there were 20 years of background of genomics knowledge that the institute developed. So basic science will continue to be important when the situation is bad. Let's look at Second World War – so many innovations happened then, like the Bosch process as well as advances in the atomic theory and technology. COVID-19 is like a third world war, but the enemy is invisible. This is the best time for science when household people know about virus, antibodies and clinical trials. Biology could not have a better day than today.

I can tell you this with my ending note that the response by genomics scientists in India to this pandemic was worth of our leaving beautiful Bangalore to go to Delhi to establish an Institute of genomics. When a sequencing laboratory was needed at the Delhi airport, the CSIR-IGIB was there. And now I came back to Bangalore from Delhi this December, with a great sense of satisfaction after completing my job of establishing genomics technology in India. What I meant is, it is really a great satisfaction that the best science was there when it was needed. But it would not have happened if in 1997, had I not left the cushy job of a professor at IISc and went to Delhi. That time it was fundamental science, purely with an interest to discover and understand, and it has shown its application now. So, you build people and it is those people who eventually deliver. It is like building the Taj Mahal – you can design it but it takes many, many people to finish. Those who start, they do not finish it. HUGO is a solid example of that. And this pandemic has shown that only they can contribute who have a solid foundation of knowledge.

HEALTH TIPS : Sugar - the latest culprit

How to find out how much sugar you can eat?

It's not possible to add upto how much sugar you are eating in your diet every day in every meal. But it is possible to acquaint with the recommendations for healthy eating. Such as minimizing eating of processed foods, and eating more whole fruits and vegetables and whole grain products.

The Sugar in the whole apple results in a slow increase in our sugar levels. But apple juice causes a sudden spike in our sugar levels putting a strain on our insulin system. From metabolic point of view, it's much easier for our body to process the sugar when it is in the form of an apple rather than apple juice. When sugar is released slowly, our body is able to metabolize it and does not store it as fat.

Perspective Piece

Changing Face of Indian Steel Industry, as Seen Through Last 40 Years in Industry

Satyakam Basu

About the Author: Mr Satyakam Basu is a Metallurgical Engineer from Jadavpur University and has done his Post Graduation in Management from Indian Institute of Management, Kolkata (IIM Calcutta). He has more than 40 years of senior level work experience, both in India and Abroad, working for various large corporates. Apart from his experience in Steel and related Industry, having worked for Tata Steel, Essar Steel, Arcelor Mittal, both in India and Abroad in very senior management levels (as Dy Divisional Manager for Tata Steel, Senior Vice President for Essar Steel, Director for Arcelor Mittal); he also have in depth knowledge of Merger & Acquisition as well as Services sector having successfully run the Industrial SBU of Quesscorp as its President & CEO.

Mr. Basu also has rich Entrepreneurial experience, by virtue of being an Entrepreneur for 14 years wherein he had put up two greenfield projects for Samshi Steel as CMD.

He is currently the Group CEO of a Diversified group based in Mumbai and Advisor to Bain & Co for Metals and Minerals. Undoubtedly very few people of iron & steel industry, have such a vast work experience in different diversified fields. Apart from his professional achievements , Mr. Basu is a prolific writer and speaker on both Industry related subjects as well as on Life coaching including Spirituality.

I started my journey in Steel and related industry way back in 1980 after completing Metallurgical Engineering from Jadavpur University and when I look back after 40 years , I realise that I was particularly lucky to have witnessed some of the major changes and developments in this Industry , over four decades. I might have never thought about reminiscing through this journey had my close friend Professor Rajib Dey not asked me to and hence before I move forward, let me say a big 'thank you' to him.

To navigate easily through my 'down memory lane' article identifying changes in the Indian Steel Industry, I have divided it into the following parts :-

1) Technological Changes
2) Advent of competition
3) Internal Power balance - Production to Marketing
4) Sellers' market to Buyers' market
5) From Cost Plus approach to Market pricing
6) Higher Cost consciousness
7) Concentration on Core Activities
8) Scalability
9) Import Substitution
10) Export Orientation
11) Mergers & Acquisitions
12) Internationalisation
13) Branding a Commodity
14) Information availability & flow
15) Environmental awareness

While I know that there are other areas as well where major changes have taken place but I will limit myself to these areas for the scope of this article.

1. **Technological Changes**:- During the last 40 years, I have seen major technological changes happening in the Steel Industry. They have taken place in areas like

a. Production Process:- I remember when I walked into IISCO Burnpur for the first time, years back, Acid Bessemer + Basic Open Hearth steelmaking was in vogue. Today, Bessemer process is not being used at all and mostly people have moved to BF-BOF (Blast Furnace – Basic Oxygen Furnace) process and some to EAF (Electric Arc Furnace) process. Similarly, today Degassing through VD/VAD/ AOD is the norm for secondary treatment of liquid steel which was not there earlier. We have also seen numerous developments in Rolling and Casting area like introduction of TMT, Thin Slab Casting etc. We also saw arrival of totally revolutionary process like Corex , Finex etc. So overall todays' Steel Plants look very different compared to when I started off.

b. Raw material choice:- I remember when I started, Hot Metal Production would not touch any Iron Ore having less than 63% Fe, while they will keep complaining if the ore had less than 64-65% Fe. Today through development of technologies through which you can use Pellets made from Iron Ore Fines people are using Raw material feed having much much lower Fe content. The people using Pellet – DRI/ HBI route are using Iron Ore fines regularly while 40 years back, Plants used to pay money to take Iron ore Fines away. Sinter Plants , which were not that much of use when we started , today plays a major role. Similar is the case for Coking Coal etc where Coal sourced from alternate countries of lower grades are also being accepted. Most important change that I see is the effort towards integration of supply chain of crucial raw materials like Fe ore , Coking Coal etc.

c. Continuous improvement in Quality and Yield:- In the last 40 years , I have seen a huge effort to continuously improve both the quality of steel as well as improving the efficiency of plant. One such area is definitely Blast Furnace availability which is touching 97-98% today. Overall Rejection levels have come down drastically and through put has increased substantially.

d. New product development:- I remember that when I started, there were only vanilla grade of Mild Steel, which was produced. Then Tata Steel started a range called Special Steel outside of JPC (Joint Plant Committee) grades which was primarily High Tensile and Forging Quality. Today, we see Steel Plants producing HSLA (High Strength Low alloy) , highest grades of API (American Petroleum Institute), highest grades of Electrical Steel etc with ease. That surely is a great positive change.

e. Product range improvement:- Product range enhancement needs a lot of adjustment in the minds of Production persons. That was not there at all 40 years back. They wanted tonnage throughput and would not sacrifice that at any cost. But slowly it came and today, producing 1.2 mm HR Coil or 6 mm TMT is no big deal. The basic grade of TMT itself has also almost moved to 500 as against 360 of yesteryears.

f. Cost reduction:- While we will discuss this in more details later but we have seen a huge improvement in cost consciousness in Steel Industry. All owners today have realized that while your revenue is dependent on market, your profitability is dependent on your cost. That's a great leap forward.

2. **Advent of Competition**:- In 1980, Steel Industry had only two players – SAIL and Tata Steel. Also they were hugely protected by the import policy of Government where anyone wanting to import Steel, had to have a NOC issued by the Steel companies. WOW. What a comfortable scenario. Then came 1991/92 – Steel was decontrolled. People like Essar, JSPL, Ispat etc came in. During the government of Mr Narasimha Rao & Mr Manmohan Singh

combine, import duties cascaded down. One was suddenly looking at Competition. Plethora of secondary producers started to eat into the market of Primary Producers. Imports from CIS countries started flooding the market. Today, we see much nimble footed Steel companies who are market savvy and have learnt the Art of Survival in a competitive market. That's surely a huge change – right ?

3. **Internal Power balance - Production to Marketing**:- When I started my career 40 years ago – looks yesterday actually – Steel companies were dictated by production because whatever you produce, will be sold easily. Difficulty was producing, not selling. Today, the difficulty is selling. That's why we see a sea change in the way top management is constituted. Today, Commercial people have more say than Production persons – simply because Market dynamics have seeped in. We even saw Marketing person becoming top person in Steel companies which was unthinkable years ago. I can take names but its irrelevant.

4. **External Power balance - Sellers' market to Buyers' market**:- I remember, I was posted to Bangalore in 1988 as Regional Product Manager, the first thing I noticed was a notice in the reception saying – CUSTOMER VISITING HOUR , TUESDAY AND THURSDAY, 2 TO 4 PM. Can you believe it? But its true. Because – it was a sellers' market. Every company worth its while had a purchase officer dedicated to Steel Purchase. Just as an anecdote – this is not only for India. When as Director of Marketing & Sales in Sidex, Romania; I visited a customer – he almost fell off his chair because no one from a steel company had visited him in his memory. Today we see this sea change in a Steel man's life.

5. **From Cost Plus approach to Market pricing** :- Till 1992-93 , Steel was a controlled item with price being decided by JPC (Joint Plant Committee), where the influencing members were from SAIL & Tata Steel. Among various factors considered for price determination, was the cost of production and more often than not, a cost plus approach to pricing was decided. Today, it is governed by free market economy and the Demand – Supply decides the price. That's a real change over last decades.

6. **Higher Cost consciousness**:- I am not saying here that there was no cost consciousness before but with market driven pricing, the emphasis on cost control has taken top priority, as one of the main ways to improve the bottom line. One of the immediate effects was concentrating on core activities, which is being discussed next. Various disruptions that we have seen affecting the Steel Industry over last 4 decades , had made its very survival difficult unless a serious control over cost was undertaken.

7. **Concentrating on core activities**:- Remember the famous tag line of Tata Steel in controlled regime – WE ALSO MAKE STEEL? Though the theme of this tag line was very positive highlighting that Tata Steel does a lot of Humane and CSR activities apart from making steel; with increased competition and with market pricing; Steel companies started concentrating only on core activities and out sourcing non- core ones. This was a paradigm shift in focus, with increased focus on bottom line through improved core functioning. For example , today we hardly see any steel plant operating its Oxygen/ Nitrogen / Argon plant and have them run by professional gas producing companies in outsourced model.

8. **Scalability**:- I remember that Tata Steel had a Management conference in 1987 in Srinagar, which I was selected to attend. During the open session, someone asked the then CMD, Mr Russi Mody, what is his dream for Tata

Steel and he answered that his dream is to make Tata Steel a 2 Mio MT company (at that time it had a capacity of approx. 1.2 Mio MT). Today, if you ask any steel person, he will say that less than 5 Mio MT capacity will not be viable in the long run. So we saw a complete change in the vision for scalability of the Steel companies and we have Indian steel companies having upwards of 10 Mio MT, easily.

9. **Import Substitution**:- Way back in 80's, India was importing a lot of Steel in grades not made in the country. In the last 4 decades, we have seen domestic plants producing almost all those grades and have substituted almost all those imports for material not produced in the country. Even today, imports to India do happen but most of them are based on economic considerations like price etc rather than grades. There are hardly any grades being imported purely based on not being produced in the country in these days.

10. **Export Orientation**:- During 80's and early 90's, exports were not a major part of sales for Steel companies and domestic sales made up for majority of their sales. However, I have seen drastic improvements in Export of Indian Steel to all corners of the globe over time. I feel very proud to have played a significant role in the same when I was in charge of Exports in Essar Steel and slowly the country became a net exporter of Steel instead of being traditionally a net importer.

11. **Mergers & Acquisitions**:- Like, many other sectors, once the economy opened up, there were new entrants to the Steel Industry also and apart from traditional producers like SAIL and Tata Steel, new producers came along like Essar, Jindal (both JSW & JSPL), Lloyds, Bhushan, Uttam etc. Also came along a lot of secondary producers, primarily in the long product space. With time, some went on to become successful and some failed. With success & failure, came the culture of Mergers & Acquisitions in the Steel Industry and today, through NCLT route, we see a lot of mega M&As. No one would have imagined this 30-40 years back.

12. **Internationalisation:-** When I started my working life in 1980, we had Indian steel companies operating in India only and no one thought of looking off shore for growth. However, with opening up of Indian economy and fast pace of globalization, Indian companies started looking outwards not only for steel making but also to have Raw material sources abroad. Today we have Indian Steel companies having both Steel assets as well as Raw material assets all over the world and also the reverse happened with Arcelor Mittal and Nippon Steel taking over Essar Steel. We are today really in the very middle of Globalisation of Steel Industry.

13. **Branding the commodity** :- Over the last 40 years , major branding exercise have taken place in the Steel Industry by all Main producers and also by secondary producers. Today , if you switch on any media , you will see a lot of celebrities endorsing Steel products , which was unimaginable when I started. Successful attempts to create product differentiation within a commodity product , has been made and the trend will continue.

14. **Information availability & flow** :- From IT perspective, I was thinking whether availability of data, awareness of situation - locally and Globally which has helped in quick decision making and reduced dependency on people - can also be an point to cover. e,g - 40 years back, it was all depending on indiviudal information which steel plant is producing how much , what product mix, about quality etc etc and also in the demand-supply side .Today a single click will let people know all these in details which might have helped in making a quick call on capacity expansion.

15. **Environmental Consciousness**:- I am not saying that environment consciousness was not there among Steel producers 40 years back but surely it has gone up drastically and ESPs , ETPs etc are a must today and have become a norm rather than exception. The move towards Green Steel is today a genuine movement and in my opinion , along with improvement in Energy consumption ; this is the most laudable movement.

Conclusion:- Lot of water has passed through the Ganges in last 40 years and I feel very lucky to not only have witnessed major changes and developments in Indian steel Industry but also to be part of this change actively during my professional career. In this article, I have tried to discuss some of the major changes in my view but I am sure that there are a lot more which have not been covered here. To summarize , let me state in very short , what has changed and what has not and going forward , what changes I foresee.

Changes :-

1. Dominance of one country (China) starting 2005-close to 1 Billion tons out of 1.8 bil tons Crude steel world-wide and dumping of steel to all parts of the world has forced Indian Steel industry to be more competitive.
2. India moved up to 120 mil tons per anum production, a massive growth in steel capacities & demand during last 10-15 years. For India; the forecast is to reach 300 mil tons production and 250 mil tons consumption in 2030 - India now is the second largest steel producer after China
3. Decontrol of steel industry in 1991- a land mark year for Indian steel industry
4. Growth of Private sector in steel-Mini mills, secondary producers
5. Monitoring of trade by WTO for some time(1990s) promoting free global trade; but, after that countries started to protect their local suppliers- Govt Protection, trade measures by countries to protect domestic-Minimum Import Price by Govt of India
6. Environment/Climate change, health & safety, quality yield, customer satisfaction, free cashflow becoming key parameters in Balance Scorecards of CEOs rather than only production & sales figures.
7. The industry is more adaptive and can move to switch on and off mode , more easily now compared to old days.
8. Higher Quality & wider product range is no more limited to imports or only select few in India.
9. Advent of Steel as a branded product, endorsed by celebs , almost like FMCG.

Continues :-

1. Steel Industry continues to be vulnerable like in 1980s & 90s due to Excess capacity
2. Despite threats of substitution from various products (plastic, wood/bamboo, concrete, aluminium), steel continues to be a very important product due to its Longevity, recyclability & wide spread use
3. The industry remains a fragmented industry despite attempts by top steel producers to consolidate - ArcelorMittal, the biggest in world only has less than 6% market share of global market
4. Continues to be Highly capital intensive industry
5. Due to its social impact, steel continues to be a focus industry for Governments
6. Steel continues to be a highly Cyclical industry & steel price trend tends to be speculative .
7. Continuation of both Tariff & Non Tariff barriers.
8. Lower quality perception about Indian steel in world market .
9. Talent profile – Steel industry , for that matter most of the core sector , still does not attract the best talents that country has to offer.

Going Forward :-

Some of the major developments which I see taking place going forward and some of which have already started :-

1. Having a separate company to install and manage mega power plants , which are part of steel plants.
2. Coal Injection to became one of the major technologies which will change the way Blast Furnaces move away from Metallurgical Coke
3. Huge increase in BF capacities like 10000 plus tons per day capacity and them replacing smaller size BFs.
4. More efficient Slag and Waste Utilization
5. More rigorous Environment Management and Pollution Control
6. Massive capacities for Making , Shaping and Treating auto grade steels with huge capacity Cold Rolling Mills coming up.
7. Increased use of Techniques and Data Analytics for Optimizing Product Mix for Maximizing Profitability.
8. Increased M&A for Indian Steel companies both locally as well as at International level
9. Complete captive Raw material integration for all Primary producers.

Acknowledgements :- While the experiences and observations those I shared are my own , I must acknowledge very useful inputs provided by my friends and relatives in the Industry as well as outside of it.

Disclaimer :- The opinions / experiences shared in the article are purely personal in nature and based on my learnings and observations , and has nothing to do with the opinion of my past and present employers or companies named herein.

Announcement

for the forthcoming issue of MGMI News Journal

The next Issue of the MGMI Mining Journal intends to address the theme:

Sustainable pathways for India's Coal Sector

We request our esteemed readers and authors to kindly send us technical notes, letter to the editor and articles highlingting relevent concepts on this theme.

- Role of Coal in low Carbon Future
- Decarbonizing the Indian Coal Supply Chain
- Technology induction for sustainable actions in coal minin

Technical Note

Mineral Deposits & Extraction of Aluminum & Tungsten : Indian Perspective

– Bappaditya Roy[1], Saugata Rakshit[2]

Aluminum Metal

Aluminum exhibits a face-centered cubic (FCC) crystal lattice. Melting point of Aluminum is 661oC. Density: 2.71 gm/cc (1/3rd of Steel). It is the 2nd most malleable and sixth most ductile metal.

Few important properties of aluminum:

1. Highest Electrical Conductivity.
2. Good Thermal Conductivity.
3. Highly Ductile metal, it can be easily machined, cast, and formed.
4. Good Corrosion and Oxidation Resistance properties by forming dense, strong aluminum oxide film.
5. Non Toxic and 100% Recyclable.
6. Non-Magnetic & Non-Sparking.

Common uses of aluminum:

1. **Cans & beverage container**: Aluminum is commonly used for packaging as it can withstand the carbonation pressure inside the can. In addition, it can be easily formed and shaped and it will not rust.
2. **Aircrafts**: Due to its low weight, considerable strength and workability, Aluminum is ideal for aircrafts, including commercial aircrafts that are produced. It isn't just the primary material used for the aircraft shell, but for the seats, too, as it reduces the weight and saves fuel spends.
3. **Windows & doors**: Aluminum has superior thermal efficiency, so windows made using this metal meet energy efficiency standards. It's strong, durable and a great long-term investment as they don't require maintenance and has a long-lifetime. Aluminum anodizing can be used to protect materials from corrosion or added as a decorative film.
4. **Construction:** Due to the weight it's easy to work with and allows for improved installation times. Due to the high thermal conductivity, buildings built using this are kept cool in summer and warm in winter.
5. **Food processing and pharmaceutical industries:** Easy to Roll and formed into thin shape foils and sheet. Use of Pressure Cooker and Non stick Cookware also made this metal very attractive to society.

Aluminium made products for human life

Fig 1 : Aluminium pressure cooker made from Al- circle in circle press, indiamart.com

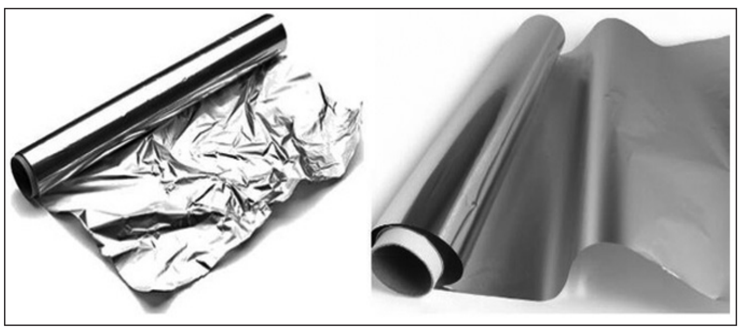


Fig 2 : Aluminium foil used for packaging and pharmaceutical, indiamart.com

1. AGM – Production Hindalco Industries Limited- Hirakud Smelter Works
2. Lecturer in Metallurgical Engg, Iswar Chandra Vidyasagar Polytechnic, Jhargram, Ex- Assistant Manager-Production: Hindalco Industries Limited, Belur Works

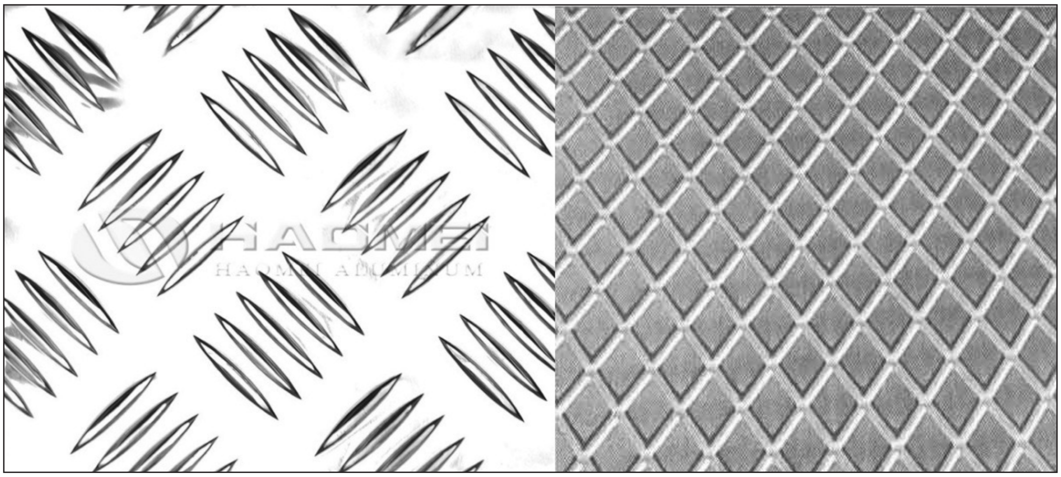


Fig 3: Aluminum chequered sheet used for flooring and pattern purpose both 5-Bar and diamond shape. manaskiaaluminium.com

Fig 4 : Recycled Aluminium cans, core77.com

Fig 5 : Aircraft Aluminium grades, matmatch.com

<u>**What so special about aluminium**</u>:

Aluminum is a widely popular metal due to the vast variety of uses. It has high strength to weight ratio. Some Special features of this metal can be written like,

1. **It weighs one third less than steel.**
2. **It does not Rust.**
3. **It is the world's most abundant metal.**
4. **It is 100% recyclable.**
5. **It is resistant to heat.**
6. **Its 2nd most malleable and sixth most ductile metals.**

Even though aluminium is the most common metal on the planet, pure aluminium does not occur naturally. Aluminium atoms easily bind with other metals, forming compounds. At the same time it's impossible to isolate aluminium by simply melting down the compounds in a furnace, as is the case with iron, for example. While its ore (bauxite) is relatively easily extracted, usually with surface mining, the process of refining the metal requires a great deal of effort. The aluminium production process is much more complex and requires huge amounts of electricity. For this reason, aluminium smelters are always built in the vicinity of power energy sources, usually hydroelectric power plants that don't contaminate the environment.

Aluminum ores:

There are several minerals available in the world from which aluminium can be obtained, but the most common raw material is bauxite. Bauxite is a mineral made up primarily of aluminium oxide mixed with some other minerals. Bauxite is regarded as high quality if it contains more than 50% of aluminium oxide. There is a lot of variation in bauxites. Structurally they can be solid and dense or crumbly. The usual color is brick red, flaming red or brown because of iron oxide. If iron content is low, bauxite can be grey or white. But yellow, dark green and even multi-colored bauxites with bluish, purple, red and black strains.

Bauxite and its reserves in india:

Bauxite is basically an aluminous rock that contains hydrated aluminium oxide as main constituent and iron oxide, silica & titania as minor constituents present in varying proportions. Hydrated aluminium oxides present in the bauxite ore are **Diaspore and Boehmite**, $Al_2O_3.H_2O$ (Al_2O_3 -85%; Al-45%); **Gibbsite or Hydrargillite**, $Al_2O_3.3H_2O$ (Al_2O_3 - 65.4%; Al-34.6%), and bauxite (containing colloidal alumina hydrogel), $Al_2O_3.2H_2O$ (Al_2O_3 -73.9%; Al-39.1%).

The major use of Bauxite is in the extraction of primary Aluminum. It is also an essential ore for Refractory and Chemical industries. India has 3,896 million tonnes of resources of bauxite which is sufficient to meet both domestic and export demands. These resources include 656 million tonnes Reserves and 3,240 million tonnes Remaining Resources.

By States, Odisha alone accounts for 51% of country's resources of bauxite followed by Andhra Pradesh (16%), Gujarat (9%), Jharkhand (6%), Maharashtra (5%) and Madhya Pradesh & Chhattisgarh (4% each).

Odisha emerged as the leading producing State accounting for about 49% of the total production followed by Gujarat (24%), Jharkhand (9%), Chhattisgarh and Maharashtra (8% each). The remaining was produced by Madhya Pradesh, Goa, Karnataka and Tamil Nadu.

Bauxite was first mined in India in Madhya Pradesh in 1908. The mining of bauxite is carried out by opencast method. The mines are classified in the following three categories depending upon the level of mechanization: (i) Manually operated mines (ii) Semi-mechanized mines (iii) Mechanized mines. In India, bauxite is mined in opencast only.

Fig 6 : Bauxite mines in different locations of India, copyright@2016 www.mapsofworld.com

Aluminum production

The aluminum production process can be broken down into three stages; firstly bauxites, which contain aluminium, are extracted from the ground. secondly, bauxites are processed into alumina or aluminium oxide, and finally in stage three, pure aluminium is produced using electrolytic reduction, a process in which aluminium oxide is broken down into its components using electric current. About 4-5 tons of bauxites get processed into 2 tons of alumina from which about 1 ton of aluminium can be made.

Alumina production

The normal production route taken is to refine the bauxite to aluminum oxide, or alumina [Al_2O_3], which is a white, crystalline powder. This powder is then smelted to form aluminum metal. There are other applications for alumina, for example as an abrasive or in ceramics. The production of alumina from bauxite is a hugely significant industry in its own right but it is also one of the most significant global users of filtration and separation technology. A typical alumina plant may use approximately 500–1000m^2 of filtration area per million tons of production (as well as many hundreds of square meters of gravity thickener/clarifier area). Production of alumina has approximately doubled in the last 20 years to more than 80 million tons. A significant proportion of this increase came from squeezing more capacity out of existing plants, or adding additional streams to these plants.

Bayer Process

Almost all alumina plants in the world use the Bayer process, patented over 120 years ago [US Patent 515,895 Process of making alumina, Karl Bayer], to refine bauxite to alumina. In this process, a large volume of caustic liquor circulates continuously around the plant. Bauxite is fed into the caustic stream and, after a number of processes; alumina is taken out of the stream. The main process steps include:

1) Dissolution of the aluminum-bearing minerals using caustic liquor at high temperature and pressure.

2) Removal of the solid residue – the non-aluminum-bearing part is usually a mixture of iron-rich minerals.

3) Precipitation of pure alumina hydroxide [Al $(OH)_3$], under conditions of controlled cooling.

4) Calcination of the alumina hydroxide to remove the water of crystallization so that it is ready for the aluminum smelter.

The principle of the Bayer process is as follows: the crystallized aluminum hydrate found in bauxite easily dissolves in concentrated caustic soda (NaOH) at high temperatures and when the temperature is lowered and the concentration of the solution increases again,

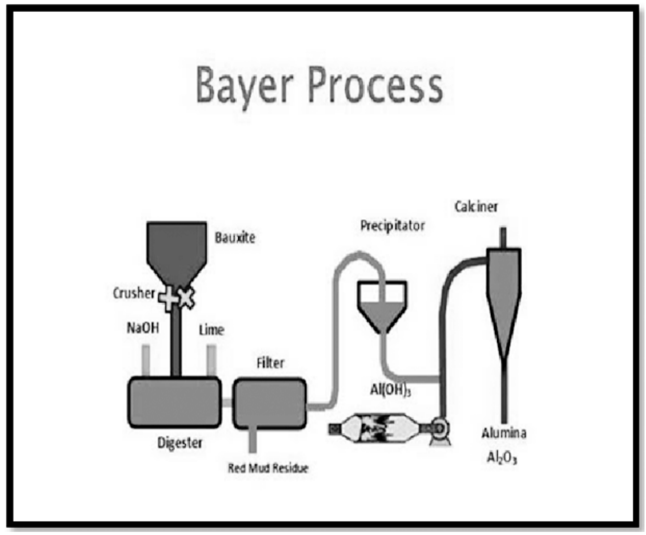


Fig 7 : Bayer process: Manufacturing of alumina, worldofchemicals.com

Aluminum hydrate crystallizes but the other elements contained in the bauxite (the so called ballast) either don't dissolve or recrystallized and settle to the bottom well before aluminum hydrate crystallizes. This means that after aluminum hydrate gets dissolved in caustic soda the ballast can be easily isolated and removed. This ballast is known as red mud. Large aluminum hydrate particles can be filtered out from the solution with relative ease. They're then washed with water, dried and calcined: i.e. heated up to remove water. The output of this process is alumina.

Red mud: Red mud is a thick red-brown paste consisting of silicon, iron, titanium and other compounds. It's disposed of in special isolated areas, called mud disposal areas. Mud disposal areas are designed to prevent the seepage of alkali contained in the mud into ground water. Once a mud disposal area has been filled up, the territory can be reclaimed by burying it in sand, ash or dirt and planting certain types of trees and plants there. While full reclamation can take years, in the end the territory will return to its original state. Many experts don't regard red mud as a waste because it can be used as a raw material for cement industries. For example, scandium can be made from it and then used in aluminum scandium alloys. Scandium makes aluminum alloys extra strong and such alloys can be used in motor vehicles, rockets, sports equipment and in the production of electric wires. Red mud can also be used in the production of cast iron, concrete and rare earth metals.

Aluminum production: Alumina is the direct source of aluminum in the aluminum production process, but in order to create the right environment for electrolysis another component is necessary, and that component is cryolite. It's a rare natural fluoride mineral which due to its scarcity in natural form has been manufactured artificially. In modern metal production, cryolite is made by mixing hydrofluoric acid with aluminum hydroxide and soda.

Hall Heroult Process: Elemental aluminum cannot be produced by the electrolysis of an aqueous aluminum salt, because hydronium ions readily oxidize elemental aluminum. Although a molten aluminum salt could be used instead, aluminum oxide has a melting point of 2072°C so electrolyzing it is impractical. In the Hall◎Héroult process, alumina, Al_2O_3, is dissolved in molten synthetic cryolite, Na_3AlF_6, to lower its melting point for easier electrolysis. The carbon source is generally a coke (fossil fuel).

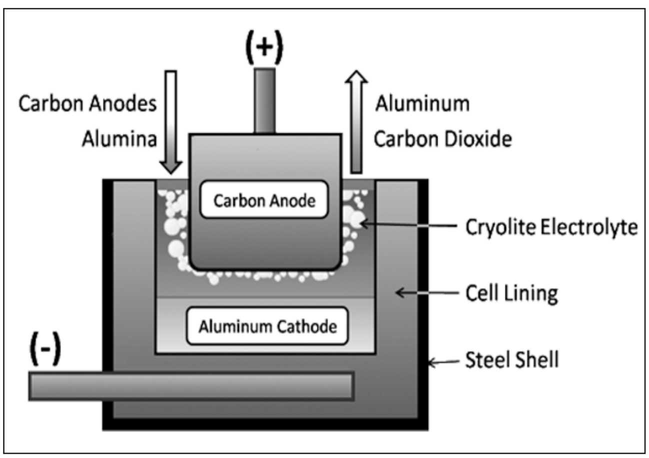


Fig 8 : Hall- Heroult process: Smelting of Aluminium, en.wikipedia.org

In the Hall–Héroult process the following simplified reactions take place at the carbon electrodes:

Cathode: $Al^{3+} + 3e^- \rightarrow Al$
Anode: $O^{2-} + C \rightarrow CO + 2e^-$
Overall: $Al_2O_3 + 3C \rightarrow 2Al + 3CO$

In reality, much more CO_2 is formed at the anode than CO

$$2Al_2O_3 + 3C \rightarrow 4Al + 3CO_2$$

Pure cryolite has a melting point of 1009±1°C. With a small percentage of alumina dissolved in it, its melting point drops to about 1000°C. Besides having a relatively low melting point, cryolite is used as an electrolyte because, among other things, it also dissolves alumina well, conducts electricity, dissociates electrolytic ally at higher voltage than alumina, and also has a lower density than aluminum at the temperatures required by the electrolysis.

Aluminium fluoride (AlF_3) is usually added to the electrolyte. The ratio NaF/AlF_3 is called the cryolite ratio and it is 3 in pure cryolite. In industrial production, AlF_3 is added so that the cryolite ratio is 2–3 to further reduce the melting point, so that the electrolysis can happen at temperatures between 940 and 980°C. The density of liquid aluminum is 2.3 g/ml at temperatures between 950 and 1000°C. The density of the electrolyte should be less than 2.1 g/ml, so that the molten aluminum separates from the electrolyte and settles properly to the bottom of the electrolysis cell. In addition to AlF_3, other additives like lithium fluoride may be added to alter different properties (melting point, density, conductivity etc.) of the electrolyte.

The mixture is electrolyzed by passing a low voltage (under 5 V) direct current at 100–300 kA through it. This causes liquid aluminum metal to be deposited at the cathode, while the oxygen from the alumina combines with carbon from the anode to produce mostly carbon dioxide. The theoretical minimum energy requirement for this process is 6.23 kWh/ (kg of Al), but the process commonly requires 15.37 kWh.

The aluminum reduction process requires huge amounts of electric power, so it's important to use renewable energy sources that don't contaminate the environment. The most common renewable energy source is a hydroelectric power plant, as they can deliver the required power without contaminating the atmosphere.

Electrolytic reduction of aluminum-Pot room operation in smelter:

The reduction area is the heart of an aluminum smelter and it looks very different from the production shops in your typical steel works that make cast iron or steel. The reduction area consists of several rectangular buildings whose length sometimes exceeds 1 kilometer. Inside there are hundreds of reduction cells or pots arranged in rows and hooked up to power sources via massive cables. The constant voltage at the electrodes of each reduction cell varies in the range of between 4 and 6 volts, while the amperage can reach 300, 400 KA and more. It's the electric current that is the main production force in this process. There are only a handful of people in a typical reduction area as all the key processes are automated.

In each reduction cell, aluminum is produced from alumina via the electrolytic reduction process. The entire cell is filled up with molten cryolite that creates a conductive environment at a temperature of 950^0C. The bottom of the cell works as the cathode while the role of the cathode is played by special cryolite-carbon blocks 1.5 meters in length and 0.5 meters in width that are lowered into the cell. Every thirty minutes an automatic alumina feeding system dumps a new portion of alumina into the cell. The electric current flowing through the cell breaks down the bond between aluminum and oxygen, causing aluminum to settle to the bottom of the cell and form a layer 10-15 cm deep while the oxygen binds with the carbon in the anode blocks to form carbon dioxide.

Two to four times per day, aluminum gets extracted from the cell with special vacuum buckets. A hole is punched in the cryolite crust that forms on the surface of the reduction cell, and then a pipe is lowered in through the hole. Through this pipe liquid aluminum is sucked into the bucket, from which all air is pumped out in advance. On average, about 1 ton of metal is recovered from every reduction cell while a vacuum bucket can hold 4 tons of molten aluminum. Once the bucket is full it is taken to the cast house. For every ton of aluminum produced, 280,000 cubic meters of gases are emitted. For this reason, every reduction cell, regardless of its design, is equipped with a gas removal system that catches the gases emitted during the reduction process and directs them into a gas treatment plant. Modern dry gas treatment systems use alumina to filter out toxic fluoride compounds from the gases. So before being used in aluminum production, alumina is first used to treat the gases emitted during the earlier production of aluminum. So it's a closed loop, in a sense.

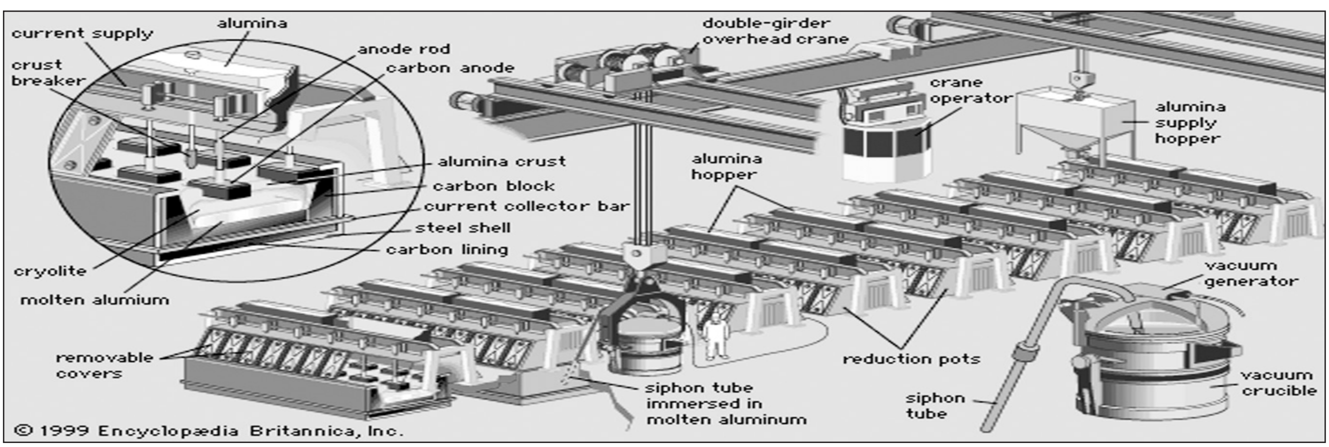


Fig 9 : Hall- Heroult industrial process: britannica.com

Challenges in indian aluminium industries: Bussiness outlook

Indian Aluminium industry is one of the leading industries in the Indian economy. Aluminium Industry in India is a highly concentrated industry with the top 5 companies constituting the majority of the country's production. In fact the production of Aluminium in India is currently outpacing the demand. Though India's per capita consumption of Aluminium is still very low (2.5 kg) comparing to other countries like Europe, US (25 & 30 kg), Japan (15 kg), Taiwan (10 kg) & China (3 kg), but the demand is growing gradually. The major Players of Aluminum industries In India are **HINDALCO, VEDANTA, NALCO, and MALCO.** Aluminium Industries can be divided into two parts, Bauxite to Alumina to Aluminium are called **Up-Stream Business sector** and Cast House and Fabrication (Rolling, Forging, Extrusion, Drawing) call it as **Down-Stream Business Sector.**

The price of aluminum fixed by primary producers is generally aligned to LME (London Metal Exchange) price. Current Trend is $2230.26. It is very fluctuating. 50% of total production cost of Aluminium is taken by **Electricity** both for Up-Stream and Down Stream sectors. Due to this Fluctuation of LME and Increase in power cost, maintaining a healthy profit margin becomes a challenging scenario for both Primary and Down Stream Aluminum manufacturing Industries in India. The Industry will face the pressure to improve the Return on Investment. So the technology has to be improved further to extract the metal from ore. Moreover the Aluminium Industry will have the internse competition from other materials like Steel, Plastics which are the substitutes of Aluminium. As the global environment become eco friendly, the industry has the pressure to reduce GHG emission and SPL, DROSS from the production process. The industry need to increase energy efficiency in the aluminum production process. They have to reduce the consumption of electricity in producing aluminum. The demand of aluminum is growing from various sectors especially automobile and Construction Industry. So Aluminum Industries also have to respond appropriately according to the changing demand of Global customers.

Future prospects of indian aluminium industries:

Aluminum Industry is one of the leading segments of the Indian Economy and is expected to play a significant role in its future growth. There is potentially large growing downstream market in Aluminium Composite Panel, Pressure Cooker, Non Stick Cookware, and Fin Stock for Air Conditioner, Foil Stock for Food and Pharmaceutical Industries, Closure Stock for Liquor Industries. Apart from that India is enriched with High quality Bauxite ore, resources of power generation and cheap labor (Skilled, Unskilled, Semi-Skilled), Indian Aluminium Industry is forging ahead with rapid expansion in both primary and downstream sectors. During the next decades India is likely to achieve a per capita aluminum consumption of about 10 kg per annum.

Tungsten Metal

Tungsten exhibits a body-centered cubic (BCC) crystal lattice. It is one of the transition elements in Group VI B of periodic table. It has the highest melting point of all metals, 3,410° C and it has good Thermal & Electrical Conductivity. High Hardness & Excellent Wear Resistance properties. It has highest Tensile Strength at elevated temperature (>1650^{0}C) when it is made into compound, though Pure Tungsten is ductile. Pure Tungsten has lustrous Silver- white to grey metal appearance. It has lowest coefficient of Thermal Expansion of all metals and excellent corrosion resistance, although it oxidizes in air at elevated temperatures.

Fig 10 : Tungsten metal (W) element chemical & physical properties tungsten.com

Fig 11 : Tungsten – Origin & uses, atoms & chemical properties tungstenringsco.com

What so special about Tungsten: Tungsten is called as "Strategic Metal", It is known as one of the toughest things found in Nature. It is a unique metal known for its high density (**19.33gm/cc**), hardness and heat resistant characteristics. Its density is comparable to Gold, Uranium.

Few important properties of tungsten:

1. Highest Electrical Conductivity.
2. Good Thermal Conductivity.
3. Ductile in pure form but it contains small amount of carbon and Nitrogen which gives tungsten metal its considerable hardness and brittleness.
4. High modulus of elasticity and wear Resistance properties.
5. Good creep resistance properties
6. Very high coefficient of Electron Emission.

Uses of tungsten:

1. Tungsten is used extensively as filaments for incandescent lamps, as electric contacts, and as electron emitters for electronic devices.
2. Tungsten also has found wide application as an alloying element for tool steels and wear-resistant alloys.
3. Tungsten carbides are used for cutting tools and hard-facing materials owing to their hardness and resistance to wear.
4. The metal is brittle at room temperature but ductile and strong at elevated temperatures. Its alloys are employed in rocket-engine nozzles and other aerospace applications.
5. Tungsten is used in super alloys with copper or silver in chemical industry.
6. Tungsten compounds are used in dyes and pigments; manufacture of paints, coatings & printing ink.
7. Other alloys bearing tungsten have a wide range of applications, i.e., ornaments, heat sinks, radiation shielding, super alloys for turbine parts.
8. Tungsten alloys and tungsten composites are used as a substitute for Lead in bullet and shot.

Fig 12: Tungsten – Elemental information, properties & uses, rsc.org

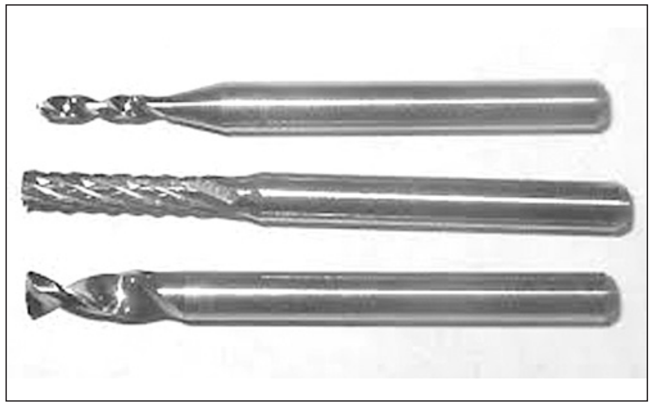


Fig 13: Tungsten – properties & uses, britanicca.com

Fig 14 : Application of Tungsten & Tungsten Alloys, refractorymetal.org

Fig 15: Tungsten in Military use, samaterial.com

Tungsten ore: Major minerals of tungsten are essentially of two categories. The first is Wolframite [(Fe, Mn) WO_4], which contains iron and manganese tungstates in all proportions between 20 and 80 percent of each. It is brown to black in colour, opaque with sub metallic luster. The second is Scheelite ($CaWO_4$), which is white, yellow, green or brown in colour, translucent with an adamantine lustre.

Deposits in india: The Total resources of Tungsten Ore in India, as on 01.04.2015, estimated at 87.39 million tones with WO_3 content of 1,42,094 tones. All these resources are under "Remaining Resources" Category. 95% Resources of Tungsten bearing ores are mainly found in Karnataka (42%), Rajasthan (27%), Andhra Pradesh (17%) and Maharashtra (9%). Remaining 5% resources distributed in Haryana, Tamil Nadu, Uttarakhand and West Bengal.

At Degana, Rajasthan, in a total of 7 blocks, the minimum and maximum values of WO_3 noticed were 0.09% and 1.62% respectively. At Balda of Sirohi district, Rajasthan, the average WO_3 content ranges from 0.24 to 0.48%. In Dewa KE Bera of Sirohi district, the average WO_3 is 0.03% and in Udwarya of Sirohi, it is 0.27%. In West Bengal Bankura (Cheendapathar) deposit contains an average of 0.1% WO_3. The analysis showed 0.01 to 0.19% WO_3 in Kuhi block, Maharastra and 0.13 to 0.38% WO_3 in Khobna block in Bhandara District Nagpur and 0.48% WO_3 in Pardi Dahegaon-Pipalgaon block. Gold are at Mysore mine of BGML in Karnataka has been reckoned as a potential source of Scheelite. The tailing dumps at Kolar Gold Fields contain about 0.01 to 0.05% WO_3 as per NMI database.

There was no reported production of tungsten ore/concentrate during 2018-19 as per Indian Minerals Yearbook 2019 (Part-II: Metals & Alloys) 58th Edition. In the past production of tungsten was reported from Degana in Rajasthan and Chendapathar in west Bengal. NMDC Ltd & Mishra Dhatu Nigam (MIDHANI) have signed a Memorandum of Understanding (MoU) to develop tungsten mines and processing technology for the metal.

NMDC Ltd on 2018-19, has submitted a proposal for reservation Khobna Tungsten Block, Nagpur District, Maharastra for tungsten prospecting and exploitation.

Mining and concentrating: Beneficiation process of Tungsten ore Wolframite includes crushing followed by gravity concentration. Flotation separation is used for scheelite that has been ground to a fine size to liberate the tungsten; this is further processed by leaching, roasting, and magnetic separation when required.

Crushing & grinding --→ Gravity concentration --→ Floatation--→ Roasting--→ Leaching --→ Seperation -à Reduction.

Extraction and refining:

Roasting: Tungsten Ore is associated with Impurities like sulfides and arsenide. It can be removed by Roasting process in air for 2-4 hrs at 800^{0}C.

Alkali leaching: Acid Leaching is done by Hydrochloric Acidand Alkali Leaching can be done by autoclave-soda process. An intermediate compound of Ammonium Paratungstate (APT) is produced. Ground ore is maintained for 1-1/2 to 4 hours in 10-18% Sodium Carbonate Solution at 190-230^{0}C temperature and under a pressure of 14.1-24.6 kg/cm2. pH level is maintained at 9-9.5. Aluminum and Manganese Sulphates are added at 70-80^{o}C and stirred for 1 hr. Phosphorus, Arsenic are eliminated and Silica level is reduced to 0.03-0.06%. Molybdenum is removed by adding Sodium Sulphide at 80-85^{0}C at pH of 10, holding for 1 hr and then stirring for 7-9 hrs to precipitate Molybdenum Sulphide. pH level is maintained at 2.5-3.

Ion exchange: Leach Liquor which is produced is Sodium Tungstate Solution. It can be further purified by liquid ion-exchange process. An Organic Extractant is used (7% alamine-336, 7% decanol and 86% kerosene). During this process, Tungstate ions transfer from the aqueous phase to the organic phase. The tungsten is then stripped from the extractant into an ammonia solution containing Ammonium Tungstate (APT). The resultant APT solution is sent to an evaporator for crystallization.

Acid leaching & filtration: In the acid-leaching process, scheelite concentrate is decomposed by hydrochloric acid in the presence of sodium nitrate as an oxidizing agent. This charge is agitated by steam spraying and is maintained at 70° C for 12 hours. The resultant slurry, containing tungsten in the form of a solid tungstic acid, is diluted and allowed to settle. The tungstic acid is then dissolved in aqueous ammonia at 60° C (140° F) for two hours under stirring. Calcium from the resulting solution is precipitated as calcium oxalate, while phosphorus and arsenic may be removed by the addition of magnesium oxide,which forms insoluble phosphates and arsenates of ammonium and magnesium. Iron, silica, and similar impurities that form colloidal hydroxides are removed by adding a small amount of activated carbon and digesting for one to two hours. The solution is clarified through pressure filters and evaporated to obtain APT crystals.

Reduction: When APT is decomposed to tungsten oxides, it displays different colors according to its composition, the Trioxide is yellow, the Dioxide is brown, and the Intermediate oxide is purple-blue.

Reduction by hydrogen: APT can be decomposed to yellow oxide when heated to above 250°C (480° F) in a furnace under a flow of air. In the industrial production of tungsten, however, APT is usually decomposed to the intermediate oxide in a rotary furnace under a stream of hydrogen, which partially decomposes the ammonia in the crystals into nitrogen and hydrogen while maintaining a reducing atmosphere. The blue oxide is then reduced by hydrogen to metallic tungsten powder in stationary furnaces at temperatures ranging from 550° to 850° C.

$$WO_3 + 3H_2 \rightarrow W + 3H_2O$$

Reduction by carbon: APT may also be reduced by carbon, although the powder is usually contaminated with tungsten carbide and some mineral elements contained in the carbon. When APT and carbon are mixed and heated at 650°–850°C, the product is a blue oxide. When heated in the range of 900°–1,050°, the brown oxide is formed. For complete reduction to metal, a temperature higher than 1,050° C is required. The purity of the metal is about 95 %.

$$WO_3 + 3C \rightarrow W + 3CO$$

Reduction by alumino-thermic process: Tungsten oxide can also be reduced by Alumino Thermic Reduction process. In Ellingham Diagram the Lower the position of the metal, Oxide is more stable. Aluminum is lower than Tungsten in Ellingham Diagram. So Aluminum can reduced Tungsten Oxide to Tungsten Powder.

$$WO_3 + 2Al \rightarrow W + Al_2O_3$$

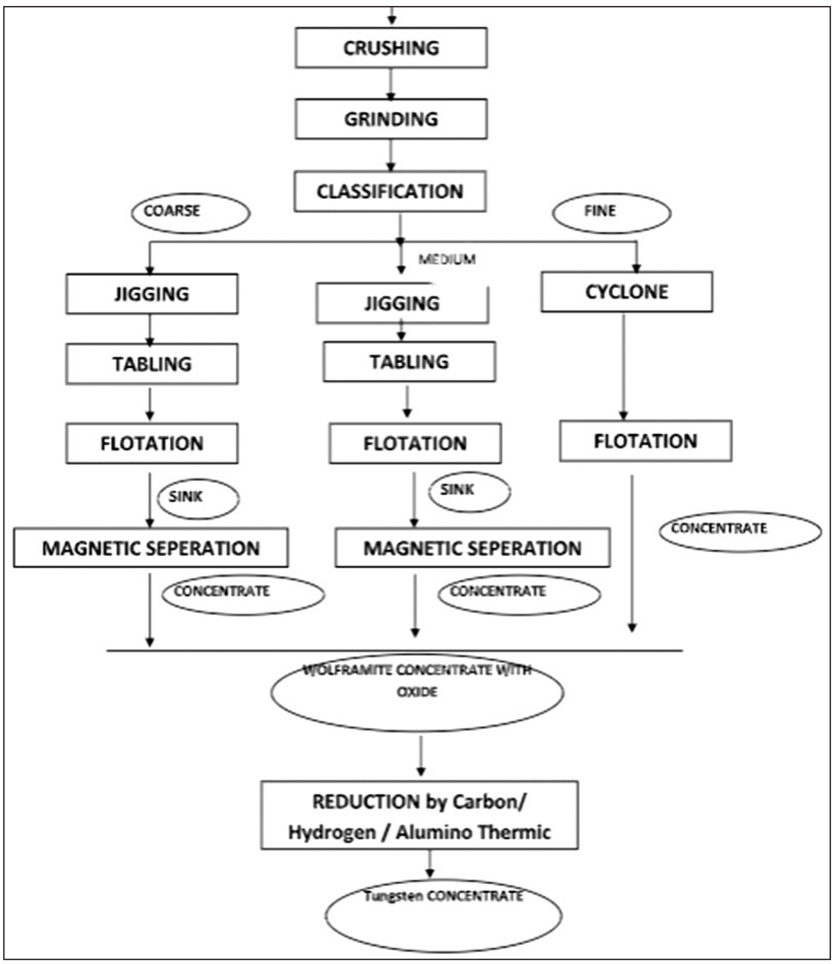


Fig 16 : Flow sheet for beneficiation of Tungsten ore

Challenges for india: In India, the entire tungsten demand met by imports and recycling. There is no such indigenous production of tungsten concentrates. Besides, to meet the demand of Tungsten, tailing dumps of Kolar can be worked on high priority as WO_3 content is very high. NMDC (National Mineral Development Corporation) has done a MoUs (Memorandum of Understandings) with both MIDHANI (Mishra Dhatu Nigam) and DMRL (Defence Metallurgical Research Laboratory) to explore tungsten investment opportunities in India and abroad. NMDC is presently conducting a detailed audit for short listing of tungsten asset to meet defence requirement, subjected to committed off-take from Defence sector companies. On the other hand MIDHANI is exploring to set up a facility to produce 500 TPA tungsten powder.

Future outlook of tungsten:

Strong growth in tungsten market is mainly driven by the increasing demand in downstream sectors. There are varities of end-user sectors in downstream including automotive, industrial engineering, energy, and Aviation, some allied industries like medical, defence and electric & electronics. They all put together provide a multiple effect on growth of the tungsten market. Based on application, global tungsten market has been segmented into 1> tungsten carbide, 2> Tungsten metal & alloys, mill products and 3> other applications, like salts, Tungstate, sulfides, oxides, etc.

Tungsten Carbide found largest application in the usage of products as cutting tools, boring, drilling in various industries. Mill products of tungsten which are basically pure tungsten metal products found applications in various components like electrodes, lighting, filaments, electrical & electronic contacts, sheets, wires, rods, etc. Developments in the Electronics Industry will be the major factor driving the tungsten market growth.

As per Tungsten - Outlook to 2029, 14th Edition by Roskill, tungsten market faces several challenges. There is a potential sustainable backlash in car production, for which 1/3rd of all tungsten units have been suffered. In addition there is an ongoing trade dispute between the USA and China, which badly affects a chemical, metal and finished products market. It includes Ferro Tungsten and Tungsten containing tools. A resolution to trade discussions would be a major boost for tungsten markets.

Apart from that there is some boost or bright spots remains for the Tungsten Industries due to Strong and continuous growth of Aerospace and electronics market. In addition there are also more opportunities of new 9 nos mines projects which is coming up for increasing the supply chain.

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Technical Note

Coking Coal Dynamics in India

– Souvik Mukherjee

Executive Summary

India is a major importer of low ash coking coal, but has considerable reserves of quality low volatile coking coal, currently being sold to power plants with 35-50% ash or after de-shaling at <34% ash. This coal is largely available at considerable depth and has difficult to very difficult washability characteristics due to the typical geological formation, finely inter-grown mineral matter and a high level of near gravity material (NGM) at cut densities.

At present ,the demand and supply dynamics stands such that India needed approx. 65MT in 2019 for making coke used in steel making through BF-BOF route. India imported about 62MT of coking coal from countries like Australia,Russia ,Canada,USA,Indonesia and about 2.5MT of BF coke from China,Poland,Japan,Russia & Columbia. BCCL & CCL, who are the primary source of indigenous coking coal supplied around 2.1MT to steel plant and cookeries in eastern parts of India and also major steel plant like SAIL & TATA Steel produced around 2MT from their captive mines. Thus India becomes the second largest consumer of coking coal as of 2019 for the second year in row and the largest importer in the world.

Also , considering the ambitious growth plans of steel production to achieve 300MT by 2030 reflected through the National Steel Policy 2017 ,it is evident that same will be on shoulders of the BF-BOF route. This also estimates coking coal requirement of 160MT approx. and 31MT of PCI. We can imagine that the global supply of coking coal will become largely dependent on India than ever before.

There has been considerable restructuring in the Indian steel industry amongst the major steel manufacturers in recent times .TATA Steel aquizition of Bhusan Steel & Usha Martin, JSW aquizition of Monnet Ispat, Vedanta aquisiziton of Electrosteel Bokaro Unit and Arcelor Mittal-Nippon Steel Sumitomo acquisition of Essar Steel is expected to bring major changes in coke making thus effecting coking coal blend and procurement style .Also, the increase in number of larger size BF amongst TATA Steel, JSPL,JSW is transforming coal procurement in terms of low volatile HCC and PCI.

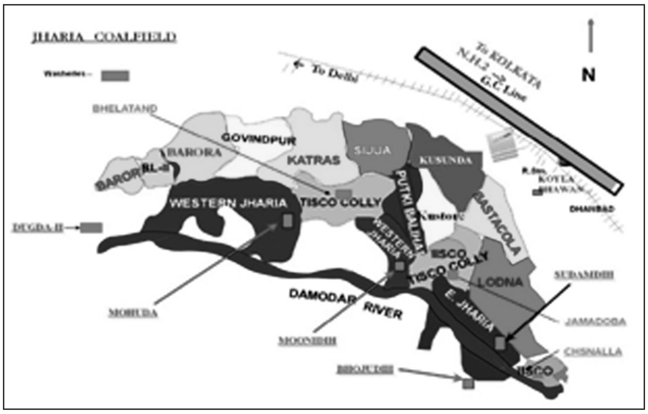
2020 has been a difficult year for the steel industry globally and India suffered no less. Major Indian steel mills had cut production during Q1 2020-21 to an extent of 50% and smaller steel mills witnessed total shutdown .This lead to drop in coking coal consumption to half on both domestic and imported font. Port stocks were all time high in Q1 , nearly double of its regular volumes due to paralysed logistics services as total lockdown hindered with movement of human resources involved in various activities. However, this situation gradually recovered in Q2 and as we stepped in Q3 , all of major steel mills in India had reached back to optimal production levels thus stabilizing coking coal consumption to almost 5.5MT per month.

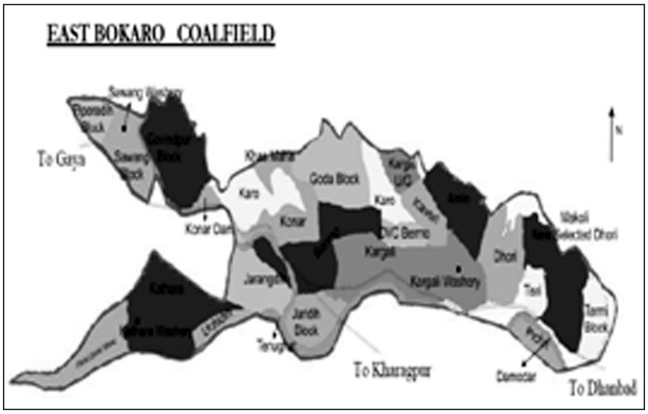
Prices of coking coal in the global market remained volatile as suppliers continued to battle demand disruptors like lockdown due to COVID 19 in Q1 of 2020-21 and later in Q3 , cut down in import from Chinese steel mills . Indian imported coking coal demand is believed to be annually contracted with index linked price formulae for major part of the quantity ,thus exposing them to the price volatility in exchange for raw material security .Hence, global coking coal prices have somewhat determined the revenue of Indian steel industry and presently there are no means by which the Indian inc or the Government can control this exposure.

Domestic coking coal availability in FY 2020

The two major producer of coking coal in India, BCCL & CCL witnessed loss of production due to

COVID pandemic .Whereas domestic production of TATA Steel and SAIL was in line to previous years.





Picture of major coking coal producing area in India

During April-September (H1) of 2020-21 (FY21), coking coal production by CCL stood at 5.51 mt, down 33 percent as compared to 8.22 mt during the corresponding period of the last fiscal.Earlier, coking coal production by CCL in FY20 surged to 20.013 mt from 9.34 mt in FY19.

During April-September (H1) of 2020-21 (FY21), BCCL's coking coal production stood at 9.65 mt, down by 11 percent as compared to 10.82 mt in the corresponding period of the previous fiscal. Earlier, BCCL saw a 5.9 percent increase in its coking coal production during 2019-20 (FY20) at 25.79 mt as compared to 24.34 mt in 2018-19 (FY19).

90% of this is currently sold to power plants as ROM coal with 35-50% ash or after de-shaling at <34% ash.The other was usually sold to small cookeries based in eastern region (Dhanbaad area), who are producing low quality ,high ash coke ,not suitable for large BF operation.

SAIL produced around 0.3MT of washed coal in FY 20 ,April to September,around same level as in 2019 .

TATA Steel produced approx. 1.8MT of ROM coal in FY 20, April to September, slightly lower than same time of year in 2019.

As per National Steel Policy (NSP) 2017 objectives, domestic availability of washed coking coal has to be increased so as to reduce import dependence on coking coal from 85% to 65% by 2030-31. At present India has nine washeries washing 28.1 mt of Indian coking coal and 11 more washeries are to come up by December to wash 20.59 mt of coking coal.

Difficulties associated with the processing of LVC coal are well known. Apart from geological challenges like depth of resources, all the processing options proposed to date indicate that to efficiently wash this particular type of coal, it would be necessary to address the problems associated with the following.

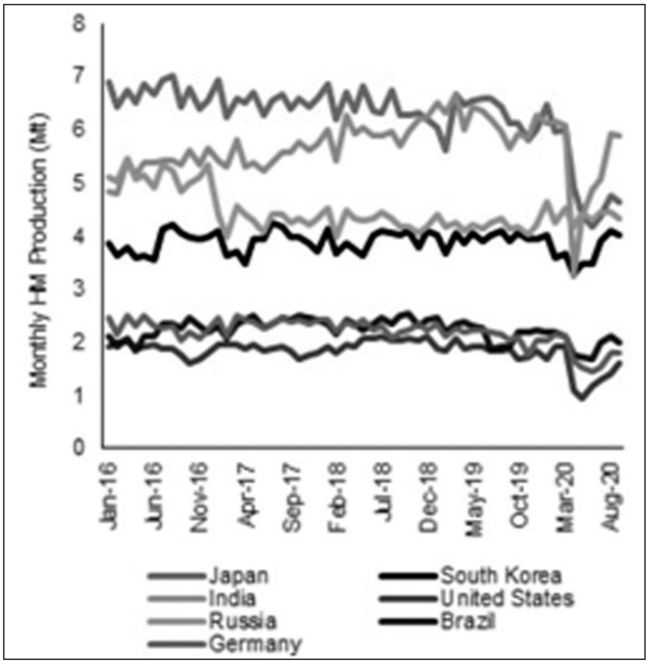
- Mindset of the coal preparation fraternity with respect to the washing of small and fine coal
- Crushing of ROM coal to -13mm or even -3mm
- Availability of quality magnetite for DM processes
- Processing of fines including flotation and dewatering

India coking coal demand and global trends

India emerged as a major importer of coking coal with a share of 18% along with China (22%) and Japan(20%) in FY 20.Once again bulk of imports happening from Australia (65%) , followed by Canada ,Russia ,US and Mozambique.

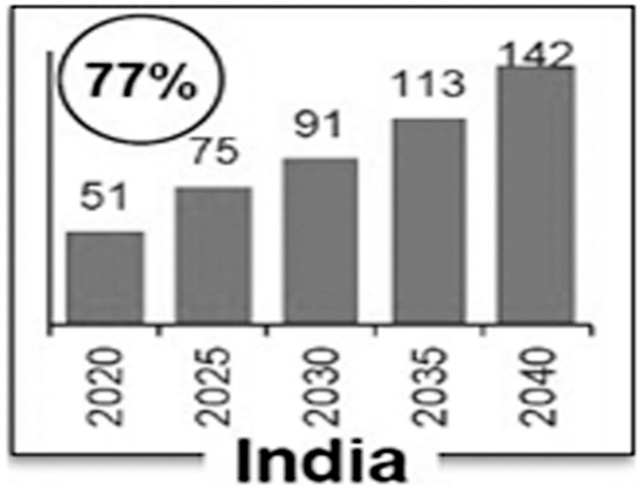
India witnessed steady growth rate in hot metal production in CY 19 ,however during April-Sept'20 production was at 30.178 mt, down by 17.6% compared to previous year. Coking coal import followed similar trend at average of 2.6-2.7MT from April-July '20 ,but saw a rebound in August to 3.2MT in

August'20 following to 3.25MT in Sept'20. Indian major steel mill usually contract for the full year upto 90% of their requirement.In times of COVID pandemic, 40% of the contracted coal was pushed to the following quarter to reduce inventory.

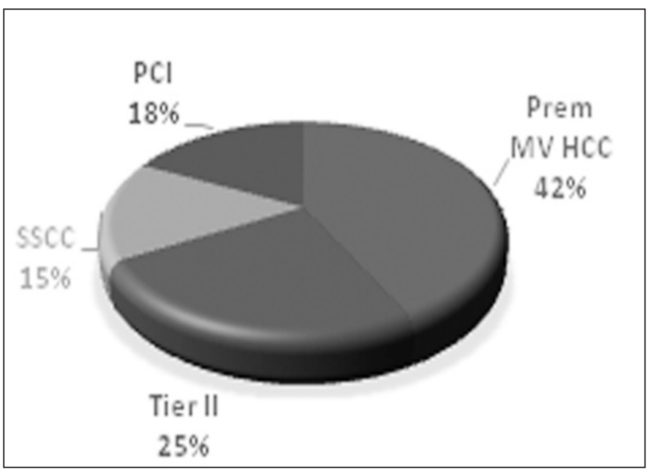


Hot metal production from 2016-20

Going forward,the vast majority of steel projects being proposed to date are integrated BF-BOF mills, which we think will increase in share from 48% in 2019 to 74% in 2040. BOF production rises from 53 Mt in 2019 to 209 Mtpa by 2040 .This indicates a growth of coking coal imports in excess of 140MT by 2040.Thus accounting for a 77% share of global growth ,considering total metallurgical coal trade to be little excess of 400MT in 2040 from 286MT in 2020.Needless to say that the global metallurgical coal sector is staring at India as its only saviour.



Indian steel mills usage of various category of coking coals have changed over years,as shown below :



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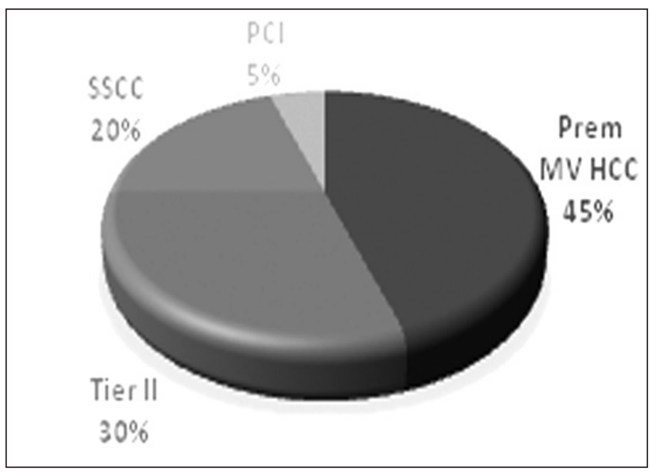


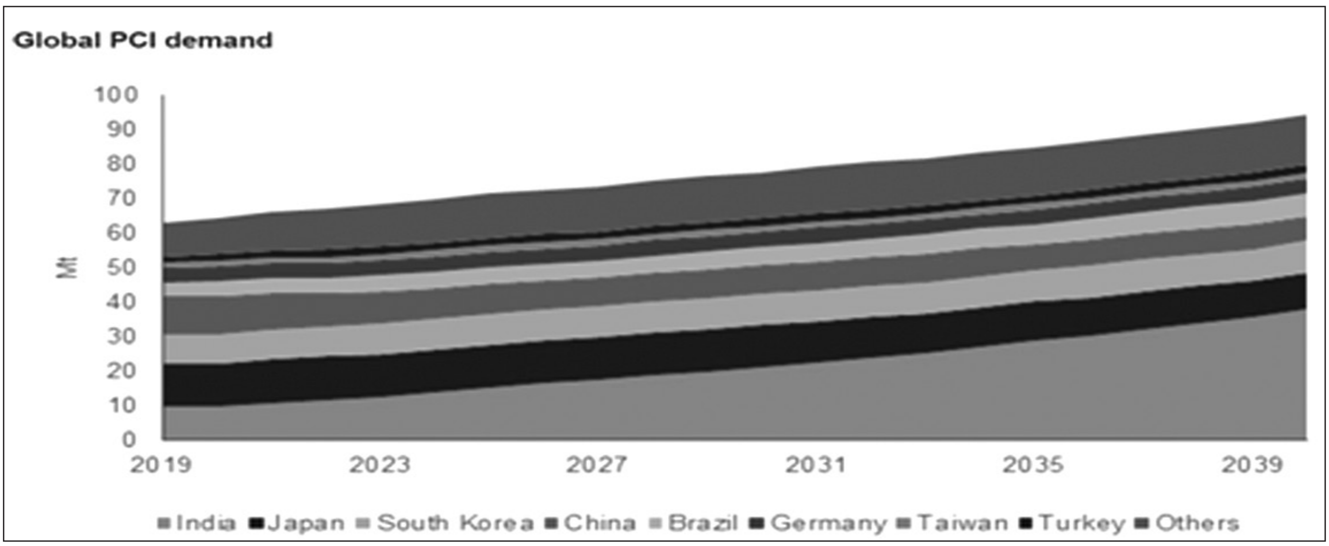
2020

The change in blending style over years took place mainly due to requirement of higher coke strength and cost optimization measures like introducing more weaker (semi soft) coals with coking properties compared to mid volatile PCI in blend ,which had no coking properties. There was also considerable importance given to diversification as volumes kept increasing, in order to minimize the risk of non-supply from a particular origin that might occur due to several factors.

<u>Major changes in consumption of coking coal & PCI going forward</u>

New BFs in India will be large and, as discussed earlier, will typically be operated using high CSR cokes, and high PCI rates. This will help propel global PCI demand to 94 Mtpa by 2040, from 63 Mt in 2019, making it the fastest growing metallurgical coal .Indian PCI usage has doubled since 2017, reaching around 10 Mt in 2019. Existing mills have quickly ramped up PCI usage in recent times which has enabled the growth to date. PCI rates of 150kg/thm are commonplace now as operations at new blast furnaces have stabilised, and new mills will be using similar PCI rates. We expect overall import demand to grow to 38 Mtpa by 2040 with average PCI rates reaching 155kg/thm.

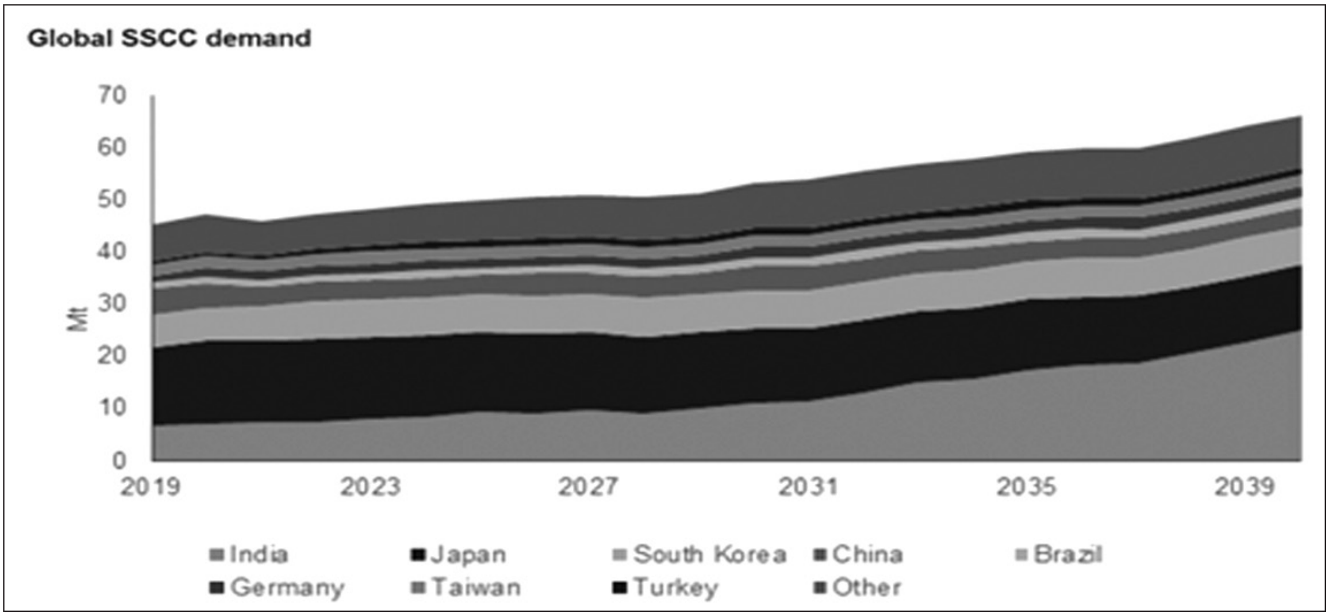
The push to decarbonise steel may see a new rivalry grow from natural gas or hydrogen over the long-term, particularly if carbon pricing spreads across the world. Potentially low conversion capital costs could see PCI demand whittled down if hydrogen production, transportation and storage costs reduce over time. In November 2019, Thyssenkrupp successfully tested hydrogen injection in one tuyere out of 28 at its blast furnace 9 in Duisburg, Germany. According to the company, they intend to test run hydrogen in all tuyeres of the blast furnace by 2023.



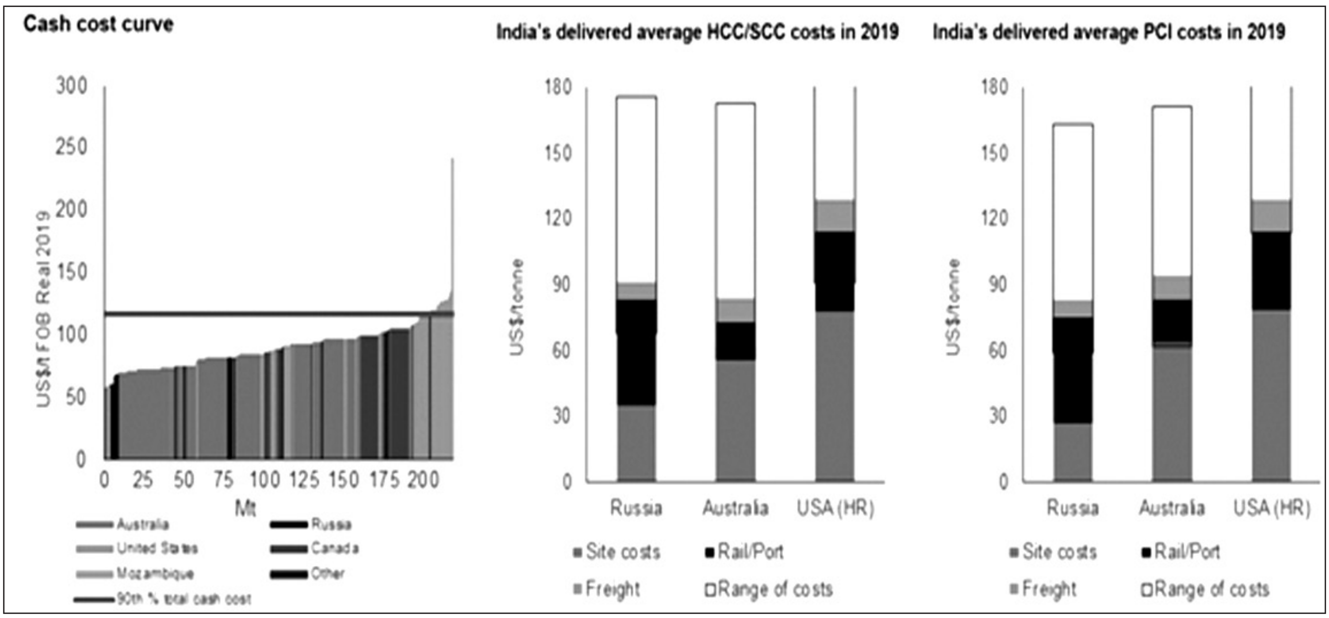
We also estimate SSCC makes up about 20% of the coke blend, at 11 Mt in total. Over time, we think this value will increase to 30% which will mean SSCC use of 42 Mtpa by 2040.

Despite domestic production rising from 5 Mtpa to 17 Mtpa as forecasted , India will need to increase imports by 18 Mtpa by the end of the forecast period. India is responsible for almost all of global demand growth in SSCC.

Technology will assist in SSCC use. Tremendous efforts have been made in using higher percentages of lower-quality coals like semi-soft in the blends to lower feedstock costs in ironmaking. Japan's Nippon Steel has been on the forefront of the research and commercialisation efforts with their process called SCOPE 21 or *Super Coke Oven for Productivity and Environmental enhancement toward the 21st Century*, which had the initial aim of using 50% semisoft coal.

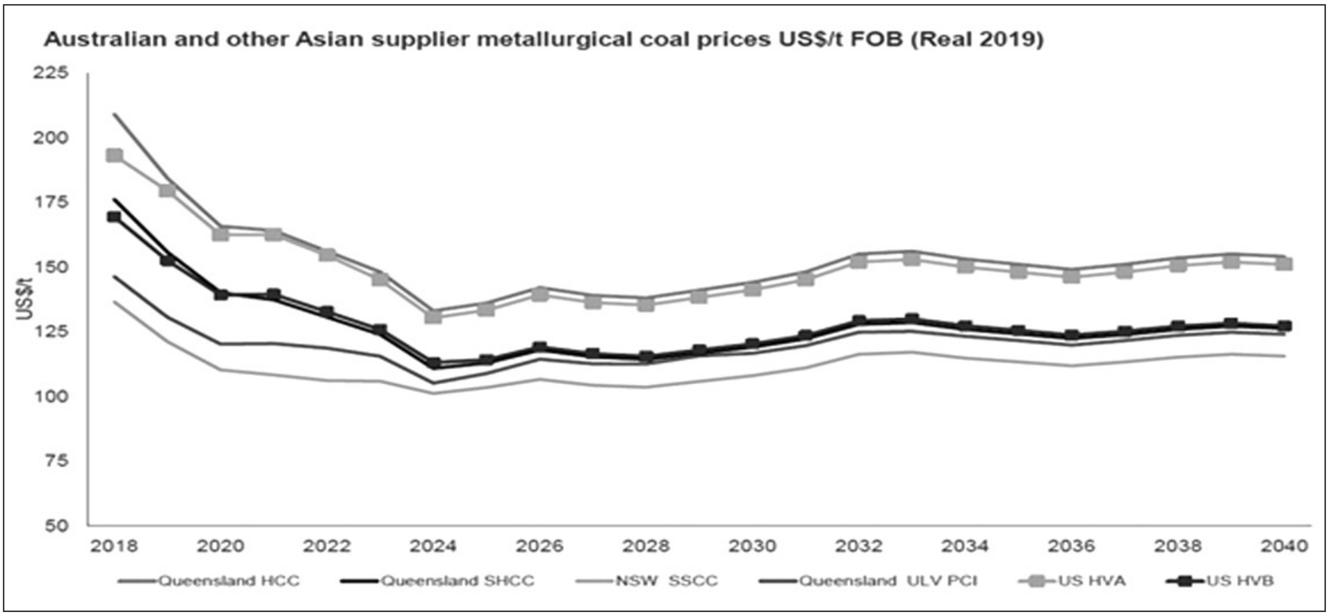


Prices of coking coal & PCI at present and future situation



Prices are unlikely to fall below above level for long periods of time. There is of course the risk that Australian suppliers accept lower prices for short periods. The marginal cash cost at Australian ports is currently around US$100/t, excluding sustaining capital, and so while it looks unlikely, prices well below US$130/t are possible for short periods.

It is worth reiterating the uncertainty over the exact timing of the transition. Prices payable by India is highly influenced by Chinese buying,A classic example is firm HCC prices during July-Sept’20 quarter when the world including India was reeling the pandemic effect but Chinese hot metal production was increasing ,however during Oct-Nov’20 ,prices fell sharply as Chinese mills stopped importing Australian HCC due to its quota restriction and trade war with Australia.



The period beyond 2020 in which Chinese hot metal demand first plateaus, and then falls, is a critical period of uncertainty. The pace of change in demand for coke and coking coal in China, the cost of coking coal supply, and the government's approach to the steel and mining sector, is highly opaque at this stage. The most likely scenario to be one in which demand, cost and price for coking coals fall gradually in China over a 4-year period. Most probable scenarios will show a reduction in price in China as demand falls, but it is the timing and pace of such falls that is hardest to predict.

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Technical Note

Upgradation of Low Grade Manganese Ore Using Different Beneficiation Techniques

– Sudhanshu Kumar Singh[1], Puja Gorai[2],
Maharshi Ghosh Dastidar[1], Arghya Majumder[3], Rajib Dey[4]

Abstract

The lean grade pyrolusite ore, mainly consist of SiO_2, $AlPO_4$, Mn_3P, Mn_4FeSi_3, Ca_3 $(Al1_{.33}Fe_{0.667})$ Si_3O_{12}, has been collected from Vizag steel. To expose the vital minerals ((MnO_2, Fe_2O_3) from ore first important elementary operations (i.e. jaw crushing and roll crushing) have been done, which are known as comminution. After that, these crushed particles have been separated by sieving. Additionally, the particles are scrutinized by XRD (phase analysis) and XRF (composition analysis). On the basis of phase and composition analysis, it has been found that there is a broad specific gravity difference between the essential minerals ((MnO_2, Fe_2O_3) and the gangue (SiO_2, Al_2O_3, K_2O). Therefore, gravity concentration beneficiation processes (jigging and tabling), have been adopted to concentrate coarser particle and finer particles having size range of 3-10mm and 400-50 microns. During the jigging operation due to pulsation and suction of the liquid medium (i.e. water), the bed lifts and tends to separate the coarser heavy particles from light particles in each cycle. Due to exhibition of better stratification of coarse particles, short jigging cycle has been adopted for the operation. Similarly during tabling operation due to the thru and fro motion of the table, the heavy particles are streamlined with the riffle, and the lighter particles are suspended into the water and come out from the tailing side. Both jigging and tabling of the samples led to the upgradation of the low grade manganese ore. Jigging has given a concentrate recovery of 71.9% with 32.4% Mn whereas tabling has given a concentrate recovery of 73.32% with 35.12% Mn.

Introduction:-

In the present situation, manganese has been considered as the 12th most profuse metal in the earth's crust [1]. Due to its abundant resources, manganese ore production has been increased to 8 million tons/year all around the world whereas production of manganese alloy has been increased to 6 million tons/year. Meanwhile, due to its huge consumption, the demand as well as production are increasing. Globally, manganese consumption has been dominantly used by industries like construction(23%), machinery (14%) and transportation (11%)[2].

From the last few years, the use of manganese ore and its alloy have been tremendously increasing (90-95%) in the steel sector, while 5% have been used by chemical, paint, fertilizer, and battery [3].Generally manganese has been used in steel industries in form of ferromanganese, because iron helps to decrease the melting point in combined form compared to pure manganese and also more economical in terms of energy & cost of raw materials. Ferromanganese has been considered as the most common ferroalloy which can be called as tonnage ferroalloy .It shows metallic form, remains brittle and hard

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in nature at room temperature, while it melts at 1244^{0}C.Therefore, the demand increases due to its essential properties, and presently no technology can replace manganese in the iron and steel sector. Additionally, it has been used in non -ferrous industries such as aluminum, copper. In addition to that, there have been certain other functions such as, it acts as a deoxidizer due to its lower standard free energy change for oxide formation, desulphurizer (avoid formation of iron sulfide), refining and impart numerous properties in steel industries i.e. hardenability, machinability, wear resistance and grain refining[4].

Due to the huge demand of manganese in the world rapid depletion of high grade manganese ore takes place whereas there are huge availability of low grade manganese ore. India itself is the huge producer of lean grade Mn ore. According to the report published by ministry of mines,68% of the total production is of lower grade (below 35% Mn), 21% of medium grade (35-46% Mn) and 10% is of high grade (above 46% Mn). Production of manganese dioxide is 35,783 tonnes during the year [5].

Now a day's researchers are facing the major challenges for upgrading the low grade manganese ore to fulfill the demand of industries. At the same time, researchers have been trying to find out the cost effective and efficient technology to upgrade the lean grade ore. From the past few years, several studies have been conducted to upgrade low grade manganese ores (<40%), via comminution, beneficiation followed by pyro-metallurgical reduction or hydrometallurgical route [6-9]. Meanwhile, a high amount of gangue has been present in low grade ore which creates numerous obstacles during washing while gangue also increases the required amount of energy during upgradation.

Hence several beneficiation process such as jigging, tabling (after crushing) should be adapted on low-grade manganese ore to remove the gangue and improve its Mn percentage. Nowadays a wide range of size fraction of lean grade ore has been beneficiated by various gravity separation beneficiation processes. Specially jigging and tabling are the most common and cost effective gravity separation process used in industries for iron ore and the main aim is to use these process to upgrade Mn ore also because the specific gravity of pyrolusite is almost near to the iron ore.

Jigging has been considered as the economical and easy process to separate the coarse size particles on the basis of gravity. In case of jigging, particles have been separated by pulsation and suction of waters which helps to produce stratification. However solid small and heavy particles will trickle inside the interstices of the bed, while large and high specific gravity particles will segregate due to hindered settling. At the end, separate layers have been formed where the top layer exhibits the lighter particles and bottom as heavier particles [10]. Tabling is also a very economical gravity separation method which is widely used in industries to beneficiate fine size particles (<400 microns) of the ore. Basically Shaking table is slightly tilted from left to right and there asymmetric motion of the table during reciprocation takes place. Due to abrupt thru and fro motion of the table heavy particles settle down in bottom and gangue which are lighter are suspended into the water and are discharged out over the edge of the left portion of the table.Those heavier particles follow the stream line water and are collected on the concentrate portion at the extreme right side of the table. The particles having lower specific gravity than heavier particles but greater than lighter gangue minerals are collected on the middling portion. Middling portion is again charged on the table to get better recovery percentage [11].

In the present study, the low grade manganese ore has been characterized.On the basis of characterization up gradation methods such as comminution, gravity concentration has been carried out to increase the Mn/ Fe ratio. The coarse particles (-5.6 to +2.6mm) have been beneficiated by Harz laboratory jig. Meanwhile, the process variables such as particle size, pulsation frequency, and time have been taken into consideration and one of the process variable set has been chosen and experiment has been performed. Similarly, the fine particles (-250 micron to +53 micron) have been beneficiated by laboratory Wilfley Table.The process parameters like particle size, flow rate and angle of the beneficiation processes leading to the highest concentrate separation have been selected. Chemical analysis of the concentrate for the jigging and tabling tests with highest concentrate percentage has been carried out to find out the manganese percentage in the concentrates. The Mn% in the concentrate helps us to determine the best beneficiation technique for specific size range of samples and the optimal level of different parameters.

Materials and Methods:-

Lean grade pyrolusite ore has been collected from RINL Vizag, India and it has been analyzed by several characterization method. First ore fines have been mixed homogeneously and XRF (X-Ray florescence) characterization method has been carried out to know the chemical composition of raw ore followed by XRD method to know about the phase present in the ore.

After analysis, different range of particle size have been selected to conduct the experiment on jigging and tabling. To obtain these particle sizes first ore has been crushed into jaw crusher, roll crusher and followed by the pulverizer. After that, these crushed ore has been aligned by sieve of different size ranging from –10mm to +53 micron. The basic difference between jigging and tabling is that jigging is used to handle coarser particle whereas tabling is used for handling fine particle. Hence,size ranging from -5.56 mm to +2.36 mm has been collected for jigging operation and size ranging from -250 micron to +53 micron has been collected for tabling operation.

Method for Jigging Operation:-

By trial and error method independent parameter like ore size pulsation frequency and time has been chosen. Size ranging between -3.36 to +2.36mm has been chosen. High pulsation frequency i.e. 1100 rpm has been taken and 11 min time has been chosen for the experiment. For experiment 100 gm of sample has been charged. After getting concentrate %, this experiment with the same parameter, has been repeated twice to validate whether the obtained concentrate is approximately same or not. Then to dry the sample, it has been charged into hot air oven.

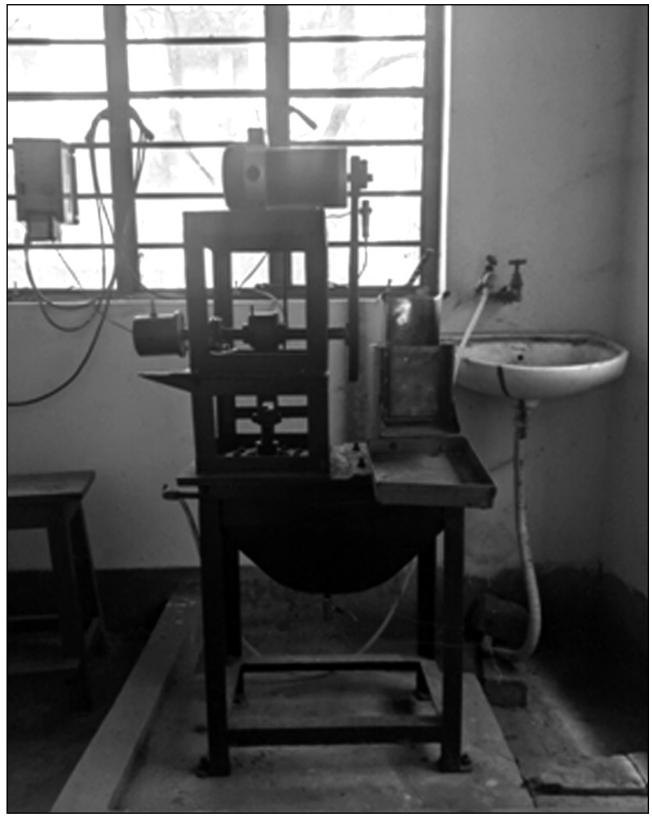

Fig.1 : The Jigging Machine

Method for Tabling Operation:-

Similarly, for tabling operation, three independent parameter like ore particle size, angle and flow rate has been chosen. Here frequency cannot be chosen because in Wilfley table the motor used has constant frequency. But here flow rate is a controllable variable so instead of frequency, flow rate has been taken into consideration for tabling operation. Size ranging between -150 microns to +53 micron has been chosen, 4 lit/min flow rate and angle 5^0 has been chosen for the experiment. For experiment 70 gm sample has been charged. Same as jigging, experiment has been repeated two extra times with the same parameters to validate whether the obtained concentrate is approximately same or not

After conducting the experiment, concentrate collected after each experiment for both jigging and tabling has been dried into the hot air oven at 100^{0}C for an hour. After that the weight of the each sample has been taken and finally the chemical composition of each dry concentrate has been analyzed by chemical analysis to see whether the ore has been upgraded or not.

Fig. 2 : Wilfley Table

Results and Discussion:-
Characterization of Raw Material:

Figure 3: Pyrolusite ore samples collected from RINL.

The samples have been collected form RINL, Vizag. The sample has been broken down below 75μm followed by WDXRF and XRD analysis to get the composition of the ore and the main phases present.

Chemical Analysis									
T.Mn	**T.Fe**	**SiO_2**	**Al_2O_3**	**TiO_2**	**CaO**	**MgO**	**P**	**Na_2O**	**K_2O**
20.15	15.79	12.34	5.71	0.30	1.55	0.14	0.29	0.07	0.87

Table 1: WDXRF analysis of ore.

The XRF analysis demonstrate in Table 1 indicates that ore mainly consist of 31.98% MnO_2, 22.55% Fe_2O_3, 12.34% SiO_2, 5.71% Al_2O_3, 0.3% TiO_2, 1.55% CaO ,0.14% MgO, 0.29% P, 0.07% Na_2O, and .87% K_2O. Therefore, majority of the compounds have been manganese oxide and iron oxide. Hence its characteristics imply a pyrolusite ore. Apparently, manganese has been present in fewer amounts, so we could name it as a lean grade manganese ore. Apart from that, there have been other dominant elements such as silica, alumina, and lime.

It has been clear from the XRD plot shown in figure 4, that the majority of phase reveals quartz and manganite which could be called as SiO_2. Additionally, alumina has been present in the form of corundum.

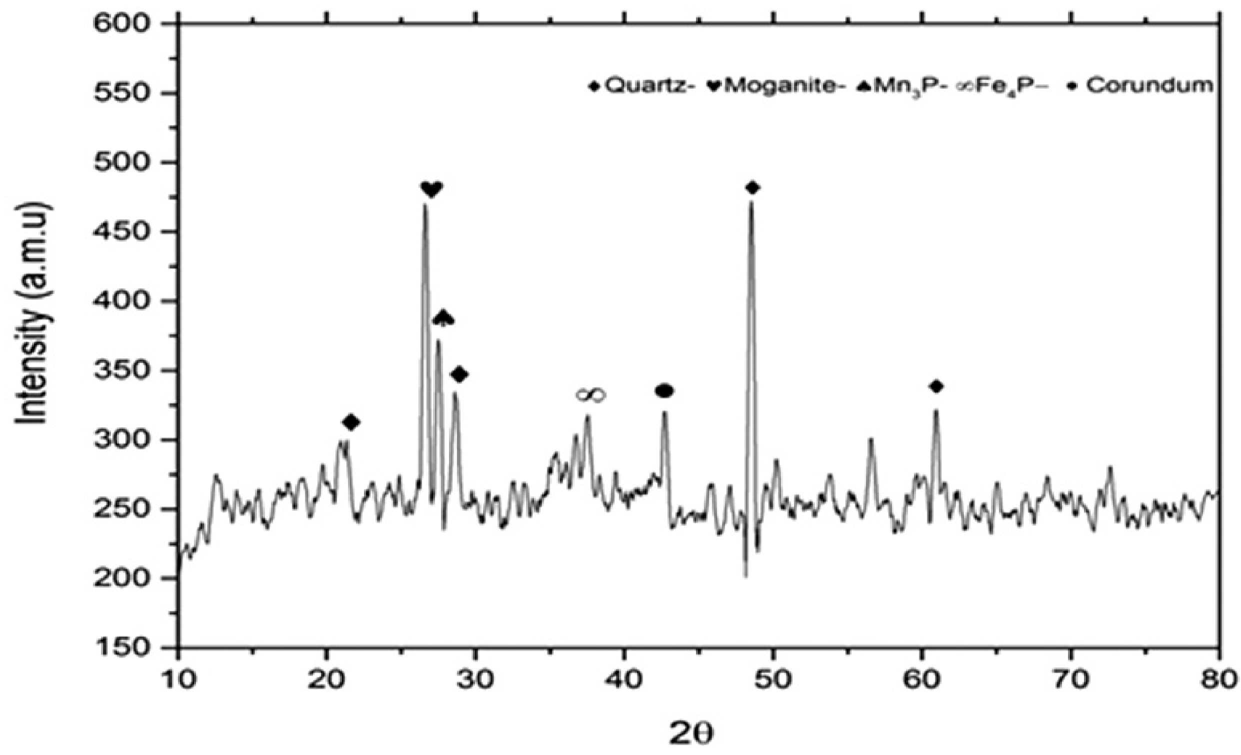

Figure 4 : XRD plot of pyrolusite ore

Manganese and iron have been present in a minute amount in the form of Mn_3P and Fe_4P. Hence, it has been confirmed from the XRD analysis that the ore could be named as lean grade manganese ore and alumina and silica have been dominantly present.

3.2 Comminution

Initially, the ore has been crushed using a jaw crusher followed by roll crusher. Therefore the size has been reduced as mentioned below:

Table 2 Primary crushing product size

Jaw crusher	-10mm to +5mm
Roll crusher	-6.30 mm to +2.36mm
Pulverizer	-400 micron to +53 micron

3.3 Jigging

The lean grade ore has been beneficiated by laboratory jig having screen aperture of 1mm whereas the ore size has been in between -6.30mm+2.36mm. The effect of three factors has been analyzed such as particle size, pulsation frequency (rpm), and time in the jigging experiment. In addition to that, the performance of the jigging or response has been acknowledged by the concentrate percentage. In this case, the mineral has been stratified in three layers based on the basis density as shown in figure 5 where light particles exhibit the gangue. Simultaneously with the passage of time the light gangue like silica, alumina will come out due to water pulsation whereas heavy mineral like iron oxide, manganese oxide will remain on the screen. Therefore mineral and gangue separated as shown in figure 6 and 7 with the help of gravity separation. Jigging was performed with sample size of -3.36 to 2.6 mm at 1100 rpm for 11 minute and the best upgradation was achieved with concentrate percentage of 71.9%.

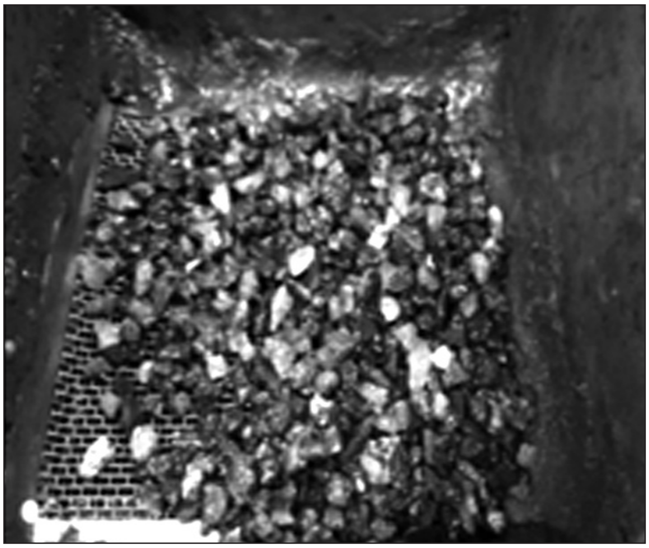

Figure 5 : Stratification of bed after jigging operation

Figure 6 : Mineral collected after jigging operation

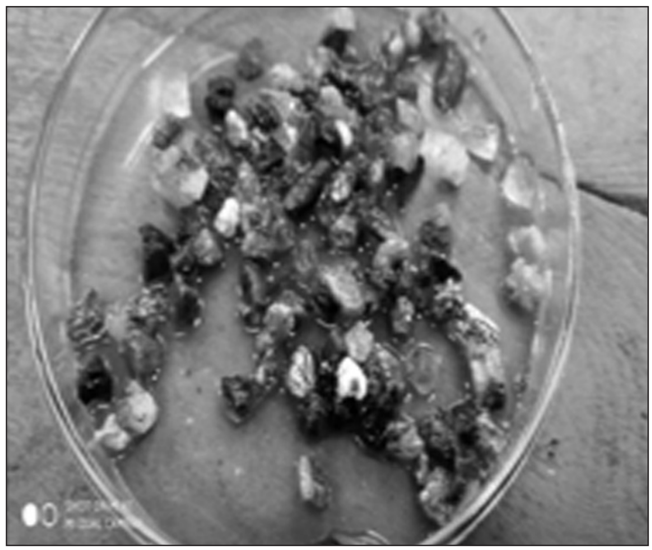

Figure 7 : Gangue collected after jigging operation

Tabling:

Wilfley table used for the experiment is a gravity separation process which is slightly tilted from left to right and has asymmetrical motion. It has slower motion in forward direction and fast motion in reversedirection. This would help the mineral particles to slide along the cleats and riffles fixed on thetable along the direction of the motion of the table. Clean water flows over the table at perpendicular direction of the motion of the table. Feed has been introduced at the feed box in the upper cornerof the table get scattered by the action of combined motion of the table and flow of clean water over the table. 70 gm sample of size -150 micron to +53 microns has been charged from the feed box. This 70 gm of sample has been scattered into three different collectors namely concentrate, middling and tailing after charging into the table during tabling operation.Then wet samples after tabling operation have been collected from three different collectorscontaining concentrates, middling and tailing and then dried for weighing and chemical analysis.

Tabling was performed with sample of -150 micron to +53 micron at 4 lit/min flow rate, 5^0 angle and the best upgradation was achieved with concentrate percentage of 73.32%.

Chemical Analysis of the Concentrates from Jigging and Tabling:-

1. 0.3 gm of ore was added into 10 ml of conc. HCl and 3 ml of conc. $HNO_3$to prepare 100 ml of standard $MnSO_4$ solution and the mixture was heated till the white fume of SiO_2 started to evolve.
2. Now the dissolved solution was cooled at room temperature and distilled water was added into it to make it 100 ml solution.
3. Now standard solution of $KMnO_4$ of 0.1 N was prepared.
4. Now 10 ml of diluted solution of ore was taken and 2 to 3 drop of 2N HNO_3 was added to it and the solution was heated into the water bath at the temperature of 40 to 60^0C.
5. After that hot solution was titrated with standard .1N $KMnO_4$ solution with constant shaking.The end point was faint pink colour to supernatant liquid which was persisted even after vigorousshaking. After that the burette reading was noted down. Which gave the idea of Mn % by calculation.

Burette reading for jigging sample = 5.9 ml
Burette reading for tabling sample = 6.4 ml
According to the standard rule 1000 ml of 1N KMO_4 shows that solution have 16.42 gm of Mn.

Hence for Y ml of 0.1 N KMO_4 = $Y*0.1*\frac{16.42}{1000}$ gm of Mn in 10 ml $MnSO_4$ solution.

Therefore Mn in 100 ml solution of 0.3 gm of ore = $Y*0.1*\frac{16.42}{1000}*10$ gm.

So after calculation it has been found that Mn present in jigging sample is 32.4 % and Mn present in tabling sample is 35.12%.

Conclusion:-

During Jigging, it has been observed that the concentrates collected while operating with the following parameters: sample size of -3.36 to 2.6 mm, 1100 rpm, for 11 minute has the highest concentrate percentage of 71.9 %.The Mn% in the concentrate achieved via Jigging is 32.4%.

Tabling gave the best separation/upgradation when operated maintaining the following parameters: sample size of -150 micron to +53 micron, at 4 lit/min flow rate and 5^0 angle tilt, with a concentrate percentage of 73.32 %. The Mn% in the concentrate achieved via tabling is 35.12 %.

Overall increase in Mn% in jigging and tabling with respect to initial Mn% are 61.32% and 74.55 %. Hence, it can be concluded that both jigging and tabling can be viable options for the upgradation of low grade manganese ore depending upon the particle size of the ore.

Here, conclusion has been drawn with one set of parameters but in the future mathematical modeling can be used to derive the optimized parameters for maximizing the efficiency of the beneficiation process.

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The members are requested to send contributions for the columns of the MGMI News Journal, like "Technical Articles" related to the mineral industry on topics dear to the members, Articles as Case History on various mine practices in the field, interesting write-ups for "Down Memory Lane", "Opinion" on burning issues of the mining industry, "Safety & Health" issues, research findings for "Technology Updates", etc.

Down The Memory Lane

– D. N. Bhargava*

After completing four years at Banaras Hindu University, I bade farewell to the Alma- Mater. When I returned to Jaipur I learnt that the Owner of Jaipur Mineral Development Syndicate which operated a Soap-stone Mine Seth Sohan Mal Golecha had offered to my father to take me as an Assistant Mine Manager of his Steatite Mine. But I did not avail of that offer. Similarly, I did not accept an offer of managing a semi-mechanised Mine belonging to another friend of my father. I thought if I devoted three years at that time as an apprentice in coal mines and passed the First Class Manager-ship examination, I could become Manager of a Coal Mine. I was already assured of the apprenticeship in a Coal Mine. By virtue of my academic record I had secured an appointment as an Apprentice at Bhutgoria Colliery of a well-known Company. It could enable me to study simultaneously for the First Class Certificate examination. Without that certificate a Graduate in Mining Engineering had little value in Coal Mining. But there was no such restriction in Metal Mining although the salaries in metal mining were much lower.

On my way from Jaipur (My home town) to Dhanbad for going to Bhutgoria Colliery I had stopped at Banaras Hindu University. There, I had met Dr. V.A.Altekar, my professor of Ore-Dressing. He was of the view that I had very good grasp of the subject of Ore-Dressing, so I should give up the idea of a career in coal mining – even though it was more lucrative- and instead pursue the subject of Ore-Dressing. He advised me to apply for a Research Studentship in Atomic Energy Commission(AEC) This post had recently been advertised. Going by his advice, after reaching Dhanbad I applied for the Research Studentship in AEC, Mumbai without ascertaining about the immediate prospects; I was driven only by the hope of securing a Doctorate in Ore Dressing. It could lead me to become a Research scientist in Ore-dressing, a specialized field.

I had hardly completed a month as an apperentice at Bhutgoria Colliery when I got a call from Atomic Energy Commission for interview for the job of Research Student. I attended the interview at Mumbai; I was selected. So I packed up from the Coal Field and joined the Ore-dressing laboratory of the atomic energy Commission. I discovered my mistake soon but it took one and a half years before coming back to Mining. I worked successively as Assistant Quarry Manager at Opencast Mine of Lime Stone in Associated Cement Companies Ltd. (ACC), Quarry Manager in Project Planning Department of Nangal Fertilizer & Chemicals (NFCL), Deputy Controller of Mines in Indian Bureau of Mines (IBM), Mine Manager in Sallitho Ores Private Ltd at Pale, Goa. and finally back to Indian Bureau of Mines.

I must explain a bit the reasons for changing jobs so many times. I had given up of my own accord the apperenticeship in coal mines in preference to a job in Atomic Energy Commission as a Research Student. I had gone by the advice of my professor of Ore-dressing in making this choice. I dreamt of earning a doctorate in Ore-dressing and making a Career in Ore-dressing. But on joining AEC I realized my mistake. There was no studentship, I was given the same job as a Senior Technical Assistant (STA) and was considered even junior to a STA. Then I struggled to get out and landed one and a half years later as an Assistant Quarry Manager in ACC. From here I was picked up only four and a half years later by- NFCL as Quarry

* Life Member of MGMI, Former Controller of IBM, has written a chronicle of his working period in different mines under the title "My Journey into an Unfolding Future".. He has sent an abstract to our readers. His letter is also appended.

Manager. I pointed out to the Project Planning Officer at NFCL that the deposit which I was to develop as a Quarry was too small to justify as a viable project. That project was given up but my superiors wanted me to continue with them. But I decided to change over to Indian Bureau of Mines as a Deputy Controller of Mines even at a loss of 25% of my monthly pay. I earned appreciation in IBM also for my work but my family faced a fall in living standard. I would have continued anyhow. But an incidental meeting with *K.S.Natrajan*- who had been one of my Examiners for First Class Manager's Service Certificate - changed the course of my life. He casually enquired about my welfare. I replied that ever-since I had passed the First Class Manager's examination, I had become a Deputy Controller of Mines. He asked me if I was interested in becoming a Mine Manager again. I replied that in case there was any prospect of getting a Mine Manager's post where my professional seniority was recognized and the job was well-paid, I would certainly be interested. I added that being a DCOM in IBM, I could neither apply for a job elsewhere nor appear in any interview. While saying so, I wondered how a change of job was possible.

I could not imagine that he would be able to get me a job even under these circumstances. He had joined M/s V.M. Salgaocars of Goa. It was the same company which had rejected me earlier on the ground that I did not have experience in Iron Ore Mining. He advised the Chairman V.M.Salgaocar to send me an offer for the post of Mine Manager. The salary, perks and bonus stated in the offer worked out to almost double of my pay as DCOM. So I resigned from Government service and became a Mine Manager in Goa. Three years later an Assistant Controller of Mines spoke to me of a vacancy of two posts of Controllers of Mines in IBM. He took me home to show the advertisement. When I observed that the last date for submission of application was just four days later, and it was impossible even to secure an Application Form, he appeared to be disappointed, as if he had lost an opportunity himself.

I tried to cheer him up and sitting at his house made a hand written application to the Secretary, UPSC giving all necessary details, but I was not in a position to attach a formal application in the prescribed form nor provide any supporting certificates. Hoping for the timely delivery of this hand-written application in the form of a letter, I posted it by ordinary post. Fortunately, it reached in time. I got acknowledgement of my hand-written application as well as a form; I was required to send the formal application again. Perhaps the last date for submission of Application might have been extended.

The UPSC selected me in the year 1970 as Controller of Mines (COM) for IBM. I was aged 39 years while the upper limit for age given in the advertisement was up-to 50 years. Among the two COMs selected, I was placed No1. The other COM was six years elder to me. Mr Hanumantha Rao, my friend who had moved from IBM to Planning Commission wrote to me not to miss this chance; he added that I would be in the line of succession and take over from Mahapatra, the Controller IBM, when he retired after 11 years. I followed the advice of Hanumanth Rao and came back to Central Government service for the third time. Choice of Government service did entail yet again financial loss; but the loss was bearable this time. I got the feeling that purely in terms of professional responsibility I had finally salvaged my professional career. But Destiny had still something in store for me.

Soon after I completed a period of three years I was promoted in August 1973 to the post of Controller of Indian Bureau of Mines. This increased my responsibility significantly. I now supervised not only the functioning of Mineral Conservation Division but also the Ore Dressing Division, the Mineral Economics Division and the Administration division. My jurisdiction now extended to all Metalliferous mines in India**.** Over the years the activities of Indian Bureau of Mines got expanded and diversified and additional responsibility of Technical Consultancy, Geological Mapping, and Publications were undertaken; the areas of Training, and Mining Research were added as additional functions. In January 1982, recognizing the expanded role of IBM my designation was changed from Controller to Controller General. I continued to hold charge of Indian Bureau of Mines for well over 15 years up-to my superannuation.

After superannuation and consequent retirement from IBM I received an offer to serve as a Professor of Mining at RKN Engineering College, Nagpur. I served there during two sessions between 1989 and 1991. During the summer vacations in the year 1990 I visited China for attending World Mining Congress. Thereafter I remained a guest of the Government of China and delivered a lecture on Laws related to Mines in India. to the officers of their Directorate of Mines. Thereafter, accompanied by two Officers of the Directorate and an interpreter, I visited places of tourists' interest across the country for the next 3-4 days. Finally, my last assignment for one year was as a Commonwealth (CFTC)Expert in Namibia; I went there as an Expert for Small- Scale Mining, but recognizing my expertise in Mining Legislation, the Secretary of Ministry of Energy and Mines advised me to draft the Mineral (Exploration & Mining) Act for Namibia in place of my original assignment. But I chose to complete both the tasks; I completed them within about a month more than the originally scheduled one-year period of assignment. That was my last professional assignment on regular basis.

After 1992 I have maintained interest in the welfare of the Mineral Sector and the general welfare of the people at large. The ensuing chapters cover the details of my journey Into an unfolding future. The succeeding chapters unfold the story.

ATTENTION BRANCHES

Branches are requested to send the list of the members of the Executive Committee with their Addresses, Telephone Numbers, and e-mail IDs for maintaining record at MGMI Headquarters. They may also activate their Branches and send Reports for inclusion in the News Journal.

Down The Memory Lane

A Letter of MGMI members from an honorable senior member...

– D. N. Bhargava

Dear Fellow Members

Here is an announcement of the completionof my manuscript of proposed book titled, "My Journey into an Unfolding Future". It is about my memoirs beginning from my education at Banaras Hindu University and covering all my years from 1953 to 1973 tossing between employment in Central Government Organizations and Mines belonging to Private as well as Public Sectors till I got the responsibility in August 1973 to lead Indian Bureau of Mines (IBM), a responsibility I shouldered for nearly 16 eventful years. During those years IBM remained a Department of the Government of India under the Ministry of Steel and Mines. These years were spent on building up the Organization as a premier Institution in India with not only the responsibility of regulating the Metalliferous Mines but also providing services of various kinds to the Government of India and the Metalliferous Mining Industry–a unique mix of responsibilities. On superannuation I worked as a Professor of Mining

Engineering for two years. Finally, I was sponsored by the Common wealth Office- London as an Expert assigned to the Ministry of Mines and Energy, Republic of Namibia. Here I was responsible for drafting the Minerals (Exploration and Mining) Act for Namibia. I also made recommendations for the support by the Ministry to the Small-scale Mining Sector of that country. I spent my retirement years providing Honorary Consultancy

to the Public Sector Mining Cos. Thirteen years after my superannuation the Ministry of Mines nominated me as a member of its Standing Scientific Advisory Group; I remained a member of this group for four years. Even thereafter I continued to interact with the Ministry of Mines occasionally. Besides, I tried to share with the citizens in general my concept of a Code of Conduct for the Citizens for the welfare of the Society as well as the Individual. The book provides a vivid description of the different phases of my life. Before I go ahead with getting the book printed I intend to have some idea about the number of the prospective readers. The intention of writing the book is generally to share the experiences of management as well as administration of mines and to provide entertainment to the readers with interesting situations gone through.

I propose to divert all the money that may be received as Royalty to help needy senior citizens, widows, and needy students of all ages, from the Primary education to University level, whatever could be possible. It could enhance the support that I am already providing by marking 10% of my pension income to such purposes. The Royalty income might make it possible even after I pass away. This announcement is merely to ascertain the interest of Fellow Members in acquiring the book; the assessment of demand will guide me to decide about the print order indicating the copies to be printed. I am keen to keep the price of the book as low as possible. Interested persons are requested to e-mail their replies to me on the following e mail id: deokinandan31@gmail.com Messages could also be sent to mobile number+91 9403658354 or by ordinary mail through Post Office; my postal address is:-

302, Danville Park, Shraddhanand Ashram Road,

Padavu, P.O. Mangaluru – 575004 Karnataka Mobile 940 365 8354

I shall be thankful for co-operation of Fellow Members by way of conveying their response. Print order would be given keeping the response in view.

Upcoming Events

Mines and Money Online Roadshow 2021

06 May 2021 - 18 May 2021
The Mines and Money Online Roadshow is the latest edition to the successful online global event series connecting sophisticated investors from around the world with mining company management teams.
Website: https://minesandmoney.com/online/roadshow.php

Mines and METS 2021

07 June 2021 - 09 June 2021
Mines and METS Online will bring together decision makers of mining companies to meet with Mining Equipment, Technology, and Services (METS) companies to discuss current and future mining challenges, compare innovative solutions, share knowledge, and most importantly do business, all in a virtual and online format.
Website: https://minesandmets.com/

Mines and Money Online Connect – August/September 2021

31 August 2021 - 02 September 2021
In response to COVID 19, Mines and Money's leading international event series for capital-raising and mining investment is now in a virtual and online format. Mines and Money Online Connect brings together miners, investors, financiers, and industry professionals to network, hear market analysis, compare investment opportunities, share knowledge, discuss, debate, and most importantly do business.
Website: https://minesandmoney.com/online/

MINExpo INTERNATIONAL 2021

13 September 2021 - 15 September 2021
MINExpo INTERNATIONAL® covers the entire industry—exploration, mine development, opencast, underground mining, processing, safety, environmental improvement and more.
Website: https://www.minexpo.com/

International Mining and Resources Conference & Expo (IMARC)

26 October 2021 - 28 October 2021
Where global mining leaders connect with technology, finance and the future.
Melbourne Convention and Exhibition Centre
1 Convention Centre Pl, South Wharf, Victoria, VIC 3006, Australia
Website: https://imarcglobal.com/

Future of Mining Australia 2022

28 March 2022 - 29 March 2022
The third edition of the Future of Mining Australia covers a vast range of content spanning the entire mining life cycle, focusing on the innovations and technologies driving the industry forward with senior representation from mining companies, service providers, government, finance and research organisations.
Sofitel Sydney Wentworth
61-101 Phillip St., Sydney, New South Wales, 2000, Australia
Website: https://australia.future-of-mining.com/

MGMI TRANSIT HOUSE

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Rules & Regulations

1. Room Rent is as follows :

Accommodation	AC	Accommodation	AC
Single Occupancy	Rs. 1,500/-	Triple Occupancy	Rs. 2,500/-
Double Occupancy	Rs. 2,000/-	Extra Bed	Rs. 600/-

2. 50% discount will be offered to MGMI member for self occupancy only.
3. Full tariff will be applicable for the nominee of MGMI member.
4. Full tariff for the employees of the Corporate Member or Patron Member.
5. 100% advance has to be deposited for confirmation of block booking (three or more rooms for two or more days).
6. Caution money @Rs. 500/- per day, per room has to be deposited along with room rent in advance. This will be refunded in full or part thereof depending on the damage caused by the Guests.
7. Cancellation of confirmed booking Period Prior to date of Occupancy Cancellation fee to be deducted from advance
   a. Cancellation before Seven days 5%
   b. Cancellation before Three days 10%
   c. Cancellation before One day 25%
8. Check-in time 12.00 noon
9. Check-out time 11.00 a.m.
10. GST : Less than Rs. 1,000/- No GST
    Rs. 1,001/- to 7,500/- 12% (6% + 6% GST)
    Above Rs. 7,501/- 18% (9% + 9% GST)

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