MINES ENVIRONMENT & MINERAL CONSERVATION ASSOCIATION, BENGALURU

MEMC WEEK 2025-26

Souvenir

Host :

R. PRAVEEN CHANDRA

ERM GROUP OF COMPANIES

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INDIAN BUREAU OF MINES
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Oath

MINES ENVIRONMENT & MINERAL CONSERVATION ASSOCIATION

ಗಣಿಯ ಪರ್ಯಾವರಣ ಹಾಗೂ ಖನಿಜ ಸಂರಕ್ಷಣಾ ಸಂಘ

INDIAN BUREAU OF MINES

BENGALURU REGION, KARNATAKA

Pledge

MINES ENVIRONMENT & MINERAL CONSERVATION (ME & MC) WEEK CELEBRATION : 01-12-2025 to 06-12-2025

ಪ್ರತಿಜ್ಞೆ

ನಾನು ಗಣಿ ಪರಿಸರ ಮತ್ತು ಸಂರಕ್ಷಣಾ ಸಪ್ತಾಹದ ಶುಭಸಂದರ್ಭದಲ್ಲಿ ಈ ರೀತಿ ಪ್ರತಿಜ್ಞೆ (ಶಪಥ) ಮಾಡುತ್ತೇನೆ. ನಾನು ಗಣಿಯ ಪರಿಸರದ ಸಂರಕ್ಷಣೆ ಮತ್ತು ಅದನ್ನು ಇನ್ನೂ ಉತ್ತಮಗೊಳಿಸಲು ಎಲ್ಲಾ ರೀತಿಯಲ್ಲೂ ಪ್ರಯತ್ನ ಪಡುತ್ತೇನೆ. ನಾನು ಪ್ರಾಕೃತಿಕ ಸಂಪತ್ತುಗಳಾದ ಗಿಡ–ಮರಗಳು, ಜೀವ–ಜಂತುಗಳು, ನೀರು ಮತ್ತು ಖನಿಜಗಳನ್ನು ಸರಿಯಾದ ರೀತಿಯಲ್ಲಿ ಉಪಯೋಗಪಡಿಸುತ್ತೇನೆ. ಇವುಗಳಿಗೆ ಸಹಾಯವಾಗುವಂತಹ ಎಲ್ಲಾ ರೀತಿಯ ನಿಯಮ ಮತ್ತು ಕಾನೂನು ಪಾಲನೆ ಮಾಡುತ್ತೇನೆ. ನಾನು ಗಣಿಯಲ್ಲಿ ಕೆಲಸ ಮಾಡುವ ಸಮಯದಲ್ಲಿ ಪರಿಸರಕ್ಕೆ ಸಂಬಂಧಪಡುವಂತಹ ನಿಯಮಗಳನ್ನು ಮತ್ತು ಕಾನೂನನ್ನು ಪರಿಪಾಲಿಸುತ್ತೇನೆ. ನಾನು ಗಣಿಯ ಪರಿಸರದ ಮತ್ತು ಪ್ರಾಕೃತಿಕ ಸಂಪತ್ತುಗಳಿಂದ ಗಿಡ–ಮರಗಳು, ಜೀವ–ಜಂತುಗಳು, ನೀರು ಮತ್ತು ಖನಿಜ ಸಂಪತ್ತನ್ನು ಸರಿಯಾಗಿ ಉಪಯೋಗಪಡಿಸಿಕೊಳ್ಳಲು ಬೇಕಾಗುವಂತಹ ಶಕ್ತಿಯನ್ನು ಸರಿಯಾದ ಮಾರ್ಗವನ್ನು ನನಗೆ ನನ್ನ ಸಹೋದರ, ಸಹೋದರಿಯರಿಗೆ ತೋರಿಸು ಎಂದು ದೇವರಲ್ಲಿ ಪ್ರಾರ್ಥಿಸುತ್ತೇನೆ.

प्रतिज्ञा

खान पर्यावरण एवं खनजि संरक्षण सप्ताह के शुभ अवसर पर, मैं प्रतज्ञि करता हूँ, मैं खान मैं पर्यावरण के बचाव एवं बडाने केलिए सभी संभव प्रयत्न करूंगा। मैं पैड–पौधें, जीव–जंतुओ, पानी एवं खनिजों जैसी प्राकृतिक संपदा का सहीं ढंग से उपयोग करूंगा। मैं खान मैं काम करते पर्यावरण के बचाव से संबंधित सभी कानून एवं नियमों का पालन करूंगा। मैं भगवान से यही प्रार्थना करूंगा की मुझे एवं सभी भाई–बहनों को प्रकृति एवं पर्यावरण के बचाव एवं बढाने के साथ खनिज संपदा का सही उपयोग करने के लिए शक्ती दे एवं सही मार्ग दिखाए।

OATH

On the auspicious occasion of Mines Environment and Mineral Conservation Week, I take the oath that I shall work for the protection and promotion of Environment by the possible means. I shall appropriately utilise the natural resource like flora and fauna, water and mineral wealth. I shall abide by the rules and regulations framed for protection and promotion of environment. I pray the God to give strength and show the right path to me and my beloved brothers and sisters for the protection of Environment and judicious utilisation of mineral wealth.

MINES ENVIRONMENT AND MINERAL CONSERVATION WEEK CELEBRATION 2025-26

(Under the aegis of Indian Bureau of Mines, Bengaluru Region, Karnataka)

PATRON

Dr. Suresh Prasad
Regional Controller of Mines,
Indian Bureau of Mines, Bengaluru

CO-ORDINATORS

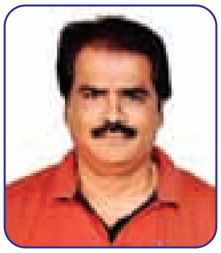
Dr. Sudhakara T. L.
Regional Mining Geologist,
Indian Bureau of Mines, Bengaluru

Shri Sandeep Kumar Singh
Senior Assistant Controller of Mines
Indian Bureau of Mines, Bengaluru

CHAIRMAN

Shri R. Praveen Chandra
Mine Owner & Chairman,
ERM Group of Companies

VICE CHAIRMAN



Shri P. Srinivas Rao
General Manager,
M/s BKG Mining Pvt. Ltd., Sandur

SECRETARY

Shri Dhananjaya G. Reddy
Chief Operating Officer,
M/s R. Praveen Chandra

HON, SECRETARY

Shri Mallikarjuna S.H.M.
General Manager (Mines),
M/s JSW Steel Ltd.

JOINT SECRETARY

Shri Ranadive N.
General Manager (Mines & Logistics),
John Iron Ore Mine

TREASURER

Shri Vinayaka B. S.
Manager (Geology & QC),
John Iron Ore Mine

MINES ENVIRONMENT AND MINERAL CONSERVATION WEEK CELEBRATION 2025-26

EXECUTIVE COMMITTEE MEMBERS – 2025-26

Dr. Meda Venkataiah,
Director, M/s MSPL Ltd., Hospet

Shri Sunil Kumar Singh
Sr. VP (Mines), M/s JSW Steel Ltd., Ballari

Shri D. Hansda
CGM – Production, M/s NMDC Ltd., Donimalai

Shri Anil Kumar
GM (Mines), M/s NMDC Ltd., Donimalai

Shri Rajesh V. Shambrey, Sr. VP (Mines),
M/s Ultratech Cement Ltd., Kalaburagi

Shri G. Laxaminarayana
Sr. GM, M/s RBSSN Pvt. Ltd., Hospet

Shri Mallikarjuna Sarapur
GM (Prod.), M/s KSMC Ltd., Bengaluru

Shri Ravindra Lagwankar, Sr GM (Mines),
M/s Ultratech Cement Ltd., Saralanagar Works

Shri Pradeep Sahoo
DGM (Mines), M/s ACC Ltd., Wadi

Shri Arunachalam K., GM (Mines)
M/s Orient Cement Ltd., Kalaburagi

Shri J. Srikanth
GM (Mines), M/s ZTC, Sandur

Shri Gururaj A.
GM, M/s Hottur Ispat, Hospet

Shri Kumar Mohan Singh
Sr. Manager Mines,
M/s Hutti Gold Mines Co. Ltd. Raichur

Shri Parthiban P.
Agent-Mines, M/s SMIORE Ltd., Sandur

Shri Madhusudhana K.
CEO, M/s MSPL Ltd., Hospet

Shri Shrishaila Gouda
CEO – IOK, Vedanta Ltd., Sesa Goa

Shri V. Bala Subramaniam
M/s Chettinad Cement Ltd., Kalaburagi

Shri Sitaram Kemmannu
GM, M/s SKME Pvt. Ltd., Sandur

Shri Arunava Ghosh
M/s Hutti Gold Mines Co. Ltd., Raichur

Shri Nandan Bhandari
AVP (Mines), M/s JSW Steel Ltd., Ballari

Shri S. Mandal
Agent (Mines), M/s VESCO, Sandur

Shri Pramod Ritti, GM – Geology,
M/s BKG Mining Pvt. Ltd., Sandur

Shri Dilip Singh Panwar, AGM (Mines)
M/s Shree Cement Ltd., Kalaburagi

Shri Debu Singh Shekhawat,
Head - Mines,
M/s Nuvoco Vistas Corp. Ltd., Kalaburagi

Smt. Sarita Dange
AGM (Mines), M/s KSMC Ltd., Bengaluru

Shri Rama Koteshwar Rao,
GM – Mines
M/s Minera Steel & Power Pvt. Ltd., Hospet

MINES ENVIRONMENT AND MINERAL CONSERVATION WEEK CELEBRATION 2025-26

OTHER COMMITTEE MEMBERS – 2025-26

Souvenir Committee

Dr. Sudhakara T. L.
RMG, IBM, Bengaluru

Dr. Meda Venkataiah
Director, M/s MSPL Ltd.

Shri Kumar Mohan Singh
M/s Hutti Gold Mines Co. Ltd.

Shri Pramodharan
M/s Ultratech Cement Ltd.

Shri Sharatkumar Hegde
M/s R. Praveen Chandra

Shri Sandeep Kumar Singh
Sr. ACoM, IBM, Bengaluru

Shri Anil Kumar
GM (P), M/s NMDC Ltd.

Shri Nandan Bhandary
M/s JSW Steel Ltd.

Ms Sanjana Anchan
M/s Vedanta Ltd.

Shri Pintu Layek
JMG, IBM, Bengaluru

Evaluation Committee

Shri Arunava Ghosh
M/s Hutti Gold Mines Co. Ltd.

Shri Mallikarjun Sarapur
M/s KSMC Ltd.

Shri Dhananjaya G. Reddy
M/s R. Praveen Chandra

Shri Bala Subramani
M/s Chettinad Cements Ltd.

Shri Sunil Kumar Singh
M/s JSW Steel Ltd.

Shri Shrishaila Gouda
M/s Vedanta Ltd.

Dr. Meda Venkataiah
M/s MSPL Ltd.

Shri Parthiban P.
Agent-Mines, M/s SMIORE Ltd.

Shri Rajesh Sambrey
M/s Ultratech Cement Ltd.

Shri S. B. Singh
M/s NMDC Ltd.

Shri S. Mandal
M/s VESCO

Shri Sitaram Kemmannu
M/s SKME Pvt. Ltd.

Shri P. Sreenivasa Rao
M/s BKG Mining Pvt. Ltd.

MINES ENVIRONMENT AND MINERAL CONSERVATION WEEK CELEBRATION 2025-26

OTHER COMMITTEE MEMBERS – 2025-26

Zonal Coordination Committee

Shri Mallikarjun S.H.M.
M/s JSW Steel Ltd., Sandur

Shri Vishwanath D.
M/s Ultratech Cement, Kalaburagi

Shri Nirmal Kumar
M/s KSMC Ltd., Mysore & Hassan

Shri Jithendra Reddy
M/s MSPL Ltd., Hospet & Ballari

Shri Prashant Rathore
M/s Shree Cement Ltd., Kalaburagi

Shri Ranadive N.
M/s R. Praveen Chandra
Tumkur, Davangere & Chitradurga

Shri Kumar Mohan Singh
M/s Hutti Gold Mines Co. Ltd., Raichur

Trophy Committee

Shri Arunava Ghosh
M/s Hutti Gold Mines Co. Ltd.,

Shri Nandan Bhandary
M/s JSW Steel Ltd.,

Shri Dhananjaya G. Reddy
M/s R. Praveen Chandra

Shri Sameer Arora
M/s Ultratech Cement Ltd.

Shri Prashant Rathore
M/s Shree Cement Ltd.,

Shri Mallikarjun Sarapur
M/s KSMC Ltd.

Shri Madhusudhana K.
M/s MSPL Ltd.

Shri Shrishaila Gouda
M/s Vedanta Ltd.

Shri Pramod Ritti
M/s BKG Mining Pvt. Ltd.

Website Committee

Dr. Sudhakara T. L.
RMG, IBM, Bengaluru

Shri Manjunath K. S.
M/s R. Praveen Chandra

Shri Arunava Ghosh
M/s Hutti Gold Mines Co. Ltd.

Shri Niranjan Singh
ACoM, IBM, Bengaluru

ಥಾವರ್‌ಚಂದ್ ಗೆಹ್ಲೋಟ್
थावरचंद गेहलोत
THAAWARCHAND GEHLOT
Governor of Karnataka

No. GOV/KAR/MSG/556/2025

MESSAGE

I extend my warm greetings to the ***Mines Environment & Mineral Conservation Association (MEMCA)*** *on the occasion of the Mines Environment & Mineral Conservation Week 2025-26. The theme for this year, "Green Mining Driving Viksit Bharat", reflects the growing importance of integrating environmental consciousness into the mining sector.*

As part of the ongoing efforts, MEMCA's publication of the Souvenir for MEMCA 2025-26, marking the culmination of the Mines Environment & Mineral Conservation Week, is a valuable initiative.

I extend my best wishes for the success of Mines Environment & Mineral Conservation Week 2025-26 and the continued success of MEMCA in its mission to protect our environment while supporting the growth of the mining industry.

(Thaawarchand Gehlot)

Lok Bhavan, Bengaluru - 560 001 (Karnataka) Ph. 080-22254102 - 108

SIDDARAMAIAH
CHIEF MINISTER

VIDHANA SOUDHA
BENGALURU - 560 001

No: CM/PS/೫೯೨/2025

Date : ೨೩.೧೨.೨೦೨೫

MESSAGE

I am pleased to note that the **Mines Environment and Mineral Conservation Association** (MEMCA), Bengaluru, under the aegis of the Indian Bureau of Mines, Ministry of Mines, Government of India, is organizing the Mines Environment & Mineral Conservation Week – 2025-26 from 1st to 6th December 2025 with the theme "Green Mining: Driving Viksit Bharat."

The theme is very apt and resonates strongly with Karnataka's commitment to sustainable development through responsible mineral exploitation, environmental protection, mine reclamation, and the adoption of clean and energy-efficient technologies. The State Government has emphasized scientific mining, transparency, digital governance, and community-centric development in mining-affected regions, in alignment with national sustainability goals.

MEMCA's efforts in promoting best practices and awareness since 1991 is commendable. I am confident that this initiative will strengthen sustainable mineral development and inclusive growth in Karnataka.

I hope that the souvenir will capture the collective commitment of the mining fraternity in Karnataka and will serve as a meaningful reference for all stakeholders.

I wish the programme all success.

Siddaramaiah
(SIDDARAMAIAH)

जी. किशन रेड्डी
జి. కిషన్ రెడ్డి
G. Kishan Reddy

कोयला एवं खान मंत्री
भारत सरकार
नई दिल्ली
MINISTER OF COAL AND MINES
GOVERNMENT OF INDIA
NEW DELHI

Message

I am pleased to extend my greetings to the Mines Environment and Mineral Conservation Association (MEMCA), Bengaluru, and all participating organizations on the occasion of the Mines Environment & Mineral Conservation (MEMC) Week 2025–26, being observed across Karnataka from 1st to 6th December 2025.

Karnataka's rich mineral resources—ranging from Iron Ore, Manganese, and Gold to Limestone and several other vital minerals—continue to play an important role in driving India's industrial and economic development. This year's theme, Green Mining Driving Viksit Bharat, reflects the nation's collective resolve to align economic growth with environmental stewardship.

Under the leadership of Prime Minister Shri Narendra Modi, India has taken decisive steps to encourage sustainable, responsible and technology-driven mining. The reforms of the past decade have transformed the sector into a key pillar of India's net-zero ambitions. India's pathway to Viksit Bharat 2047 requires minerals, but it requires them to be extracted with minimum ecological footprint.

Green mining practices, such as advanced technology, real-time monitoring systems, drone-based surveys, and advanced beneficiation are helping improve productivity while reducing emissions. The promotion of underground mining, exemplifies our commitment to safer operations and reduced surface disturbance. Equally important is scientific mine closure and reclamation.

MEMC Week remains a valuable platform for promoting scientific mining practices, mineral conservation, environmental protection, and community engagement. Recognizing outstanding performers further motivates the mining fraternity to uphold high standards of responsible and sustainable operations.

I congratulate the organizers and all participants for their efforts toward environmental excellence. Let this week reinforce our shared mission to build a mining sector that powers national growth while preserving nature for generations to come.

(G. Kishan Reddy)

ಈಶ್ವರ ಬಿ. ಖಂಡ್ರೆ

ESHWAR B. KHANDRE

ಅರಣ್ಯ, ಜೀವಿಶಾಸ್ತ್ರ ಮತ್ತು ಪರಿಸರ ಸಚಿವರು
ಹಾಗೂ ಬೀದರ ಜಿಲ್ಲಾ ಉಸ್ತುವಾರಿ ಸಚಿವರು

Minister for Forest, Ecology
& Environment and
Bidar District In-charge Minister
Government of Karnataka

Ref: FEEM/ 2031 /2025 Date: 26.11.2025

: MESSAGE :

I am pleased to know that the Mines Environment & Mineral Conservation Association is organizing **Mines Environment and Mineral Conservation Week 2025–26**, from 1st to 6th December 2025, and are releasing a Souvenir on this occasion.

The theme **"Green Mining – Driving Viksit Bharat,"** emphasizes our national commitment to sustainable development, responsible mineral extraction, and environmental safeguards. While mining plays a crucial role in supporting economic growth and national infrastructure, it is equally important that mining activities adhere to scientific, eco-friendly and conservation-oriented practices.

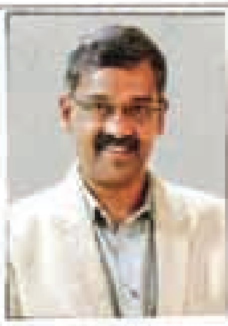
I urge the mining industry to adopt advanced technologies, improve resource efficiency, strengthen environmental compliance, and work proactively towards land restoration, water conservation, biodiversity protection, and reduction of pollution. True progress lies in achieving a balance between developmental needs and ecological integrity. It will serve as an important platform to share best practices, promote awareness, recognize outstanding efforts, and reaffirm our collective dedication to sustainable mining in India. I am confident that the initiatives undertaken during this week will inspire transformative action across the sector.

I extend my warm greetings and best wishes to all stakeholders of the mining sector for their future endeavors.

(ESHWAR B. KHANDRE)

ಶ್ರೀನಿವಾಸುಲು, ಐ.ಎಫ್.ಎಸ್.
ಸರ್ಕಾರದ ಪ್ರಧಾನ ಕಾರ್ಯದರ್ಶಿ
(ಜೀವಿಪರಿಸ್ಥಿತಿ ಮತ್ತು ಪರಿಸರ)
ಅರಣ್ಯ, ಜೀವಿಪರಿಸ್ಥಿತಿ ಮತ್ತು ಪರಿಸರ ಇಲಾಖೆ

SRINIVASULU, I.F.S.
Principal Secretary to Government
(Ecology & Environment)
Department of Forest, Ecology & Environment



Dated:27-11-2025.

MESSAGE

It gives me great pleasure to convey my greetings to the Mines Environment & Mineral Conservation Association (MEMCA), Bengaluru, on the occasion of the Mines Environment & Mineral Conservation Week 2025-26, being organized under the aegis of the Indian Bureau of Mines, Bengaluru Region.

The theme for this year—"Green Mining: Driving Viksit Bharat"—is both timely and relevant. As the nation moves ahead with a vision of sustainable and inclusive development, the mining sector has a crucial responsibility to adopt scientific, environmentally responsible, and socially sensitive practices. Karnataka, being one of India's most resource-rich states, has the unique opportunity to demonstrate leadership in implementing eco-friendly mining technologies, strengthening ecological safeguards, and ensuring that mineral development contributes positively to local communities and future generations.

I appreciate the efforts of MEMCA, mining companies, regulatory institutions, and field professionals who continuously work to promote best practices in mine planning, reclamation, waste management, biodiversity conservation, and community welfare. Such initiatives not only minimize environmental impacts but also reinforce public trust in the mining sector.

I am confident that the Mines Environment & Mineral Conservation Week 2025-26 will serve as an important platform for knowledge exchange, innovation, and collaboration among stakeholders. I hope this Souvenir becomes a valuable record of the collective commitments and achievements of the mining fraternity in advancing sustainable mineral development in Karnataka.

I extend my best wishes to MEMCA, the Indian Bureau of Mines, participating organizations, and all individuals involved in making this event a success.

Thanking You,

(SRINIVASULU)

पंकज कुलश्रेष्ठ
महानियंत्रक
Pankaj Kulshrestha
Controller General

भारत सरकार
GOVERNMENT OF INDIA
खान मंत्रालय
MINISTRY OF MINES
भारतीय खान ब्यूरो
INDIAN BUREAU OF MINES

Dated 07th January, 2026

MESSAGE

I am pleased to note that the 24th Mines Environment and Mineral Conservation Week was successfully observed by the Bangalore Regional Office of the Indian Bureau of Mines from 01.12.2025 to 06.12.2025.

In alignment with transition to *"viksit bharat*", the Government of India has launched the National Critical Minerals Mission which will enable India to become a powerhouse in critical minerals.

Under the guiding philosophy of *"Sabka Saath, Sabka Vikas, Sabka Vishwas"*, and with active support from MEMCA, IBM Bangalore region has, over the past three years, taken focused steps to promote and encourage increased participation of women in the mining industry

The Bengaluru Region is well known for its rich deposits of iron ore, manganese, gold, cement-grade limestone, magnesite, and other minerals. The State's mining fraternity has consistently shown leadership in the adoption of sustainable mining practices, as evidenced by the presence of seven star-rated mines in the State and the growing number of Five-Star and Four-Star rated mines under the Sustainable Development Framework.

I am confident that such periodic observance provides valuable opportunities to explore innovative approaches for mineral conservation and environmental protection in and around mining areas.

I extend my congratulations to all participating mines and to the host, John Iron Ore Mine of M/s. R. Praveen Chandra, for their dedicated efforts, and wish every success for the celebrations. I also wish grand success to the final day function scheduled to be held on 24th January 2026.

(Pankaj Kulshrestha)

इन्दिरा भवन, सिविल लाईन्स, नागपुर 440 001 फोन क.0712 2560041 ईमेल- cg@ibm.gov.in
Indira Bhavan, Civil Lines, Nagpur 440 001 Phone No. 0712 2560041 E mail: cg@ibm.gov.in

डॉ. योगेश जी. काले
मुख्य खान नियंत्रक
एम. डी. आर. डिविजन

Dr. Yogesh G. Kale
Chief Controller of Mines
M.D.R. Division

भारत सरकार
GOVERNMENT OF INDIA
खान मंत्रालय
MINISTRY OF MINES
भारतीय खान ब्यूरो
INDIAN BUREAU OF MINES

MESSAGE

It gives me immense pleasure to convey my greetings on the occasion of Mines Environment and Mineral Conservation Week (MEMCW) for the year 2025–26, organized by the Mines Environment and Mineral Conservation Association (MEMCA), Bengaluru, under the aegis of the Indian Bureau of Mines, Bengaluru Region, during 01.12.2025 to 06.12.2025. This significant event, marked by the active participation of major mines representing Large Mechanized, Medium Mechanized, and Manual mining operations from the states of Karnataka, aims at fostering awareness and driving positive change in the mining sector which is truly commendable and reflects the growing commitment of the mining fraternity towards responsible and environmentally conscious mining.

The observance of MEMC Week has, over the years, emerged as a significant platform for fostering meaningful collaboration among mining companies, government agencies, and local communities. This collective endeavour plays a vital role in promoting sustainable mining practices, environmental protection, and conservation of mineral resources in alignment with national priorities. The release of this souvenir on this occasion aptly captures the collective efforts and achievements of stakeholders in advancing sustainable mining, environmental stewardship, and mineral conservation in the region.

The chosen theme, **“Green Mining: Driving Viksit Bharat”**, is both timely and relevant, underscoring the critical responsibility of the mining sector in supporting India’s vision of inclusive and sustainable development of Viksit Bharat. The Bengaluru Region, endowed with rich mineral wealth including Iron Ore, Manganese, Gold, Cement Grade Limestone, and occurrences of Copper, Chromite, Magnesite, and Graphite, continues to play a pivotal role in the nation’s mineral economy. The sustainable development of these minerals is of prime importance

I extend my heartfelt congratulations to the organizing committee of MEMCA for their dedicated efforts in successfully conducting this important event. I also place on record my sincere appreciation to the host organization, and all supporting institutions for their continued commitment to these essential objectives. I wish the celebrations every success and look forward to continued collective efforts towards greener and more responsible mining. With best wishes.

(Dr. Yogesh G. Kale)
Chief Controller of Mines
MDR Division, Indian Bureau of Mines

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श्री. शैलेंद्र कुमार
खान नियंत्रक(द.अ.)
Sri. Shailendra Kumar
Controller of Mines (SZ)

सत्यमेव जयते

भारत सरकार
Government of India
खान मंत्रालय
Ministry of Mines
भारतीय खान ब्यूरो, बेंगलूरु
Indian Bureau of Mines, Bengaluru

MESSAGE

It gives me immense pleasure to extend my warm greetings to all participants and stakeholders from States of Karnataka & Kerala attending the Mines Environment & Mineral Conservation Council (MEMCC) programme of the Bengaluru Region. This esteemed platform continues to play a pivotal role in fostering responsible mining practices, facilitating knowledge sharing, and promoting sustainable mineral development.

The State of Karnataka holds a prominent position in the country's mineral economy, endowed with a wide range of mineral resources such as Iron ore, Manganese, Gold and others, and has played a vital role in driving the economy of the country. However, this privilege also brings with it the responsibility to ensure judicious extraction and optimal utilization of mineral resources, keeping in view long-term sustainability and environmental protection. In this context, the role of MEMC Week becomes even more significant in encouraging innovation, adoption of advanced technologies, and adherence to sustainable mining principles in the State.

I am delighted to note that Mines Environment and Mineral Conservation (MEMC) Week, 2025-26 was conducted from 1st to 6th December 2025 in parts of Karnataka and Kerala states under the patronage of the Regional Office, Indian Bureau of Mines, Bengaluru. This programme has witnessed encouraging 64 participations from a broad spectrum of mining leases, including 03 Gold mines, 15 Limestone mines, 04 Manganese mines, 40 Iron ore mines, and 02 Magnesite mine. Such active involvement reflects the collective commitment of the mining fraternity towards environmental stewardship, mineral conservation, and technological advancement within the sector.

In recent years, mining activities in the state have shown remarkable improvements through the adoption of scientific, sustainable, eco-friendly, and digitalized mining practices. These initiatives have significantly strengthened the foundation for sustainable mining, ensuring that mineral development is harmonized with ecological protection and social responsibility.

I commend the MEMCC, Bengaluru Region, for its consistent efforts in guiding the mining industry towards best practices and for fostering a culture of responsible and sustainable mining. I also extend my best wishes to all participating mines for their dedication and valuable contributions. May this programme inspire continued excellence in environmental protection, mineral conservation and sustainable development.

(Shailendra Kumar)

सं.29, भारतीय खान ब्यूरो, तुमकूर रोड यशवंतपुर, औद्योगिक उपनगर, दूसरा चरण, बेंगलूरु- 560 022
No. 29. Indian Bureau of Mines. Industrial Suburb. 2nd Stage. Gorgunte Palya. Yashwanthpur. Bangalore-560 022

ಎಸ್. ರಂಗಪ್ಪ, ಎಫ್.ಸಿ.ಎ., ಐ.ಎ.ಎಸ್.
ನಿರ್ದೇಶಕರು
ಗಣಿ ಮತ್ತು ಭೂ ವಿಜ್ಞಾನ ಇಲಾಖೆ

S. RANGAPPA, F.C.A., I.A.S.
Director
DEPARTMENT OF MINES AND GEOLOGY

ಅ.ಸ.ಪ.ಸಂಖ್ಯೆ

D.O. No.

I am pleased to note that the **Mines Environment & Mineral Conservation Association (MEMCA)**, Bengaluru, under the aegis of the **Indian Bureau of Mines (IBM), Bengaluru Region**, is organizing the **"Mines Environment & Mineral Conservation Week – 2025–26"** in the State of Karnataka, with the theme **"GREEN MINING DRIVING VIKSIT BHARAT."**

Karnataka is endowed with rich mineral resources namely Gold, Iron Ore, Bauxite, Platinum, REE and Critical Minerals. There are many operating mines in the state which is governed by sustainable mining practices in place. The observance of Mines Environment & Mineral Conservation Week plays a vital role in creating awareness among mining stakeholders on the importance of **sustainable mining practices, mineral conservation, environmental protection, and community engagement.** Such initiatives significantly contribute to strengthening responsible mining and aligning the mineral sector with India's vision of inclusive and sustainable development.

I appreciate the efforts of MEMCA in bringing together mining companies, government agencies, professionals, and local communities on a common platform to promote best practices in environmental stewardship and mineral conservation. I am confident that the **MEMC Souvenir 2025–26** will effectively showcase collective achievements, innovative practices, and policy initiatives that encourage eco-friendly and scientifically managed mining operations.

I extend my best wishes to MEMCA for the successful conduct of the **Mines Environment & Mineral Conservation Week 2025–26** and hope that the programme will inspire all stakeholders to work together towards responsible mineral development in Karnataka.

Yours sincerely,

(Signature)

Regional Controller of Mines

From Patron's Pen

"Green Mining Driving Viksit Bharat"

Mining has always been a key pillar supporting India's economic and industrial growth. The sector provides vital raw materials, strengthens the manufacturing ecosystem, and generates employment across regions. As India accelerates towards high-growth development, the mining industry is witnessing a paradigm shift, embracing scientific approaches, environmental responsibility, and technological modernisation. In alignment with transition to *viksit bharat*, the Government of India has initiated various reform strategies and launched the National Critical Minerals Mission, aimed at ensuring secure, long-term access to minerals essential for clean energy technologies, advanced manufacturing, and national strategic capabilities.

Karnataka, endowed with rich mineral resources, continues to play a vital role in meeting the nation's mineral demands. Minerals such as iron ore, manganese, limestone, magnesite, and gold form the backbone of India's infrastructure, chemical, and allied sectors. The State's mining fraternity has consistently demonstrated leadership in adopting sustainable practices, as reflected in the existence of seven star rated mines in the state and in the increasing number of Five-Star and Four-Star rated mines under sustainable development framework. These mines serve as benchmarks for responsible mining, environmental care, safety, and community development.

With the guiding philosophy of "Sabka Saath, Sabka Vikas, Sabka Vishwas", and with the active support of the Mine Environment & Mineral Conservation Association (MEMCA), IBM has undertaken a focused initiative to encourage, promote, and sensitize the mining industry towards greater participation of women in the industry since the last three years. In alignment with this objective, this year of a total of eleven teams including two dedicated all-women inspection teams have been constituted which will be participating in the Mine Environment & Mineral Conservation (MEMC) Week activities.

This landmark step not only showcases IBM's commitment to gender inclusivity and professional empowerment but also sends a strong message to the mining fraternity that women's participation is both essential and transformative for the future of Indian mining.

I extend my sincere appreciation to the Mines Environment & Conservation Week Association (MECWA), Karnataka Region, for their continued efforts in guiding, coordinating, and promoting MEMC Week activities across the State. Their commitment to environmental awareness, mineral conservation, and capacity-building has strengthened the culture of responsible mining within the industry.

I also wish to acknowledge all inspection teams, participating mine officials, industry professionals, and IBM officers for their enthusiastic involvement in MEMC Week 2025–26. Their dedication reinforces our collective resolve to promote scientific, transparent, and environmentally accountable mining.

Finally, I convey my heartfelt gratitude to the management of John Iron Ore Mine of Shri R. Praveen Chandra/ ERM Group for graciously hosting this year's MEMC Week and for their proactive efforts in organising the diverse activities planned for the event. Their leadership exemplifies the partnership and responsibility required to drive the mining sector towards a greener and more developed India.

I am confident that initiatives like MEMC Week will continue to strengthen our shared vision of "Green Mining Driving Viksit Bharat", ensuring that mineral development goes hand-in-hand with environmental stewardship and sustainable growth.

भवदीय

(डॉ सुरेश प्रसाद/ Dr. Suresh Prasad)
क्षेत्रीय खान नियंत्रक/ Regional Controller of Mines
क्षेत्रीय कार्यालय, भा.खा.ब्यू., बेंगलुरु / Regional Office, IBM, Bengaluru

MINES ENVIRONMENT & MINERAL CONSERVATION ASSOCIATION BENGALURU

From Chairman's desk,

It gives me immense pleasure to extend my warm greetings to all stakeholders of the mining fraternity on the occasion of 24th Mines Environment & Mineral Conservation Week 2025-26, being organized under the aegis of the Indian Bureau of Mines, Bengaluru Region from 01-12-2025 to 06-12-2025.

Since inception, MEMC Week has played a significant role in promoting sustainable mining, environmental protection, and mineral conservation by bringing together industry, regulators, and professionals on a common platform.

The theme selected for this year, **"Green Mining Driving Viksit Bharat,"** aptly reflects the vision of aligning mineral development with India's national goal of sustainable and inclusive growth. Green mining practices, adoption of cleaner technologies, efficient resource utilization, and environmental stewardship are no longer optional—they are essential for building a resilient and developed nation.

The enthusiastic participation of mines across Karnataka once again highlights the industry's resolve to go beyond compliance and embrace sustainability as a core value. The quiz competition, inspection programmes, technical interactions, and the final-day deliberations planned during this MEMC Week will further strengthen knowledge sharing and encourage continuous improvement in mining practices.

I wish to place on record my sincere appreciation to the RCOM and his team of Officials of Indian Bureau of Mines for their constant guidance and support, and to all the members of the MEMCA Executive Committee, various sub-committees, and participating organizations for their dedicated efforts in organizing this event successfully.

Let us reaffirm our commitment to responsible mining, environmental protection, and mineral conservation, and work collectively towards creating a mining sector that contributes meaningfully to the **Viksit Bharat** while safeguarding our natural resources for future generations.

I wish all the member mines participating in the Mines Environment & Mineral Conservation Week 2025-26, every success and trust that it will inspire all stakeholders to pursue greener, safer, and more sustainable mining practices.

I thank the MEMCA and the India Bureau of Mines, Bengaluru Region, for giving us the opportunity to host Mines Environment & Mineral Conservation Week 2025-26.

With warm regards,

R. Praveen Chandra

(R. Praveen Chandra)
Mine Owner & Chairman, MEMCA

जी.वी. किरण
अध्यक्ष-सह-प्रबंध निदेशक
G.V. KIRAN
Chairman-cum-Managing Director

केआईओसीएल लिमिटेड
(भारत सरकार का उद्यम)
II ब्लॉक, कोरमंगला, बेंगलूरु-560 034.
KIOCL LIMITED
(A Government of India Enterprise)
II Block, Koramangala, BENGALURU-560 034.

Message

It gives me great pleasure to convey my message on the occasion of the **Mines Environment & Mineral Conservation Week**. This year's theme, *"Green Mining: Driving Viksit Bharat,"* aptly underscores both our responsibility and our opportunity to contribute to national development while safeguarding the environment for future generations.

Karnataka has long been at the forefront of mineral development, and it is equally incumbent upon us to lead by example in environmental stewardship. By adopting sustainable mining practices—through scientific exploration, efficient resource utilization, progressive mine closure, and the integration of advanced green technologies — we not only strengthen our sector but also align ourselves with the broader national vision of a *Viksit Bharat*.

We must remain steadfast in upholding the highest environmental standards, fostering meaningful partnerships with local communities, and ensuring that every aspect of our progress is firmly anchored in sustainability. I extend my sincere appreciation to all stakeholders, including regulators, whose dedicated efforts continue to advance responsible and environmentally conscious mining practices across Karnataka.

Let us reaffirm our collective commitment to protecting the environment while driving development, ensuring that Karnataka continues to serve as a model for green, resilient, and future-ready mining.

With Regards,

(G.V. Kiran)
Chairman-cum-Managing Director

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वेबसाइट Website : www.kiocltd.in
https://www.facebook.com/kiocltd

आईएसओ 9001, 14001 तथा 45001 कम्पनी
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ಹಟ್ಟಿ ಚಿನ್ನದ ಗಣಿ ಕಂಪನಿ ನಿಯಮಿತ

THE HUTTI GOLD MINES COMPANY LIMITED

(A Govt. of Karnataka Undertaking)

CIN No. U85110KA1947SGC001321

22nd December,2025

R.Shilpa, KAS
Managing Director

MESSAGE

On the occasion of MEMC Week, observed under the aegis of Indian Bureau of Mines (IBM), I extend my warm greetings to all the employees, stake holders and all the members of mining fraternity.

Mining plays a vital role in nation building by contributing to economic growth and resource security. However, this also demands a strong commitment towards environmental protection, scientific Mining and conservation of mineral resources. Sustainable development is not merely a regulatory obligation, but a moral responsibility that we owe to future generations.

HGML has always been committed to adopting eco-friendly mining practices, systematic mineral conservation, waste minimization, progressive mine closure.

Through continuous monitoring, technological interventions and adherence to statutory guidelines, we strike a balance between mineral extraction and environmental stewardship.

The observance of this week helps to create awareness, review best practice and re-affirm our collective commitment towards safe, sustainable and responsible mining.

Let, us work together with renewed determination to uphold the principles of sustainable mining, Mineral conservation and environmental protection, in line with the vision of the Indian Bureau of Mines and the Government of India.

I wish the Mine Environment and Mineral Conservation Week a great success and also convey my best wishes to the host M/s. R. Praveen Chandra in organizing the final day function.

R. Shilpa

Managing Director

KSMC

Sri. Basavaraju, K.A.S.,
Managing Director, KSMCL

Message

It gives me immense pleasure to learn that Mines Environment and Mineral Conservation Council is organizing the Mines Environment and Mineral Conservation Week from 1st to 6th December 2025 by M/s. R. Praveen Chandra, ERM Group under aegis of Indian Bureau of Mines, Bangalore.

The theme for this year's MEMC week is **"Green Mining Driving Viksit Bharat"**. The primary objective of MEMC celebrations is to bring greater awareness among the people in the mining industry towards the Environment and Conservation of non-renewable resources. The State is endowed with abundant Mineral Resources which contributed significantly to the economy of Karnataka.

The Mining can become more sustainable by adopting advanced technology and integrating practices that reduce the Environmental Impacts of Mining operations and conserving the mineral resources.

It is imperative that all the efforts are to be made jointly by the mining community during the Mines Environment and Mineral Conservation Week and beyond for sustainable mining and conservation of nature.

Basavaraju, K.A.S.,
Managing Director

MINES ENVIRONMENT & MINERAL CONSERVATION ASSOCIATION BENGALURU

MESSAGE

On behalf of the Mines Environment and Mineral Conservation Association, Bengaluru, I extend a warm welcome to all the mining organizations, professionals, regulators, and stakeholders participating in the **Mines Environment & Mineral Conservation Week 2025-26**, observed in Bengaluru Region from 1st to 6th December 2025 under the theme **"Green Mining Driving Viksit Bharat."**

MEMCA, functioning under the aegis of the Indian Bureau of Mines, Bengaluru, has consistently endeavoured to promote responsible mining practices through capacity building, awareness creation, and industry-government collaboration. The annual observance of MEMC Week has emerged as an important forum to assess the implementation of environmental safeguards, mineral conservation measures, and progressive mine management practices adopted by the mining sector in the State.

Karnataka occupies a significant position in India's mineral landscape, and the role of its mining industry extends beyond production to responsible resource utilization, land rehabilitation, and community development. The theme selected for this year emphasizes the need to integrate sustainability principles into operational decision-making, technological adoption, and long-term planning, so that mineral development contributes meaningfully to the national growth while preserving environment.

The various programmes like Quiz Competition, Flag-off Ceremony, inspections / observations, technical interactions, and recognition of meritorious performance during the FINAL DAY function on 24th January 2026 are intended to encourage continuous improvement and practical adoption of best practices across different categories of mines. The "MEMC SOUVENIR 2025-26" comprising of Technical papers, Messages of Eminent personalities and endorsements of the Industry is being released by the Chief Guest on the occasion.

I convey my sincere gratitude to Dr. Suresh Prasad, RCoM and his team of Officials of Indian Bureau of Mines for their continuous support and guidance, which remains central to success of this event. My special thanks to the executive committee, inspections team members, zonal co-ordinators of MEMCA for their contribution in organising MEMC Week 2025-26 successfully. I express my special gratitude to Shri R. Praveen Chandra, Chairman, MEMCA, for his guidance and leadership, in success of this annual event.

I am confident that MEMC Week 2025-26 will further strengthen cooperation among stakeholders and contribute positively towards advancing responsible, efficient, and forward-looking mining practices in Karnataka.

With best wishes,

10/01/2026

Dhananjaya G. Reddy
Secretary, MEMCA &
COO, M/s. R. Praveen Chandra

MSPL LIMITED baldota.co.in

BALDOTA

Dr. Narendrakumar A Baldota
Chairman & Managing Director
M/s. MSPL Limited,
Baldota Enclave,
Abheraj Baldota Road,
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Dist: Vijayanagara

MESSAGE

I am pleased to note that the Mines Environment and Mineral Conservation Association, Karnataka is organising the Mines Environment and Mineral Conservation Week 2025-26 under the aegis of the Indian Bureau of Mines. This initiative reflects the collective commitment of the mining fraternity towards environmental protection and responsible mineral development.

Mining plays an important role in the development of the nation. At the same time, it is our duty to protect the environment while carrying out mining activities. Careful use of natural resources, adoption of scientific mining practices, and compliance with environmental norms are essential for sustainable mining.

Sustainable mining requires a harmonious balance between environmental protection and mineral development. Efficient utilisation of non-renewable mineral resources, progressive mine closure planning, reclamation of mined-out areas and adoption of green practices are key to ensuring long-term sustainability. Responsible mineral production and consumption, guided by sustainability principles, will strengthen the foundation for inclusive and environmentally conscious growth.

It is equally important to create greater awareness among mining professionals and workers about environmental conservation and responsible mining practices. Such awareness plays a vital role in fostering a culture of environmental stewardship and compliance within the industry.

I am confident that this week-long observance will significantly contribute to enhancing environmental consciousness, promoting best practices and encouraging sustainable growth within the mining sector.

I wish the Mines Environment and Mineral Conservation Week every success.

(Dr. Narendrakumar A. Baldota)
Chairman & Managing Director

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Bahirji A Ghorpade
Managing Director

Message

I am delighted to know that Mines Environment and Mineral Conservation week, organised from 01 December 2025 to 06 December 2025 by the Mines Environment and Mineral Conservation Association under the Aegis of Indian Bureau of Mines hosted by Shri R Praveen Chandra, ERM Group of Companies across Karnataka to evaluate the best industry Practices in Mine Environment and Mineral Conservation and to reward them.

Mining being the backbone of the country's economy contributing significantly for raw material security of Manufacturing sector needs to inculcate the best practices for carrying out Mining in a Safe, Systematic and Sustainable way.

SMIORE focused approach towards sustainability is backed by strong policies and institutional frameworks that help us monitor our progress, innovate and build strong ties with stakeholders. The Company has pioneered working on sustainability issues since its inception. Development of local areas, community development, employee wellbeing, quality education, health care facilities, taking care of biodiversity, flora & fauna etc have been predominant aspects taken care by the Company and are part of the Company's philosophy and vision statement.

The celebration of MEMC Week serves as a powerful reminder of our commitment to nature and society at large. I Extend my best wishes to the Mines Environment and Mineral Conservation Association and all the mine management for actively participating in the Mines Environment and Mineral Conservation Week 2025.

With Best Regards

Bahirji. A. Ghorpade

Bahirji A Ghorpade

BKG®

Director's Message

I am contented and joyous to know that, the Mines Environment & Mineral Conservation Week, 2025-2026 was celebrated from 1st to 06th December 2025 across the state of Karnataka under the aegis of Indian Bureau of Mines, Sothern Zone Bengaluru on theme "Green Mining – Driving Viksit Bharat" which is very relevant in today's scenario. The MEMC Week is being conducted since many years for creating awareness about Mines Environment and at the same time for Mineral Conservation. The week long programme at Mining industry shall definitely bring awareness about sustainable mining operations and mineral conservation among employees of the organization and stake holders.

As we all know, the conservation of Minerals and Environment has been an inevitable and important for the generations to come to make the future more sustainable. It is our core responsibility to have a prudent approach of rejuvenating the vegetation in the land which is used for mining practices. The Mineral conservation with advanced mining technologies is going to help generations to be more resourceful and in an era marked by rapid technological advancements and an ever-increasing global demand for high-tech products, the role of critical minerals has become paramount. India, with its vision of "Aatmanirbhar Bharat", recognizes the importance of securing a sustainable and resilient supply chain for listed critical minerals.

I am sure that the deliberations from the series of events that take place throughout this event is definitely going to help many young talents in understanding the importance of Mines Environment & Mineral Conservation in this mighty mining industry.

I congratulate and convey my best regards to the Organizer and wish the Mines Environment & Mineral Conservation week 2025-2026 a grand success.

B. Rudragouda
Managing Director,
M/s. BKG Mining Private Limited

JSW Steel Limited

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Phone : +91 8395 250 120-30
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Message from the Desk of the President

*It gives me immense pleasure to extend my warm greetings on the occasion of the Mines Environment & Mineral Conservation (MEMC) Week 2025–26, being observed under the theme **"Green Mining – Driving Viksit Bharat".** This theme aptly reflects the mining sector's shared responsibility to support India's growth ambitions while safeguarding environmental and social interests.*

MEMC Week provides an important platform for industry, regulators, and stakeholders to collectively reinforce the principles of responsible mining, mineral conservation, and environmental stewardship. As India advances towards its aspiration of becoming a USD 5 trillion economy, the mining sector will continue to play a critical enabling role. Equally important is the need to ensure that growth is pursued sustainably, with a clear focus on reducing environmental impact and improving resource efficiency.

At JSW, our approach to green mining is guided by the belief that sustainability and operational excellence must progress together. Across our captive mining operations, we are implementing environmentally focused technologies that reduce emissions, enhance safety, and improve efficiency. The adoption of the Downhill Pipe Conveyor (DHPC) system is a key example, significantly lowering dependence on truck haulage, reducing dust and emissions, and minimising the overall environmental footprint from mine to plant.

Looking ahead, digitalisation and emerging technologies, including automation and data-driven systems, will play an increasingly important role in enabling safer operations, better environmental monitoring, and enhanced compliance. Alongside technology, building a more inclusive workforce, with greater participation of women across mining and leadership roles, is essential for long-term resilience and innovation.

I commend the ERM Group of Companies for hosting MEMC Week 2025–26 and for their leadership in promoting sustainable mining practices. I encourage all participants to use this forum to exchange ideas and strengthen collaboration in shaping a responsible and future-ready mining sector.

I wish MEMC Week 2025–26 every success and meaningful impact.

Regards,

PK Murugan
President - JSW Steel Vijayanagar & Salem Works

vedanta sesa goa

Mr. Vinod Kumar
Chief Operating Officer - Mines
Vedanta Sesa Goa

Dear Colleagues,

Mines Environment and Mineral Conservation (MEMC) week 2025- '26 is an occasion that brings the mining industry together & presents us with the opportunity to learn from each other while contributing to the progress of the mining sector and the Nation. Organised under the aegis of the Indian Bureau of Mines (IBM), the MEMC, over the years, has transformed into a platform that fosters innovation & sustainability, while promoting inviolable safety.

Mining as an industry is recognized for its centrality to all aspects of human existence & for its role in sourcing the resources needed to fuel the Nation's progress. With over 1200 mines operational and the Government providing the much-needed policy push, the mining industry is on the verge of a breakout period. This phase of growth coincides with the Hon'ble Prime Minister of India, Shri Narendra Modi's call for an 'aatmanirbhar' & 'viksit' Bharat. It is incumbent upon us, in the mining industry, to contribute to these ends responsibly with capacity building, tech absorption, innovation and sustainability as the key pillars of our onward trajectory.

At Vedanta Sesa Goa, with a rich legacy of over seven decades, we continue to prioritize processes & practices that foster environmental sustainability, resource optimization and improved efficiency. Our push for electrification of screening plants, transition to dry beneficiation practices, adoption of EV tech in core operations, onboarding of solar power for powering logistics and deployment of radars/AI tech for promoting enhanced safety are all aimed at rendering our operations increasingly responsible, safe & sustainable. Through this, we also further and pursue Vedanta's goal of achieving 'net zero' by 2050. Furthermore, our interventions for the betterment & progress of communities, in collaboration with the Vedanta Foundation, are focused on achieving lasting transformation through skilling, women empowerment, bridging of the digital divide, vocational training, community development and by engendering sporting excellence

The MEMC Week 2025-26 is a unique gathering in terms of size & scope and we must resolve to benefit collectively as an industry sector by evolving and aligning our processes with the demands of time and sustainability. I am confident that with your collective efforts, we will continue to make strides in the mining industry and take steps towards achieving our common goal.

Date: 26th November 2025

Vinod Kumar

MESSAGE ON MEMC WEEK 2025-26

The mining sector is a key contributor to India's growth trajectory, supplying essential raw materials to core industries and supporting economic development. Minerals, being non-renewable and extracted through intrusive processes, demand that we adopt sustainable, scientific, and environmentally conscious mining practices. The Mines Environment and Mineral Conservation (MEMC) Week is an important platform that reiterates our responsibility to safeguard natural resources, conserve mineral wealth, and protect ecological balance.

Karnataka's mining landscape has evolved significantly with advancements in technology, regulatory reforms, and improved environmental practices. These developments have enabled the industry to reduce its ecological footprint and strengthen its commitment to responsible mining.

I express my sincere appreciation to the **Indian Bureau of Mines, Bengaluru Region**, for their continuous guidance and leadership in nurturing a culture of sustainability and conservation.

I also extend my good wishes to the host of MEMC Week 2025–26, **M/s. R. Praveen Chandra** for taking up the responsibility of organizing this year's event. The inspection schedule from **01.12.2025 to 06.12.2025** provides an opportunity for all participating mines to showcase their initiatives, innovations, and adherence to environmental best practices.

I wish the organizers, participants, and the entire mining fraternity a successful, impactful, and forward-looking MEMC Week 2025–26.

(Shivendra Bahadur Singh)
Executive Director
NMDC Limited
Donimalai Complex

PARTICIPATED MINES IN MEMC 2025-26

Group	Location	Name of the Mine	Name of the Organization
1	Kalaburagi	Rajashree Limestone Mine	M/s Ultratech Cement Limited
		Vicat Sagar Limestone Mine	M/s Kalburgi Cement Pvt. Limited
		Injepalli Limestone Mine	M/s Ultratech Cement Limited
		Wadi Limestone Mine	M/s ACC Limited
		Kodla Limestone Mine	M/s Shree Cement Limited
2	Kalaburagi	Kallur Limestone Mine	M/s Chettinad Cement Corporation Limited
		Kharchikhed Limestone Mine	M/s Kalburgi Cement Pvt Limited
		Itagi Limestone Mine	M/s Orient Cement Limited
		Ferozabad Limestone Mine	M/s Gulbarga Cement Limited
		Chittapur Limestone Mine	M/s Nuvoco Vistas Corporation Limited
3	Raichur	Hutti Gold Mine	M/s Hutti Gold Mines Co. Limited
		Uti Gold Mine	M/s Hutti Gold Mines Co. Limited
		Hira-Buddini Gold Mine	M/s Hutti Gold Mines Co. Limited
4	Chitradurga & Ballari	Ramanadurga Iron Ore Mine	M/s SKME Private Limited
		Donimalai Iron Ore Mine	M/s NMDC Limited
		Kumaraswamy Iron Ore Mine	M/s NMDC Limited
		Kammatharu Iron Ore Mine	M/s SMIORE Limited
		Bhomman Iron Ore Mine	M/s JSW Steel Limited
		A Narrain Iron Ore Mine	M/s Vedanta Limited (Sesa Goa)
5	Chitradurga & Ballari	Narayana Iron Ore Mine	M/s JSW Steel Limited
		Rama Iron Ore Mine	M/s JSW Steel Limited
		Devadari Iron Ore Mine	M/s JSW Steel Limited
		Subbarayanahalli Iron Ore Mine	M/s KSMC Limited
		Haddinapade Iron Ore Mine	M/s BKG Mining Private Limited
		John Iron Ore Mine	M/s R. Praveen Chandra
6	Ballari	Ramanamalai Iron Ore Mine	M/s VESCO
		Iyli Gurunath Iron Ore Mine	M/s Ramgad Minerals & Mining (P) Limited
		Narasimha Iron Ore Mine	M/s MSPL Limited
		Nandi Iron Ore Mine	M/s JSW Steel Lmited
		Bhadra Iron Ore Mine	M/s JSW Steel Limited
		Thimmappanagudi Iron Ore Mine	M/s KSMC Limited
7	Ballari	Ramgad Manganese Ore Mine	M/s SMIORE Limited
		Ubbalagundi Iron Ore Mine	M/s Minera Steel & Power Pvt. Limited
		Ubbalagundi Iron Ore Mine	M/s JSW Steel Limited
		Dharma Iron Ore Mine	M/s JSW Steel Limited
		Dharmapuri Iron Ore Mine	M/s VESCO
		Zeenath Iron Ore Mine	M/s Zeenath Transport Company

Group	Location	Name of the Mine	Name of the Organization
8	Ballari	Ramgad Iron Ore Mine	M/s Zeenath Transport Company
		S. A. Thawab	M/s Zeenath Transport Company
		Tunga Iron Ore Mine	M/s JSW Steel Limited
		Janikunta Iron Ore Mine	M/s Hothur Ispat Private Limited
		Tonasigere Manganese Ore Mine	M/s Marwa Mining Company
		Sankalapuram Iron Ore Mine	M/s RBSSN Pvt. Ltd.
		S. M. Block Iron Ore Mine	M/s M. Hanumanth Rao
9	Ballari & Vijayanagara	Dharmapura Iron Ore Mine	M/s VNK Menon
		Haraginadona Iron Ore Mine	M/s Allum Prashant
		Kallahalli Mines Iron Ore Mine	Shri H. N. Prem Kumar
		Auro Minerals Iron Ore Mine	M/s Minera Steel & Power Private Limited
		Kirloskar Bharath Mines	M/s Kirloskar Ferrous Industries Limited
		Thimmappanagudi Iron Ore Mine	M/s H.G. Rangan Goud
10	Chitradurga, Mysore & Kerala	Thangavelu & Others	Smt. B. L. Ranisamyuktha
		Doddabyladakere Iron & Manganese Ore Mine	M/s SJMP Holdings LLP
		Kanchipura Limestone Mine	M/s RAMCO Cements Limited
		Talooru Magnesite Mine	Shri N. Rajashekar
		Karya Magnesite Mine	M/s KSMC Limited
		Pandarathu Limestone Mine	M/s Malabar Cements Limited
11	Chitradurga, Tumkur & Ballari	Sanjeevarayanakote Iron Ore Mine	M/s Allum Prashanth
		Haraginadona Iron Ore Mine	M/s GVPR Engineers Limited
		Kadathi Manganese Mine	M/s Yerrithatha Mining Company
		Ittigehalli Limestone Mine	M/s Lakshmi Cement & Ceramics Industries
		Kudurekanvekaval Iron Ore Mine	M/s Garudadhri Implex Private Limited
		Dindadahalli Iron Ore Mine	M/s Goa Sponge & Power Limited
		Mahadevapura Manganese Mine	Smt. M. Yashodha
		Karekurchi Iron Ore Mine	M/s Karnataka Limpo Cement Industry

INSPECTION TEAM MEMBERS OF MEMC 2025-26

Group	Location	Team Member	Name	Designation	Organization
1	Kalaburgi	Convenor	Mrs. Yamini Singh	DGM, Exploration	M/s MSPL Ltd.
		Team Member	Ms. Tejaswini	Environment Engineer	M/s JSW Steel Ltd.
			Dr. Binutha	Manager (Environment)	M/s KSMC Ltd.
			Ms. Savithri Pawar	Geologist	M/s VESCO
2	Kalaburgi	Convenor	Mr. Sujit Kumar	DGM (Mining)	M/s NMDC Ltd.
		Team Member	Mr. Sandeep B.	Geologist	M/s Minera Steel & Power Pvt. Ltd.
			Mr. Dhaval Nayi	Associate Manager	M/s Vedanta Ltd.
			Mr. Kariveda Sreekanth	Manager-Environment	M/s SKME Pvt. Ltd.
3	Raichur	Convenor	Mr. Siriki Satyanarayana	AGM - Mines	M/s BKG Mining Pvt. Ltd
		Team Member	Mr. Prakash Y.	Mines Manager	M/s SJMP Holdings
			Mr. Vasanth N.	Geologist	M/s Malabar Cements Limited
4	Chitradurga & Ballari	Convenor	Mr. N. Devaraj	GM Mines	M/s MSPL Ltd.
		Team Member	Mr. B. Divesh	Sr. Geologist	M/s Kalburgi Cement Pvt. Ltd.
			Mr. Keshav Chandra Mahto	Asst. Geologist	M/s BKG Mining Pvt. Ltd.
			Mr. Gopal J.	Sr. Officer (Environment)	M/s BKG Mining Pvt. Ltd.
5	Chitradurga & Ballari	Convenor	Mr. Vishwanath D.	Sr. Manager (Mines)	M/s Ultratech Cement Ltd.
		Team Member	Mr. Harish Ningenahalli	Manager	M/s SMIORE Ltd.
			Mr. Rashmi Ranjan Sahu	Asst. Manager Geology	M/s ZTC
			Mr. Sheik Madeena	Dy. Manager (Mines)	M/s NMDC Ltd.
6	Ballari	Convenor	Mrs. Sarita Dange	Asst. General Manager	M/s KSMC Ltd.
		Team Member	Ms. Megha Kulkarni	Geologist	M/s KSMC Ltd.
			Ms. Navya	Asst. Manager	M/s Vedanta Ltd.
7	Ballari	Convenor	Mr. Rudraiah A. M.	General Manager	M/s Karnataka Limpo Cement Industry
		Team Member	Mr. Anjini Kumar S.	Sr. Manager EHS	M/s MSPL Ltd.
			Mr. Darshan B. U.	Dy. Manager	M/s R. Praveen Chandra
8	Ballari	Convenor	Mr. Rama Mohan Reddy	DGM	M/s R. Praveen Chandra
		Team Member	Mr. Khaja Bandenawaz	Mining Engineer	M/s HGM Co. Ltd.
			Dr.Venkateswarlu Kumba	Dy. Manager Geology	M/s NMDC Ltd.

Group	Location	Team Member	Name	Designation	Organization
9	Ballari & Vijayanagara	Convenor	Mr. Shivananda Nayak	Manager (Mining)	M/s HGM Co. Ltd.
		Team Member	Mr. P. Ganesh Kumar Reddy	Geologist	M/s RBSSN Pvt. Ltd.
			Mr. Praveen Kumar	Engineer	M/s SMIORE Ltd.
10	Chitradurga, Mysore & Kerala	Convenor	Mr. Imran Shaik	Mining Engineer & 1st Class	M/s VESCO
		Team Member	Mr. Sameer Shaik	Geologist	M/s HGM Co. Ltd.
			Mr. Sakthi Venkatesh S.	Asst. Manager – Environment	M/s Vedanta Limited
11	Chitradurga, Tumkur & Ballari	Convenor	Mr. T. Bala Gokul	Asst. Manager & Mining Engineer	M/s Chettinad Cement Corporation Ltd.
		Team Member	Mr. Siddarth B.	Mines Manager	M/s JSW Steel Ltd.
			Mr. Vikash K. P.	Asst. Manager, Geology	M/s Hothur Ispat Private Limited

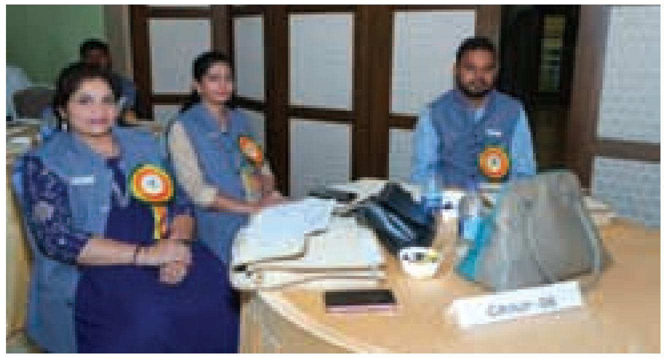
Glimpse of 1st Executive Meeting

Glimpse of MEMC Quiz

Glimpses of Material Distribution of MEMC Week Celebration

Glimpse of Flag Off Ceremony

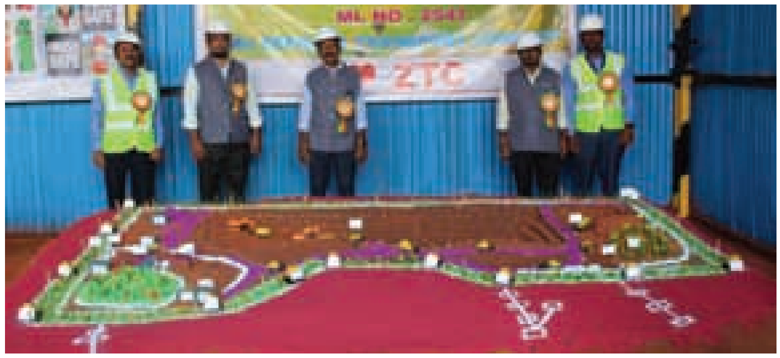


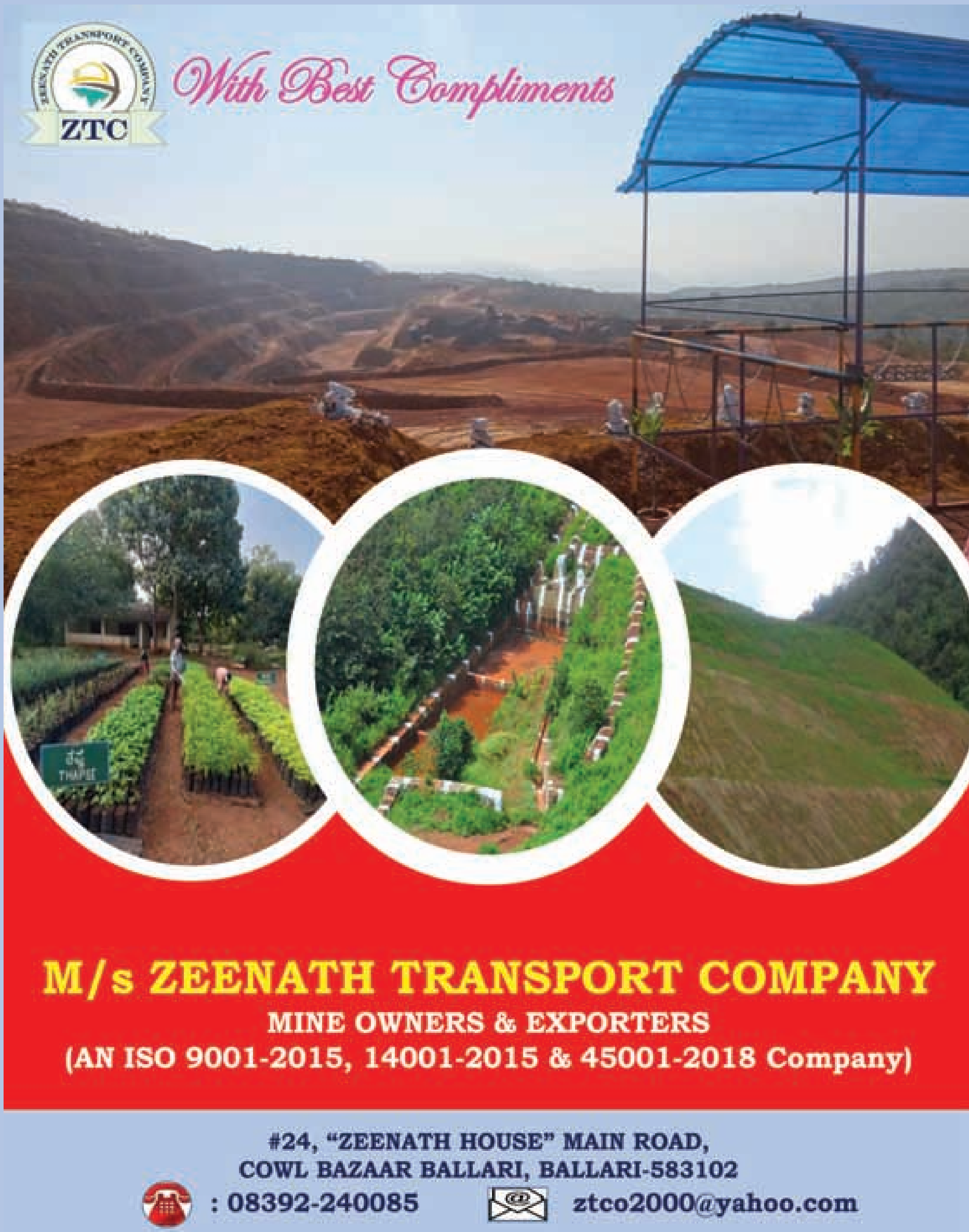


Glimpse of MEMC Week 2025-26 Inspection

Glimpse of MEMC Week 2025-26 Inspection



Glimpse of MEMC Week 2025-26 Inspection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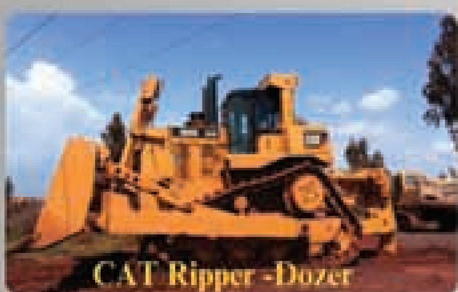

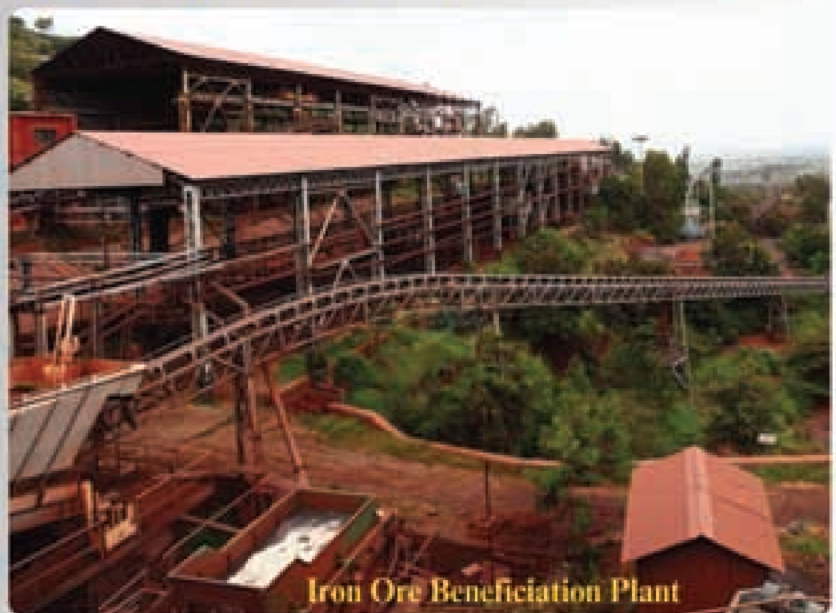

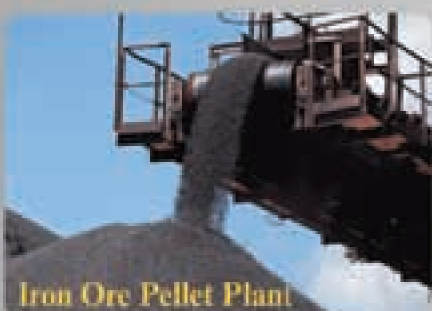

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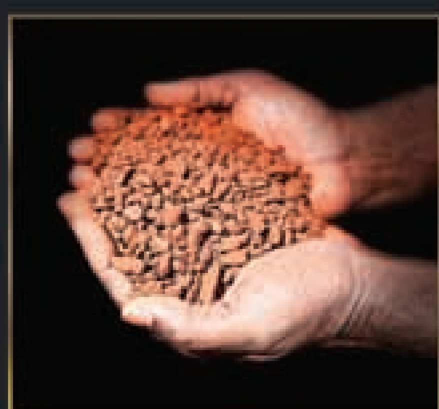

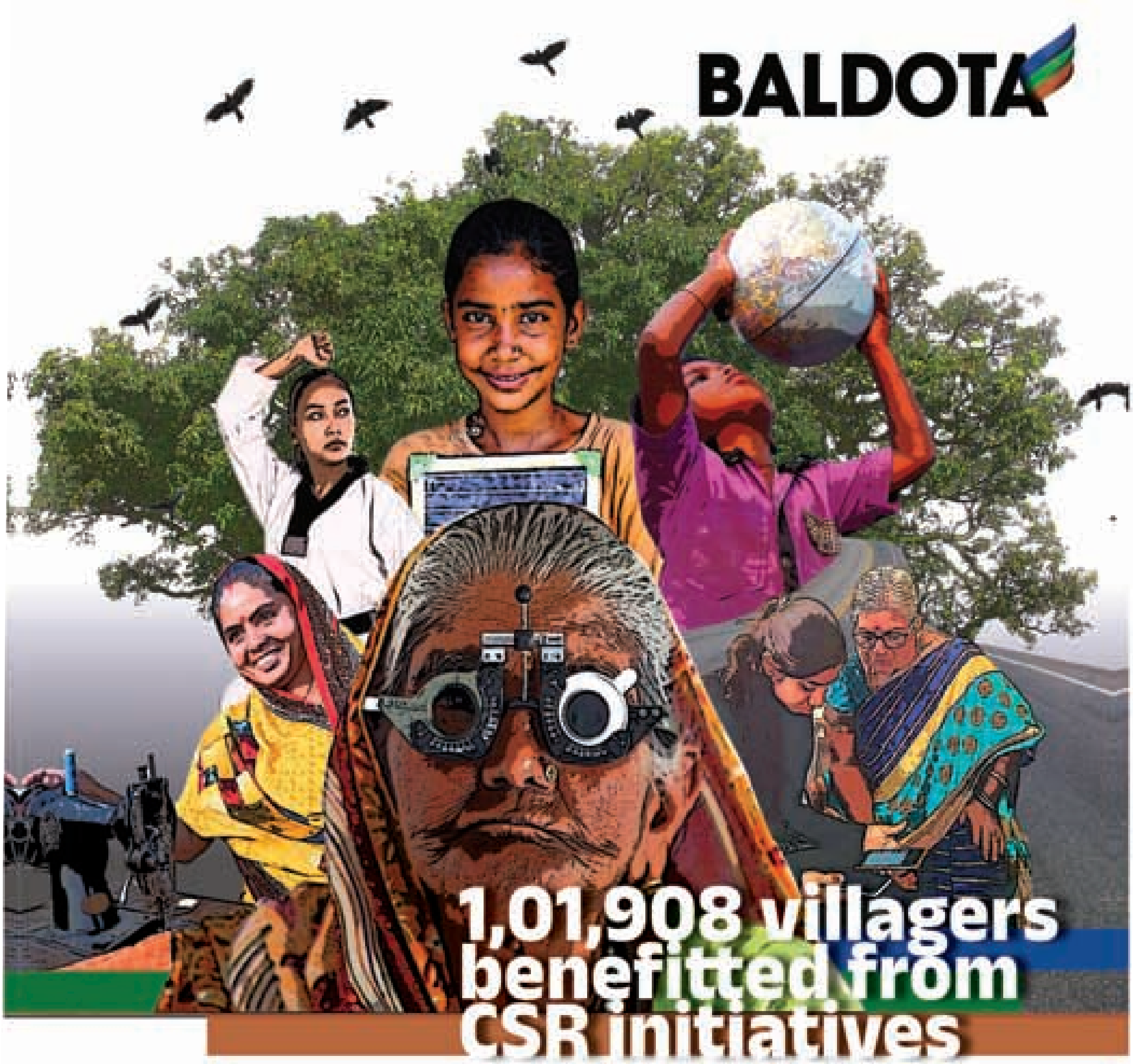

20,15,963 Saplings planted for a greener tomorrow

38,254 students across 101 schools benefited from better educational facilities and infrastructure.	14,509 people helped through eye screening and surgeries.
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2,832 differently-abled individuals supported with CSR activities.	4,37,352 young girls across 2,046 schools trained in self-defence.
6,661 individuals equipped with employable skills.	716 scholarships provided.

TECHNICAL PAPER'S INDEX

Liquid Gold: Integrated Water Management at Hutti Gold Mine for a Green Mining, Driving Viksit Bharat

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ABSTRACT

Water management in mining operations is a critical component of environmental sustainability, particularly in regions facing water scarcity and ecological sensitivity. This paper presents a comprehensive study of sustainable water management strategies implemented at the Hutti Gold Mine in Karnataka, India—one of the oldest and most productive gold mines in the country. The research evaluates current water usage patterns, sources, and discharge practices, highlighting the challenges posed by underground mining, ore processing, and seasonal variability.

Through field data analysis, stakeholder interviews, and review of operational protocols, the study identifies key interventions such as water recycling systems, rainwater harvesting, and zero-discharge initiatives. The paper also explores the integration of regulatory frameworks and community engagement in shaping water governance at the mine. Findings suggest that while significant progress has been made in reducing freshwater dependency and mitigating contamination risks, further improvements are needed in monitoring infrastructure and adaptive planning.

This case study offers valuable insights into scalable and replicable water management models for other mining operations in semi-arid regions, emphasizing the balance between resource extraction and ecological stewardship.

1. Introduction

Despite covering over 70% of the Earth's surface, usable freshwater constitutes less than 4% of the total global water volume, making it a critically scarce and finite resource. Rapid population growth, urbanization, and industrial expansion have intensified pressure on water systems, leading to rising demand across agriculture, municipal, and industrial sectors. India, in particular, faces acute water stress, with per capita availability declining steadily and projections indicating a potential 40% water deficit by 2030 under a business-as-usual scenario.

The mining industry, which accounts for a significant portion of industrial water use, is increasingly challenged to adopt sustainable water practices. In this context, Hutti Gold Mines Company Limited (HGML)—India's only primary gold producer—serves as a vital case study. Located in the drought-prone Raichur district of Karnataka, HGML operates in a region where water scarcity and pollution pose serious environmental and operational risks.

HGML sources water primarily from the Krishna River and underground mine aquifers to support its labor-intensive operations and community infrastructure. Recognizing the need for sustainable water management, HGML commissioned The Energy and Resources Institute (TERI) to conduct a comprehensive water audit across two seasons (August 2022 and January 2023). The audit aimed to evaluate current water consumption patterns, assess equipment efficiency, and identify conservation opportunities aligned with HGML's expansion plans.

This paper presents the findings of the water audit, highlighting baseline consumption metrics, operational insights, and strategic recommendations for enhancing water use efficiency. The study underscores the importance of integrated water resource management in mining operations and contributes to broader efforts toward sustainable industrial development in water-stressed regions.

2. Methodologies:

This study employed a mixed-methods approach to evaluate water management practices at Hutti Gold Mines Company Limited (HGML). Key methodologies included:

- **Primary Data Collection:**
  - Site visits to water infrastructure including treatment plants, pumping stations, and tailings ponds.
  - Structured interviews with mine engineers, environmental officers, and plant operators.
  - Direct observation of water handling systems such as dewatering pumps, recycling units, and sewage treatment facilities.
- **Secondary Data Sources:**
  - Operational reports, environmental impact assessments, and regulatory compliance documents from HGML.
  - Historical water flow and energy consumption logs maintained by operators.
- **Instrumentation & Analysis:**
  - Flow meters and sampling at intake and discharge points to quantify water usage and treatment efficiency.
  - NABL-certified laboratory testing of water samples for quality parameters including pH, TDS, BOD, COD, and cyanide levels.
- **Geospatial Mapping:**
  - GIS tools used to visualize water flow pathways and infrastructure layout across the mine site.
- **Performance Evaluation:**
  - Statistical analysis of pump efficiency, seasonal variability, and specific energy intensity (kWh/m^3) for each water source.

This study employed a mixed-methods approach to evaluate water management strategies at Hutti Gold Mine. Primary data were collected through site visits, structured interviews with mine engineers and environmental officers, and direct observation of water handling infrastructure, including pumping systems, settling ponds, and recycling units.

Secondary data sources included operational reports, environmental impact assessments, and regulatory compliance documents obtained from the Hutti Gold Mines Company Limited (HGML). Water usage metrics were analyzed using flow meters and sampling at key discharge and intake points to assess consumption patterns and treatment efficiency.

Geospatial mapping tools were used to visualize water flow pathways and identify potential areas of loss or contamination. Data were processed using standard statistical techniques to evaluate performance indicators such as water recovery rate, discharge quality, and seasonal variability. The methodology was designed to align with national environmental guidelines and international best practices for sustainable mining.

2.1 Water Consumption Profile

The Hutti Gold Mine, located in the Hutti-Maski greenstone belt of Karnataka, is one of the oldest known metal mining sites globally, with historical operations dating back to the Pre-Ashokan period. The deposit lies within Archaean metavolcanic rocks and has been mined to depths exceeding 1050 meters. Modern mining began in the late 19th century and was significantly expanded by M/s. John Taylor & Sons and later by Hyderabad Gold Mines Company Limited, before transitioning to The Hutti Gold Mines Company Limited (HGML) in 1947.

Over the decades, HGML has implemented several technological upgrades to enhance production capacity and operational efficiency. Key milestones include:

- Tripling of processing capacity to 910 TPD in 1971
- Adoption of Carbon-in-Pulp (CIP) technology in 1996
- Expansion programs with Ball Mill additions (1998–2002)
- Installation of large agitators and high-rate thickeners (2002–2005)
- Introduction of SAG & Ball Mills (2010–2012) and Mega Circular Shaft sinking (2013)
- Recent proposals for decline mining and additional milling capacity (2014–2015)

Currently, HGML operates below the 28th level at a depth of 933.70 meters, with an annual ore processing capacity of 800,000 tonnes. As of March 2019, cumulative ore mined stands at 16.93 million tonnes, yielding approximately 89.59 tonnes of gold at an average grade of 5.29 g/t. Proven and probable reserves are estimated at 16.3 million tonnes with a grade of 4.41 g/t.

2.2 Water Consumption Overview

Gold extraction at Hutti involves wet processing technologies such as crushing, grinding, flotation, and CIP, all of which demand substantial water input. Water is primarily used for:

- Ore slurry preparation and transport
- Leaching and recovery processes
- Dust suppression and equipment cooling
- Tailings management and sand stowing

The plant's water consumption profile is closely monitored, with efforts to optimize usage through recycling, detoxification systems, and high-rate thickeners. Despite improvements in recovery grade and productivity until FY 2019–20, the COVID-19 pandemic led to a temporary decline in output due to operational constraints and delayed stoping permissions below the 20th level.

HGML's commitment to environmental compliance and adoption of proven technologies has enabled it to maintain water use within acceptable regulatory limits while supporting sustainable production growth.

3. Water Scenario of – HGML

Water is one of the main resources for wet processing of gold mining operations. Apart from that being labour intensive operations, water as essential need is supplied to employee residential premises and associated communities. Water demand for the HGML operations and communities welfare, is being met with two primary sources namely

- Krishna River Basin (Mainly for drinking)
- Underground mines dewater

Apart from these, HGML also uses the following secondary sources of water through recycling.

- Tail pond dump water
- Sewage treatment plant - Treated water

Major observations on the various sources and performance evaluation of associated equipment along with design specifications are explained in subsequent sections.

HGML has made arrangements to draw the fresh water from Krishna river basin near Hatti Hala through Jackwell pumping station and then to Tamankal Water treatment plant, situated in the same premises of Lingasuguru Taluk, Raichur District. Tamankal water supply system is located at geographical coordinates of 16.338043 N 76.610163 E around 375 m above the mean sea level. Geographical mapping of Tamankal water intake and treatment plant is shown in below figure - 1.

Figure 1: Geographical mapping of Tamankal water treatment plant of Krishna Basin.

Tamankal water supply station was established in 1948 by HGM with Jackwell system and sand jewel filter system. Over the years, with the increased production and increasing population pumps and pipelines were upgraded as per the actual demand of HGML (including residential and communities). Average water flow from Krishna river basin near Tamannakal is around 6 Lakhs Cusecs. Presently Tamankal water station has two jackwells, namely old jackwell and new jackwell with approach bund and partition chamber upto 100 ft from the intake well across Krishna River. Photographs captured at Tamankal jackwell raw water pump house during our site visit are provided in figure 2.

Figure 2: Krishna river water intake at Tamankal and jackwell raw water pump house.

3.1. Tamankal Water Treatment Plant

Tamankal water treatment plant was constructed in 1948 as initial water supply scheme to Hutti gold mines with Krishna River water as source. Tamankal Water treatment plant, is located at Krishna river basin with geographical coordinates of 16.338043 N 76.610163 E around 381 m above the mean sea level near Tamankal village of Lingasuguru Taluk, Raichur District. Over the years, with the increased production and increasing population pumps and pipelines were renovated / upgraded several times as per actual demand of HGML (including residential and communities).

Presently the water supply scheme was designed for 1.2 Million Gallons per Day (5.45 million litres per day) to supply water for estimated population of 20,000 at Hutti Gold Mines and associated communities. Tamankal water treatment plant consists of aerator, flash mixer, clari-floculator, clarifier, rapid sand filter, backwash pump, ground level storage reservoir and treated water pumps for requisite operations of water supply to HGML. Photographs captured at Tamankal water treatment plant during our study period are given in below figure.3.

Figure 3: Sub-processing equipment in Tamankal water treatment plant.

Plant has installed two medium capacity centrifugal pumps for supplying the treated water from ground level storage reservoir to Gurganta intermediate pumping station, Lingasugur Taluk. Installed pumps are of multistage horizontal type coupled to induction motors integrated with soft starters. Both intake and delivery lines of these centrifugal pumps are of 150mm dia, while rising main is of 350mm dia discharge header for 11 km is made up of composite materials of mild steel (MS) and Portland Slag Cement (PSC).

Normally, two pumps will be continuously operating majority of time (around 18 – 20 h) in a day based on the reservoir levels of Tamankal and Gurganta pumping station, sometimes operator switches off one pump. Butterfly and globe valves are provided for the capacity control, however during the study period valves were appeared to be in full open condition. Performance evaluation results of the operating pumps along with its design details are given in below table.

Underground water system is located at geographical coordinates of 16.19° N Lattitude and 76.65° E Longitude around 670 m below the HGML elevation of 527 m above the mean sea level. Geographical mapping of Underground water at HGML is shown in the below figure 4.

Figure 4: Geographical mapping of Underground water system outlets at HGML

Out of these installed pumps, few pumps are highly energy intensive and operates continuously for significant time. Design details of major energy intensive pumps are given in the below table.

At present dewatering is from +2200 feet MSL. As the mining depth increase number of pump units will increase, and then there is an increase of electricity consumption cost for pumping needs at mine. This increase will continue to occur until the mine development reach the targeted elevation according to mine planning, so at this elevation should be planned dewatering system which has more efficient power consumption and has the capacity to manage flooding at mine. This dewatering system will be used until mine closure. Hence it is very important to monitor the operating efficiency of dewatering pumps to optimise the pumping power consumption.

Underground dewater to HGML is finally delivered by the pumping system in 1000feet level. Both intake and delivery lines of these centrifugal pumps are of 150 mm dia, while rising transmission main of discharge header is also 150 mm diameter for plant is made up of composite materials of mild steel (MS). Photographs captured at underground dewatering system during our site visit are provided in figure 5.

Figure 5: Underground dewatering system of HGML.

Normally, one pump will be intermittently operating (around 12 – 14 hours in a day based on the reservoir levels) during the underground mining activities. Butterfly and globe valves are provided for the capacity control, however during the study period valves were appeared to be in full open condition. Performance evaluation results of the operating pumps along with its design details are given in below table.

From the above table, it can be seen that estimated operating efficiencies of the pump in both scenario are slightly on the lower side, mainly due to mismatch in design consideration (required head is lower than actual). Presently at full speed, pump is handling 110% flow at 82% head with 94% power consumption as against to the design values.

HGML has installed bulk water flow meters for the monitoring the actual underground dewater pumped. Based on the pump operator's logbook data of historical operating hours data, underground dewater supplied for every month is estimated and given in below graph.

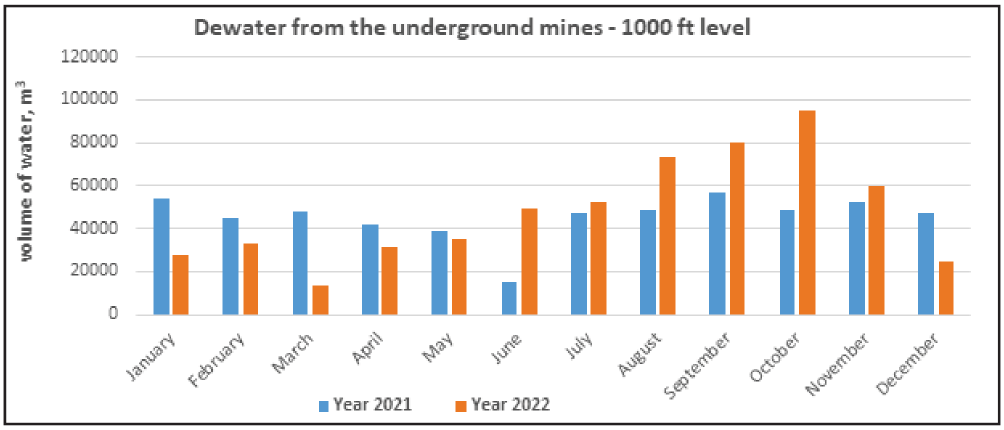

Figure 6: Month-wise dewater from the underground mines by 1000ft level pumps

From the above graph, it can be observed that significant variation in monthly pattern of dewater from the underground mines. However, based on the data analysis annual total volume of dewater remains very similar and average day wise dewater in every month from mines is estimated and same is illustrated graphically in the below figure 7.

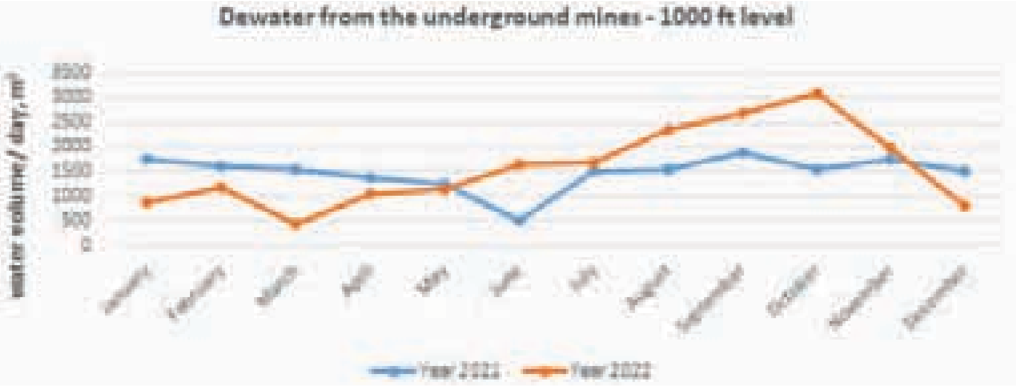

Figure 7: Average day-wise dewater from the underground mines by 1000ft level pumps

From the above graph data, average day wise dewater flow from underground mines was around **1532 m³/day (1.53 MLD)** and same is considered for the baseline calculation. Similarly average energy consumption by the major dewatering pumps of 2200 ft, 1500ft and 1000 ft level were estimated to be around 3642 to 5345 kwh/day. Based on the same, average annual specific energy intensity of underground dewater pumps is estimated to be **~3.0 kWh/m³**.

During the study period, water samples of underground dewater was collected and tested in NABL for the water quality parameters analysis. Test reports are given in the **Appendix 4/5** and summarized results of the same are given in the below table.

Table 1: NABL results of water quality analysis of Underground dewater

Sl. No	Parameters	Unit	Underground dewater
1	pH value	-	7.68
2	Total dissolved solids, Max	mg/L	2110
3	B.O.D (3 days @27°)	mg/L	9.0
4	Chemical Oxygen Demand	mg/L	24.0
5	Electrical Conductivity, Max	µS/cm	2720
6	Cyanide as CN, Max	mg/L	BDL

From the above table data comparison with standard norms indicates the necessary treatment for the desired water specifications of gold processing operations.

3.2 Tail Dump Water Underground Water

Tailings are the leftover materials from the processing of mined gold ore. Tailings consists of ground rock, unrecoverable and uneconomic metals, chemicals, organic matter and effluent from the process used to extract the desired products from the ore. Tailings generally leave the mine processing plant in a slurry form (diluted with water) and HGML is made multiple ponds for storing the tailings on the surface. Tailings dump pond of HGML is located at geographical coordinates of 16.203250 N Latitude, 76.646792 E Longitude around

510 m above the mean sea level. Geographical mapping of tailings dump pond of HGML is shown in the below figure.8.

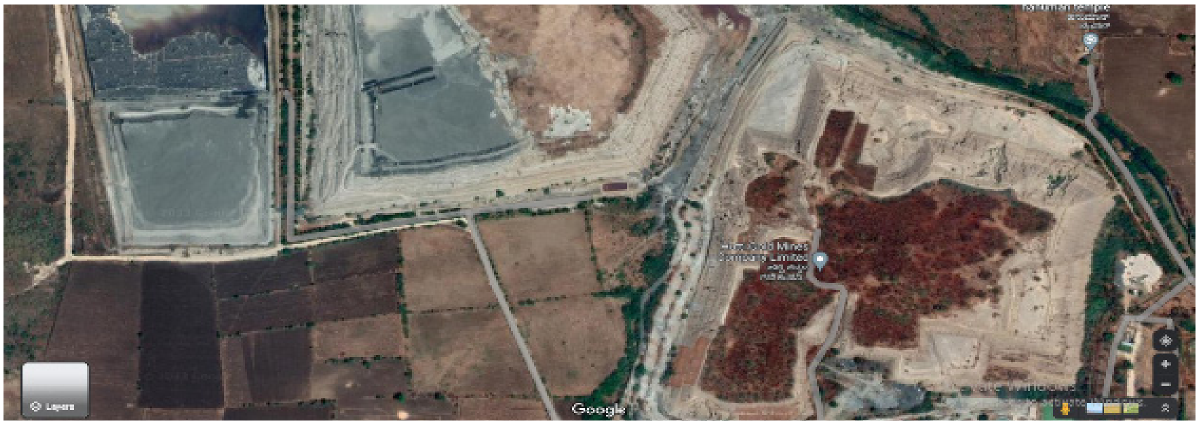

Figure 8: Geographical mapping of tailing dump pond of HGML

Each of these tailing impoundments utilizes engineered containment to minimize the seepage solutions into the environment. Tailing slurry typically containing 1 to 2 parts of finely ground solids to 1 to 2 part of water. Pumping system is used to collect any errant seepage (solution

Photographs captured at Tailings dump pond station during our site visit are provided in figure 9.

Figure 9: Tail dump pond recycling system of HGML.

Plant has installed two small capacity centrifugal pumps for supplying the decanted water from tailing dump pond to Hutti Gold Mines Process water tanks. Installed pumps are of horizontal split case type coupled to induction motors. Both intake and delivery lines of these centrifugal pumps are of 100mm dia, while rising main of discharge header is 125 mm diameter for 1 km is made up of composite materials of High density poly ethylene pipes.

HGML has not installed bulk water flow meters for the monitoring the actual tailing dump water recycled back to process. As per the pump operator's logbook data average decanted water from tailing dump is around **416 - 512 m³/day**. Based on the same, annual average value was estimated to be around **464 m³/day (0.46 MLD)** and same is considered for the baseline calculation. Similarly average energy consumption by the pump is estimated to be around 89 to 102 kwh/day. Based on the same, average annual specific energy intensity of tail dump water pumps is estimated to be around **~0.2 kWh/m³**.

During the study period, water samples of tail dump recycle water was collected and tested in NABL for the water quality parameters analysis. Test reports are given in the **Appendix** and summarized results of the same are given in the below table.

Table 2: NABL results of water quality analysis of tail dump recycle water

Sl. No	Parameters	Unit	Dump recycle water
1	pH value	-	8.23
2	Total dissolved solids, Max	mg/L	2756
3	B.O.D (3 days @27°)	mg/L	120.0
4	Chemical Oxygen Demand	mg/L	408.0
5	Electrical Conductivity, Max	µS/cm	3740
6	Cyanide as CN, Max	mg/L	BDL

From the above table data comparison with standard norms indicates the necessary treatment for the desired water specifications of gold processing operations.

3.3.Centralized Sewage treatment plant - Treated water

HGML has established centralized sewage treatment plant (C.S.T.P) of 1.5 Million Litres per day (MLD) capacity for treatment of sewage collection from HGML residential quarters, hospital, mines, police station and HGML campus (toilet water, lavatory, mess). Centralized sewage water treatment plant is located at geographical coordinates of 16.1987 N Latitude, 76.6539 E Longitude around 515 m above the mean sea level. Geographical mapping of Centralized sewage water treatment plant of HGML is shown in the below figure 10.

Figure 10: Geographical mapping of centralized sewage water treatment plant of HGML

Sewage treatment technology adopted in Hutti Gold Mines is based on the activated sludge treatment process. C.S.T.P comprises of Grit chambers, bar screen, oxylation pond, primary clarifier, equalization tank, aeration tank, secondary clarifier, prefiltration tank, sand filter, activated carbon filter, sludge drying bed, treated water storage tank. Photographs captured at C.S.T.P of HGML during our site visit are provided in the below figure 11.

Figure 11: Sub-processing equipment in centralized sewage treatment plant.

HGML residential quarters are not fully covered with underground drainage system and hence the inflow to C.S.T.P is much lower than the installed capacity. HGML has installed bulk water flow meters for the monitoring of raw sewage inflow and treated water recycled back to plant. TERI had collected the historical water inflow and treated water monitoring details for every month and same is given in the below graph.

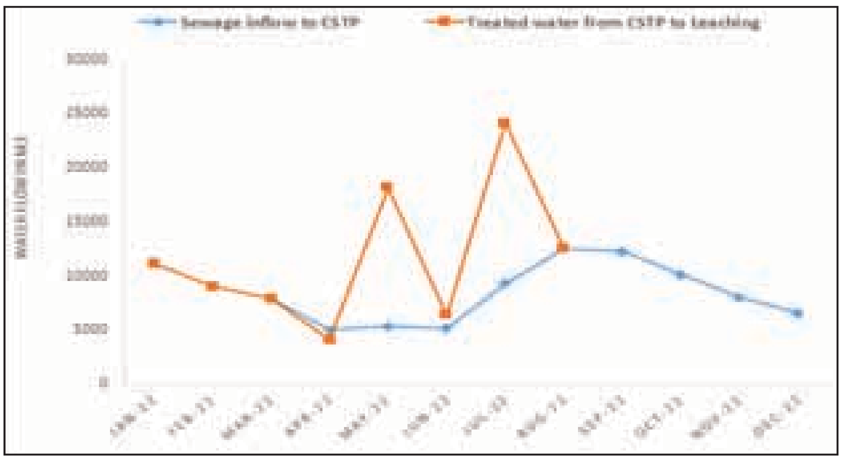

Figure 12: Month-wise sewage inflow to CSTP and treated water to leaching

From the above graph, it can be seen that in most of months treated water to leaching section is higher than the sewage water inflow to CSTP. This indicates the malfunctioning of water flow meters (due for calibration). Hence during the study period,

From the above table, it can be seen that pump performance is slightly on the lower side mainly due to pipeline restriction leading to higher velocity and subsequent pressure drop with increased resistance to the flow. As per the pump operator's logbook data, during the study period average sewage water inflow is around 850 m^3/day and treated water supplied to CSTP is around **504 m^3/day (0.5 MLD)** and same is considered for the baseline calculation.

Similarly, average energy consumption by the C.S.T.P is estimated to be around 300 kwh/ day. Based on the same, average annual specific energy intensity of C.S.T.P is estimated to be around **~0.5 kWh/m³**.

During the study period in February 2023 it was known from the plant personnel that additional sewage drain line from residential communities to C.S.T.P was under renovation and recently in September 2023 the same was connected for sewage water collection system. Installed Bulk water flow meters show increased flow from 15800 m^3/month in February 2023 to 18000 m^3 /month in September, but the treated water pumps operation towards leaching plant remained the same. However, the monitored data is only for 15 days and hence for the reliable estimation, more months monitoring of water quantity will be essential. Daily sewage water inflow quantity monitored by the plant is given in the **Appendix** .

During the study period, water samples of underground dewater was collected and tested in NABL for the water quality parameters analysis. Test reports are given in the **Appendix** and summarized results of the same are given in the below table 13.

Table 13: NABL results of water quality analysis of tail dump recycle water

Sl. No	Parameters	Unit	C.S.T.P raw water
1	pH value	-	7.27
	Total dissolved solids, Max	mg/L	1128
3	B.O.D (3 days @27°)	mg/L	88.0
4	Chemical Oxygen Demand	mg/L	240
5	Electrical Conductivity, Max	µS/cm	1660
6	Cyanide as CN, Max	mg/L	BDL

From the above table data comparison with standard norms indicates the necessary treatment for the desired water specifications of gold processing operations.

3.4 Total Water Availability from Various Sources

Based on the data collection, measurements and subsequent analysis, total water availability for the HGML is estimated and results of the same are given in below table.

Table 14: Total water availability for HGML from various sources

Particulars – Water source	Total water supplied (m^3/day)	Specific users
Krishna River water Gurgunta supply works	4609	Drinking & process
Underground dewater	1532	Process operations
Tail dump water	464	Process operations
Centralized sewage treatment plant water	504	Process operations
Total	**7109**	

From the above table, it can be seen that around 7.2 MLD of water is availability for the HGML. Source-wise break up of water availability is pictorially represented in the below figure.

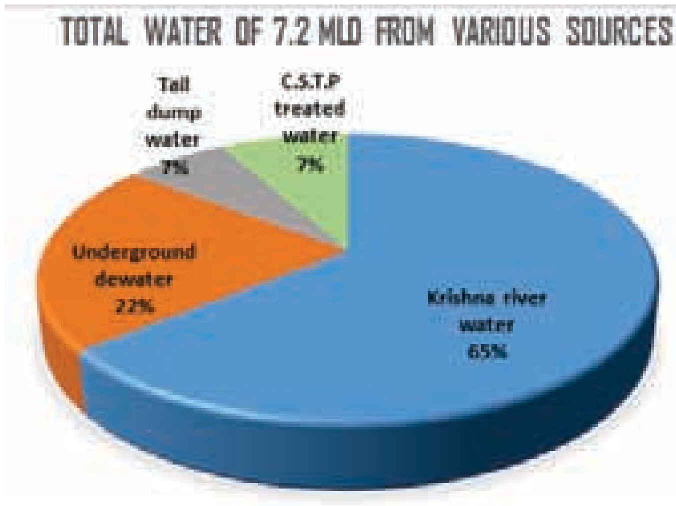

Figure 13: Break-up of water availability from various sources

From the above figure, it can be seen that around 65% of water

The water scenario at Hutti Gold Mines Company Limited (HGML) reflects a well-established and evolving infrastructure designed to meet the dual demands of industrial gold processing and community welfare. With primary water sources drawn from the Krishna River Basin and underground mine dewatering, HGML has effectively supplemented its supply through secondary sources such as tail pond recovery and treated sewage water, demonstrating a strong commitment to resource optimization and environmental sustainability.

4. Discussion:

This paper presents a robust evaluation of water management practices at the Hutti Gold Mine (HGML), emphasizing the critical role of integrated water resource strategies in mining operations within water-stressed regions. The study combines field data, operational audits, and stakeholder insights to assess HGML's approach to balancing industrial water demand with environmental sustainability.

Key findings highlight HGML's multi-source water strategy, which includes:

- Primary sources: Krishna River and underground mine dewatering
- Secondary sources: Tailings pond recovery and treated sewage water

The infrastructure supporting these sources—such as the Tamankal Water Treatment Plant, underground pumping systems, and centralized sewage treatment—demonstrates significant investment in water recycling and energy-efficient operations. Notably, the average daily water availability of 7.2 MLD is distributed across process operations and community needs, with a growing emphasis on reducing freshwater dependency.

Technical evaluations reveal areas for improvement, including pump efficiency mismatches, calibration issues in flow meters, and incomplete sewage coverage. Despite these challenges, HGML's efforts in water quality monitoring, energy intensity tracking, and adaptive planning reflect a forward-thinking approach aligned with national sustainability goals.

The paper concludes by positioning HGML as a replicable model for sustainable mining, reinforcing the importance of ecological stewardship in India's development narrative.

5. Conclusion

The case of Hutti Gold Mine exemplifies how sustainable water management can be effectively integrated into the broader framework of green mining and national development. Through a combination of legacy infrastructure, modern treatment technologies, and resource-conscious operational practices, Hutti Gold Mines Company Limited (HGML) has demonstrated a proactive approach to balancing industrial productivity with environmental stewardship.

The integrated water management practices at Hutti Gold Mines demonstrate a significant reduction in freshwater dependency through the adoption of recycling and treatment systems. Based on the study, the daily water availability of ~7.2 MLD comprises 65% freshwater (Krishna River) and 35% treated/recycled sources (underground dewater, tail dump water, and CSTP).

The water consumption ratio of fresh to treated water is approximately 65:35, indicating substantial progress in resource optimization. Continuous monitoring and infrastructure upgrades have improved treated water quality, making it suitable for process operations. This shift not only reduces environmental stress on the Krishna River but also enhances sustainability in mining operations.

By leveraging both primary sources—such as the Krishna River and underground mine dewatering—and secondary sources like tail pond recovery and treated wastewater, HGML has optimized its water footprint while supporting the needs of its workforce and surrounding communities. These efforts not only enhance operational resilience but also align with India's vision of **Viksit Bharat**, where economic growth is harmonized with ecological responsibility.

As India advances toward becoming a developed nation, the mining sector must evolve into a model of sustainability. HGML's initiatives in water conservation, recycling, and infrastructure modernization offer a replicable blueprint for other resource-intensive industries. This study underscores the critical role of integrated water resource management in achieving long-term environmental and economic goals, reinforcing the idea that **gold, water, and growth** can indeed coexist in a sustainable and inclusive future.

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Synergizing Scientific Mining with Environmental Stewardship: A Case Study on Sustainable Mineral Development at Ramgad Iron Ore Mine

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ABSTRACT:

The Ramgad Iron Ore Mine (ML No. 2547), operated by M/s Zeenath Transport Company in Karnataka, exemplifies a "Triple Bottom Line" approach to mining by balancing economic viability, environmental protection, and social responsibility. This case study examines the implementation of scientific mineral extraction practices, including optimized bench geometry to maximize ore recovery and strategic "sweetening" of sub-grade ore for effective mineral conservation. The study further highlights integrated environmental management measures such as bio-engineered waste dump stabilization, comprehensive rainwater harvesting, and community-led afforestation initiatives. Governed by ISO-certified management systems and implemented in accordance with mandated Reclamation and Rehabilitation (R&R) plans, RIOM demonstrates that fully mechanized opencast mining can be effectively synergized with rigorous environmental stewardship.

KEYWORDS: *Scientific Mining, Mineral Conservation, Sustainable Mining, Environmental Stewardship, Waste Dump Stabilization, Water Management, Triple Bottom Line, Opencast Iron Ore Mining.*

1. INTRODUCTION

The Ramgad Iron Ore Mine (ML No. 2547), operated by M/s Zeenath Transport Company, is a Category 'A' fully mechanized opencast mine covering 49.73 ha with an annual production capacity of 0.48 MTPA. The mine is located in the Ramandurga Block of Ramgad range in Ramgad Village, Sandur Taluk , Ballari District, Karnataka.

Operating under a "Triple Bottom Line" framework, the mine integrates economic viability, environmental protection, and social responsibility. Guided by the vision of "Safe and Responsible Mining," operations are aligned with the Supreme Court–mandated Reclamation and Rehabilitation (R&R) Plan.

An Integrated Management System (IMS) certified to ISO 9001:2015, ISO 14001:2015, and ISO 45001:2018 governs all activities, ensuring scientific mineral extraction, proactive environmental management, and occupational safety while safeguarding regional biodiversity.

2. SCIENTIFIC MINING AND MINERAL CONSERVATION

RIOM follows a scientific approach to bench geometry, specifically designed to balance safety with resource optimization:

Bench Parameters: In accordance with the Slope Stability Report by NITK, Surathkal and DGMS Permission No. 330342/SZ/

BELLARY REGION 1/PERM/2023/260817 dated 15.12.2023 and strictly governed by the yearly production and development plans approved by the Indian Bureau of Mines (IBM)., the mine maintains a bench height of 8 meters and width of 3 meters.

Mineral Conservation through Width Reduction: To prevent the locking of ore under wide benches, the bench width has been optimized to 3 meters. This precision engineering allows for a steeper overall pit slope maintaining the Factor of Safety (FoS), significantly reducing the “stripping ratio” and ensuring that maximum mineral tonnage is recovered from the lease area.

(Photograph showing Mine Working)

Safety Protocols: Despite the reduced width, safety is maintained through rigorous slope monitoring carried out by DGPS and regular vibration studies during blasting.

A mine drainage system using HDPE pipes is provided along the benches to drain out rainwater away from all the benches to prevent safety hazards like erosion or wash out of benches.

(Drainage System installed at Mine Benches)

Low-Grade Utilization:

Low-grade ore utilization is a core component of mineral conservation at the Ramgad Iron Ore Mine and is practiced in accordance with the principles of scientific mining. This approach ensures optimal utilization of mineral resources by minimizing wastage and maximizing the effective life of the mine.

Regular sampling and chemical analysis are carried out during active mining operations to accurately delineate ore zones, ensuring proper identification and classification of all mined material.

Strategic blending of sub-grade ore with high-grade material is undertaken in predetermined proportions based on iron (Fe) content and the physical characteristics required to meet market specifications.

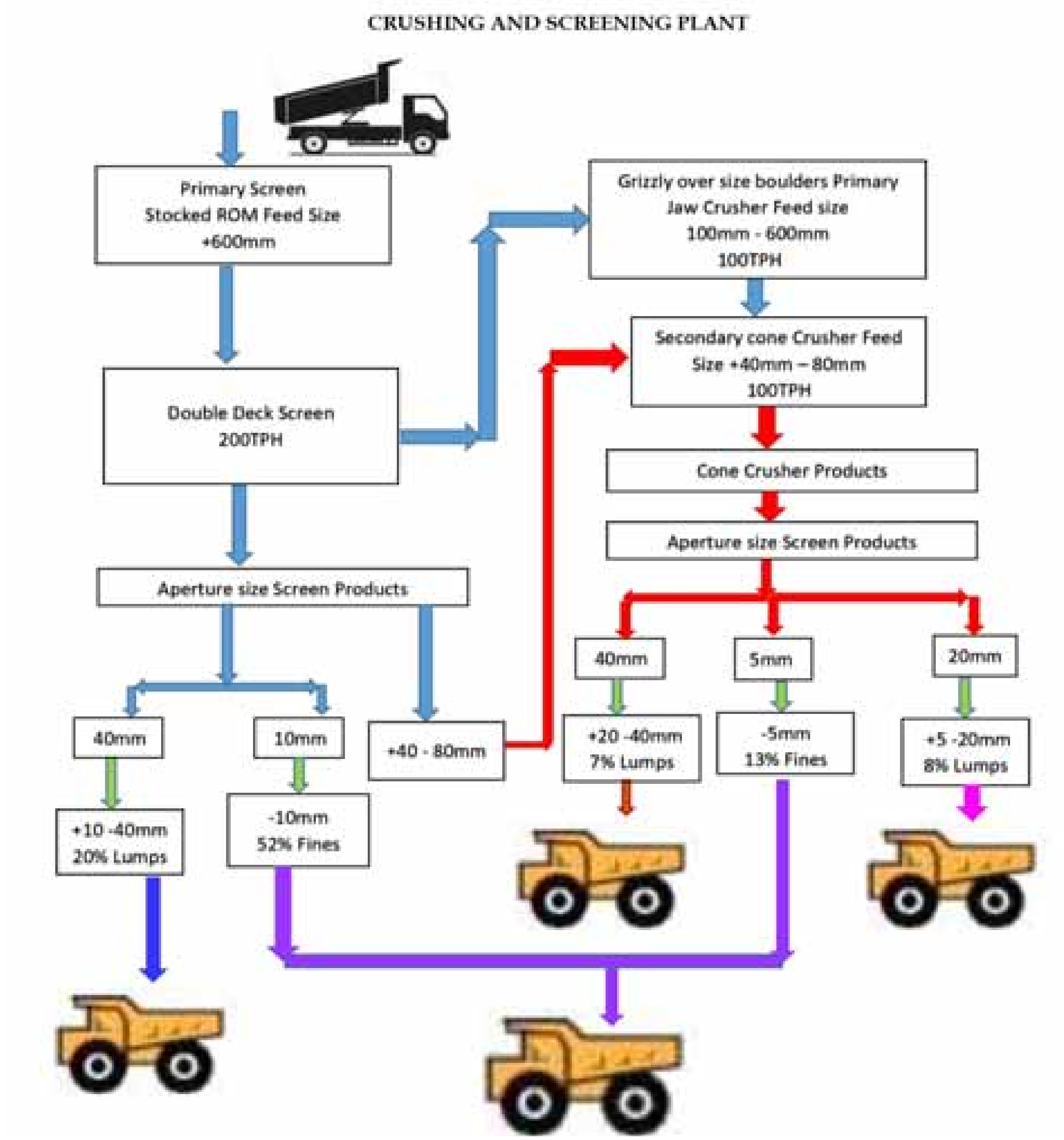
This "sweetening" process enables the production of saleable-grade ore while maintaining consistency in product quality. The practice reduces selective mining of high-grade pockets, enhances overall resource recovery, and supports sustainable mineral development in line with the mine's conservation objectives.

3. MINERAL PROCESSING

Mineral processing at the Ramgad Iron Ore Mine involves screening and crushing of run-of-mine ore to achieve marketable size fractions.

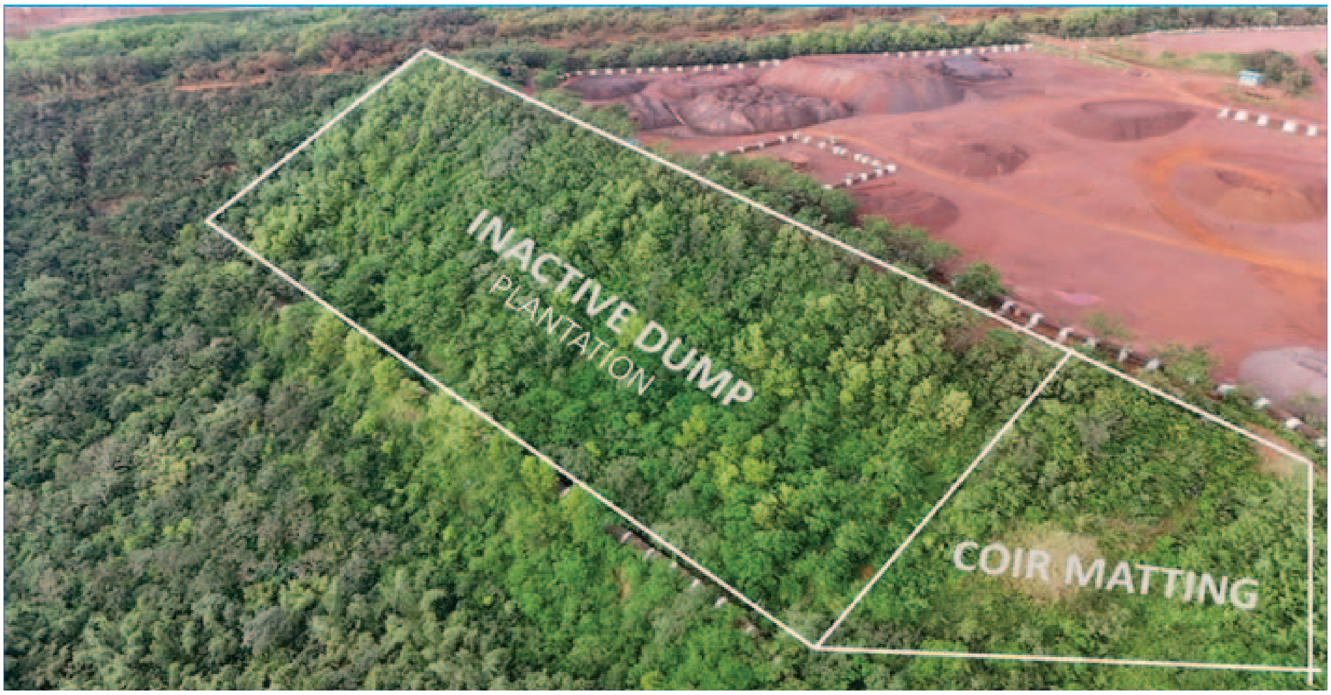
Controlled material handling, reduced free-fall at transfer points, and water spraying at crusher locations are adopted to suppress dust and conserve fines. Processed ore is segregated and stacked systematically to maintain saleable grade specifications.

The Flow chart of mineral process adopted at mine:



4. SYSTEMATIC WASTE DUMP MANAGEMENT & RECLAMATION

Two waste dumps are located within the mine lease. One stabilized dump (ID-1) is located at NW side of lease covering an area of 2.20Ha and Active dump (AD) at the SE part of lease with 4.63Ha and inactive part 2.00Ha made inactive. The waste of Ramgad iron ore mine mainly contains shale and phyllite. The waste is dumped at the demarcated area as per the approved "Reclamation & Rehabilitation" (R&R) plan by ICFRE and Dump management plan by IBM. Year wise dump stabilization is done as per approved Progressive mine closure plan by IBM by using the geo-textile coir mats and saplings on inactive dump slopes combined with grass seeds to prevent soil erosion.



(Fully Stabilized Dump (ID-1)

(Use of Coir Mat at Dump)

(Part of Active dump made Stabilized (ID-2)

Engineering Protections:

Engineering controls such as retaining walls, garland drains, gully plugs, check dams, and silt settling tanks have been constructed to control erosion, manage runoff, and prevent siltation of natural drainage courses. All the proposed R & R Engineering structures have been constructed as per the R & R plan and regular maintenance is taking place. The details of R & R engineering structures are as follows:

(Retaining Wall & Garland Drain at Active Dump)

(Retaining Wall & Garland Drain at Stock Yard)

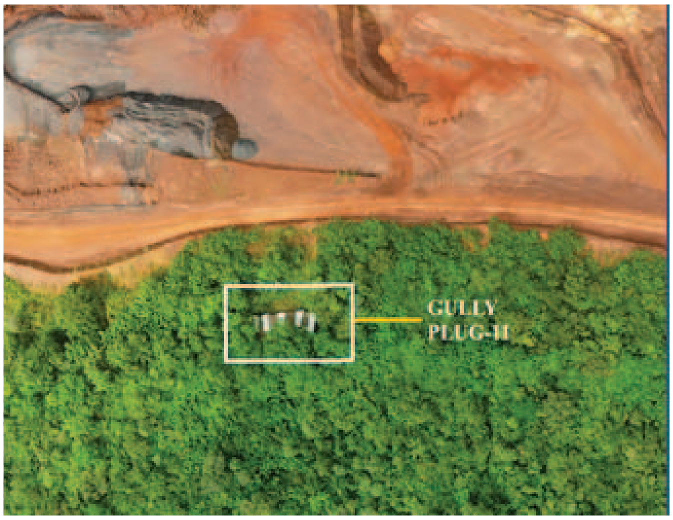
(Retaining Wall & Garland Drain at Inactive Dump)

(Garland Drain)

(Silt Settling Tank-2)

(Silt Settling Tank-4,5&6)

(Gully Plug-8)



(Gully Plug-11)

(Masonry check Dam)

(Rock Fill Check Dam)

Environmental Monitoring:

- A dedicated Environmental Monitoring Cell has been established with experienced officials to oversee environmental activities.
- Regular air, water, and noise monitoring is carried out by the NABL accredited Laboratory.
- A dedicated environmental team is constituted for regular inspection and maintenance of environmental protective measures.

Afforestation: Systematic plantation of native species are planted year wise. The mine maintains a dedicated nursery at Dhamapur village.

(Avenue Plantation) (Green Belt Plantation)

(Nursery)

Plantation Drive:

M/s. Zeenath Transport Company (ZTC) extends its environmental stewardship beyond the lease boundaries. This program bridges the gap between industrial operations and community-led conservation.

Educational Engagement: Every year, the company collaborates with local schools to conduct plantation drives where students and teachers plant native saplings, fostering a sense of environmental ownership and consciousness among the future generation.

Sapling Distribution: To enhance the regional green cover, ZTC organizes distribution drives for the surrounding villages. By providing fruit-bearing and shade-giving native species to villagers, this ensures that the local community actively participates in, and economically benefits from, the region's broader ecological restoration.

(School Plantation and Sapling Distribution)

5. WATER MANAGEMENT AND CONSERVATION

Silt settling tanks have been constructed to facilitate groundwater recharge and promote effective rainwater harvesting. Collected water is recycled and utilized for dust suppression and plantation activities.

(Water sprinklers for dust control along haul roads) (Water Sprinklers for Green Belt Plantation)

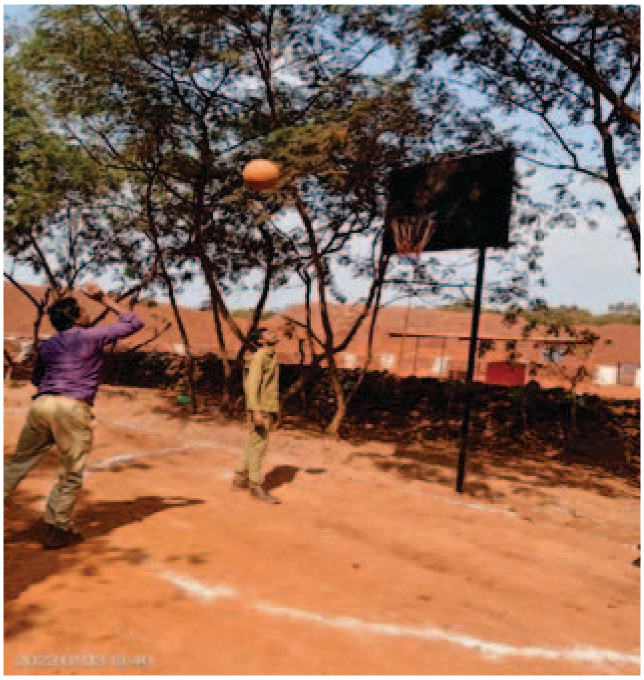
Green Zone and Parks

Green zones and parks have been developed within the premises to provide food and water for birds and animals, contributing to local biodiversity conservation.


(Replica Model of Tungabhadra Dam)


(Food and Water provided to Birds and Animals)

Recreational Area: To refresh employees, traditional games such as spinning top, ring catch, cricket, and volleyball are encouraged during rest intervals. This helps to improve their health by relieving work/personal tension and develops teamwork. Revives old traditional games.



6. Conclusion

The sustainable mining practices adopted at Ramgad Iron Ore Mine demonstrate that scientific mine planning, mineral conservation, and systematic reclamation can be effectively implemented in environmentally sensitive regions. Optimized bench geometry, controlled waste dumping, water conservation, and ISO-based management systems have enabled responsible mineral development while safeguarding environmental and occupational health. The practices documented in this case study are technically viable and replicable for similar opencast iron ore mines.

Prospect of Critical Minerals - A Case study undertaken at John Iron Ore Mine of R. Praveen Chandra, Chitradurga

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Abstract:

The prospect in identifying the critical minerals associated with each other a classic approach in a new exponential era. In the discovery of the critical mineral, REE, PGE the indicator mineral facilitates in prospecting the critical minerals by reporting the field samples collected during field studies from fully opened/broken up surfaces like mining leases, landslides, river bed, onshore area etc., followed by analysis for data derivation. A case study has been conducted in the working mine – JIOM of R. Praveen Chandra by analysing the samples collected from the insitue formation of Shale/Phyllite and fully weathered Quartzite band.

Introduction:

India's journey to become "VIKSIT BHARAT," the contribution of the mineral inventory strengthens the aim of the national vision & mission. As a national interest the discovery of the minerals are the vital responsibility of the professionals and scientists who are involve in the respective field. Now a days the precise study on the occurrence and discovery of the minerals are in place with the help of established, sophisticated technologies. In the geological context there are some minerals exhibits the existence of other minerals and explains the climatic conditions, characteristics and its occurrence in the earth's crust, they are Indicator and Index minerals. These minerals are the guide for further investigation by exploration to discover more importantly critical minerals required for national security development, clean energy, automobiles and the development of other technological fields followed by driving economic growth through the development of mineral value chains.

In lieu of the "VIKSIT BHARAT" vision, the Indian Bureau of Mines under the Ministry of Mines, Government of India promoting the mining fraternity towards the standpoint of National Critical Mineral Mission (NCMM) to speed up the exploration and investigation of the Critical, REE & Strategic minerals followed by mining & processing. The Government of India had listed the critical minerals, REE & PGE under the National Critical Mineral Mission (NCMM) as below:

1. Antimony	15. Nickel	iv. Neodymium	20. Rhenium
2. Beryllium	16. PGE	v. Promethium	21. Selenium
3. Bismuth	i. Platinum	vi. Samarium	22. Silicon
4. Cadmium	ii. Palladium	vii. Europium	23. Strontium
5. Cobalt	iii. Rhodium	viii. Gadolinium	24. Tantalum
6. Copper	iv. Ruthenium	ix. Terbium	25. Tellurium
7. Gallium	v. Iridium	x. Dysprosium	26. Tin
8. Germanium	vi. Osmium	xi. Holmium	27. Titanium
9. Graphite	17. Phosphorous	xii. Erbium	28. Tungsten
10. Hafnium	18. Potash	xiii. Thulium	29. Vanadium
11. Indium	19. REE	xiv. Ytterbium	30. Zirconium
12. Lithium	i. Lanthanum	xv. Lutetium	
13. Molybdenum	ii. Cerium	xvi. Scandium	
14. Niobium	iii. Praseodymium	xvii. Yttrium	

Courtesy by: Ministry of Mines, Government of India

Table-1: List of the critical minerals, REE & PGE

There are minerals called indicator minerals/pathfinder elements are the category of minerals which gives the clues on the other minerals associated to each other and which makes the process easy in the essential mineral discovery.

Indicator Minerals or a pathfinder element:

Indicator minerals/pathfinder elements are the mineral/elements species that indicate the presence of a specific mineral deposit, alteration or lithology of the rocks. Ideal indicator minerals are found in few, if any rocks other than the host deposit or lithology, for example;

- Garnet & Chromite indicator of Diamond
- Pyrite, Arsenopyrite indicator of Gold

Physical and chemical characteristics of the indicator minerals allow them to be readily recovered from exploration sample media (e.g. stream, alluvial, glacial or aeolian sediments or soils) and make them sufficiently abundant. The characteristics include visual distinctiveness, moderate to high density, silt or sand size and ability to survive weathering and/or clastic transport. Most often, only indicator mineral abundance in a sample is reported. However, grain morphology, surface textures or mineral chemistry also may be determined.

Magmatic and hydrothermal minerals such as zircon, apatite, titanite and rutile are resistant to weathering and so end up in the soil, till or stream sediments, indicating their presence in the bedrock of a specific type of mineralization, hydrothermal alteration or lithology and these minerals are increasingly targeted in mineral exploration studies. The indicator minerals provide information of source magma chemistry, including crystallization temperature, degree of fractionation, water content and oxidation state.

Currently, suites of indicator minerals for different types of deposits have been identified by several studies.

Table 1. Different types of deposits, indicator minerals, and elements.			
Deposits of Interest	**Type of rocks**	**Main Pathfinder Minerals**	**Main Pathfinder Elements**
Gold	-	Pyrite, chalco-pyrite, arsenopyrite, bismuthinite magnetite, tellurides, tetrahedrite, pyrite, sphalerite, muscovite, monazite, bastnäsite, quartz, scheelite, wolframite, cassiterite.	Fe, Mn, Cu, Co, Ni, Sb, Zn, As, Bi, Te, Sn, Se, Tl, Ag, Hg, Pb, Mo and W.
REE	Carbonatite rocks	Bastnasite group, ancylite, monazite, (fluor)apatite, pyrochlore, xenotime, florencite.	Na, Mg, Fe, P, Ba, F, S, Sr, Ca, Nb, Th, U, Zr, Cu, Ta, Ti, V, Mn, Pb.
	Igneous rocks (including hydrothermal upgrade)	Bastnasite group, aegirine, eudialyte, loparite, allanite, monazite, fergusonite, zircon, xenotime, fluorapatite, ancylite, gadolinite, euxenite, mosandrite.	Na, K, Fe, Al, Zr, Ti, Nb, Ta, Li, F, Cl, Si, Th, U, P, Cs, Rb, Sn, W, Mo, Be, Ga, Hf, Mn, B.
	Placers and palaeoplacers	Monazite, xenotime, allanite, euxenite.	Ti, Nb, Zr, Au, Sn, Th, U, Pb, F
	Laterites	Monazite, apatite,pyrochlore, crandallite, group, bastnäsite group, churchite, rhabdophane, plumbogummite, zircon, florencite, xenotime, cerianite.	Fe, Al, Nb, Zr, Ti, Sn, Mn, P, low Si, negative Ce anomaly.
	Ion-adsorption	Clay minerals (mainly kaolinite and halloysite).	High Si (>75%), low P.
	Iron oxide-associated (including Iron Oxide Copper Gold (IOCG)) deposits	Bastnäsite, synchysite, monazite, xenotime, florencite, britholite.	Fe, Cu, U, Au, Ag, Ba, F, P, S.
	Seafloor deposits, such as manganese nodules, ferromanganese crust, phosphorite.	Vernadite, todorokite, Fe-oxyhydroxide, carbonate fluorapatite, francolite.	Mn, Fe, P, Cu, Ni, Co.
Cu-Ni-PGE	-	pentlandite, chalcopyrite, pyrite, millerite, PGM, chromite, Cr-diopside, enstatite, olivine, Cr-andradite.	Ni, Cu, Pd, As, Cr, Co, S, PGE
Volcanogenic massive sulphide (VMS) deposits (Cu, Pb, Zn, Ag, Au)	-	Galena, sphalerite, chalcopyrite, pyrrhotite, gold, pyrite, gahnite, staurolite, cassiterite, spessartine, sillimanite, andalusite, beudantite, jarosite, barite, tourmaline, hogcomite, nigerite.	Cu, Zn, Pb, Ag, Mo, Sn, Ba As, Sb, In, Te, Bi, and Tl

W-Mo-Bi, and Sn-Zn-In deposits	-	Cassiterite, wolframite, molybdenite, topaz, chalcopyrite, galena, sphalerite, arsenopyrite, pyrite, loellingite, beudantite, anglesite, plumboferrite, plumbogummite.	Ag, As, Cd, Cu, Pb, Re, Te, Tl
Li	-	Spodumene, petalite, amblygonite, quartz, K-feldspar, albite, or montebrasite, lepidolite, zinnwaldite, eucryptite, cassiterite, lithiophilite, holmquisite, triphylite, quartz, muscovite, apatite, tourmaline tantalite-columbite, beryl.	K, Ca, Rb, Sr, Y, Nb, Sn, Cs, Ta, Sb, W, Bi, As, Ga, Tl, and the REE
Kimberlite-hosted diamonds	-	Cr-pyrope, Cr-diopside, eclogitic garnet, Mg-ilmenite, chromite, olivine, diamond.	C
U	-	Uraninite (pitchblende), thorianite, tourmaline, sulphides, monazite, allanite, zircon, baddelyite, niccolite, U-Th anatase, U-Th rutile, brannerite, magnetite.	Cu, Ag, As, Cr, Pb, Zn, Ni, Co, Re, Be, P, Mo, Mn, REE and radiogenic Pb isotopes

Courtesy by: National Geophysical Research Institute, Hyderabad

Table-2: Different types of deposits, pathfinding minerals, and elements

Government of India initiatives:

- **National Critical Mineral Mission (NCMM):** This seven-year mission aims to build a robust and resilient ecosystem for critical minerals, covering all stages from exploration to recovery from end-of-life products.
- **Mines and Minerals (Development and Regulation) Act 1957:** Amendments have been made to the MMDR Act to include 24 critical and strategic minerals, empowering the government to auction these mine blocks.
- **Auction of critical minerals:** The government launched the first auction of 20 blocks containing minerals like Graphite, Lithium, and Nickel, signalling a move towards domestic production.
- **Recovery from tailings:** A new tailings policy enables the recovery of critical minerals from mining waste, increasing domestic availability.

For illustration:

A case study on Cobalt Mineralization Associated with Copper from Kalyadi Area, Western Dharwar Craton, South India

By Mahantesha P., K.N. Prakash Narasimha, M. Shareef, G. Gopala Krishna and T.K.A. Rahim

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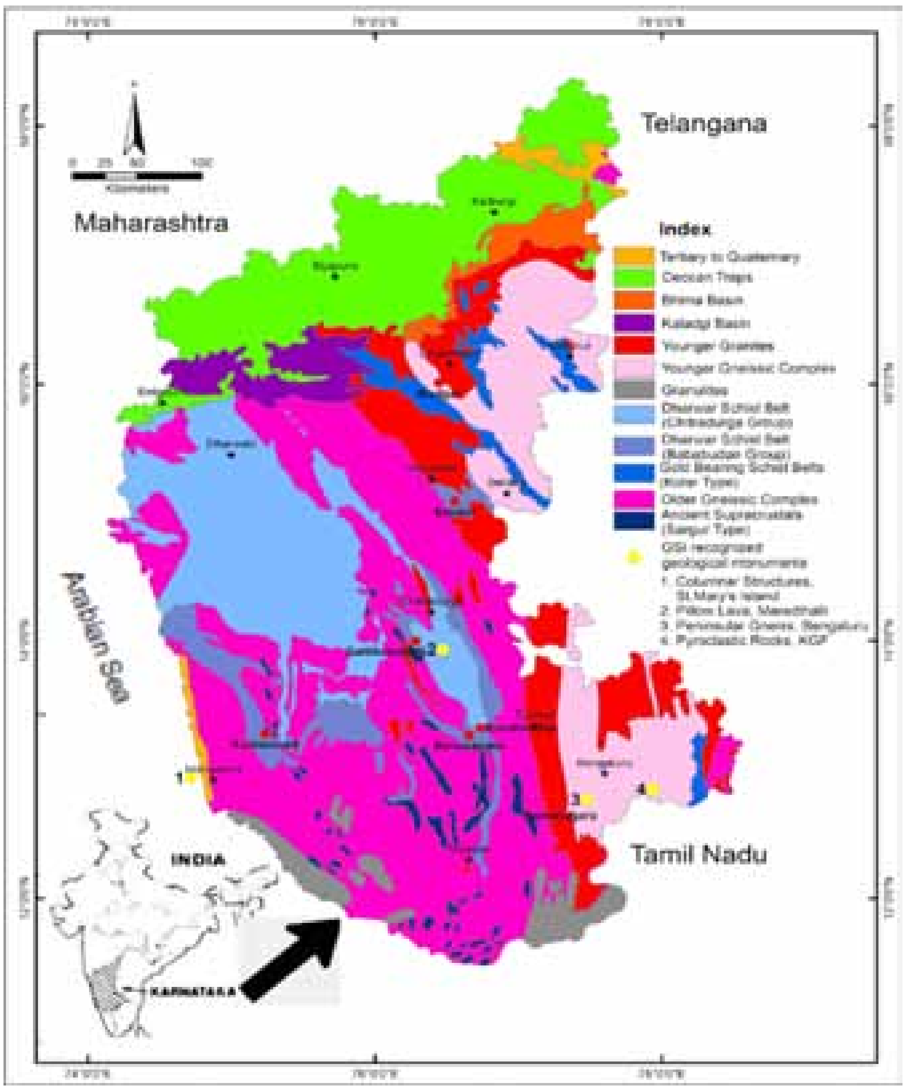
Kalyadi Schist Belt (KSB) of the Western Dharwar Craton (WDC) is well known for Kalyadi ploymetallic copper deposit of Meso Archean (3.0Ga) age. The Kalyadi Supracrustal dominantly made-up of quartzite, ultramafic to mafic schist inter-bedded with chemogenic cherts. The copper mineralization in Kalyadi schist belt occurs as 1) disseminations and patches in quartzite, 2) stringers and veinlets in meta- volcanics and 3) rich concentrations along fractures. The mineralisation is lithologically and structurally controlled by narrow brittle-ductile shear zone as evidenced by the development of numerous fractures, joints, faults, veins, stringers and foliations in KSB. Magnetite, chalcopyrite, pyrite pyrrhotite and arsenopyrite are some of the common sulphide minerals observed in the area. Apart from Cu, Cobalt (Co) association is also known from Kalyadi schist belt. There is no separate Co mineral phases present in the area and the Co is ubiquitously associated with pyrite. Petrographic studies reveal that the chalcopyrite replaced the early pyrite and pyrrhotite. Chemical analyses of the samples from the mineralized zones by AAS have yielded Co values up to 1200 ppm and Cu up to 2.3 %. Negative correlation between Co and Cu is noticed.



Courtesy by: Research Gate

Figure-1: Geological map of the Karnataka state showing the schist belts of Dharwar Craton

A Case study by John Iron Ore Mine of R. Praveen Chandra:

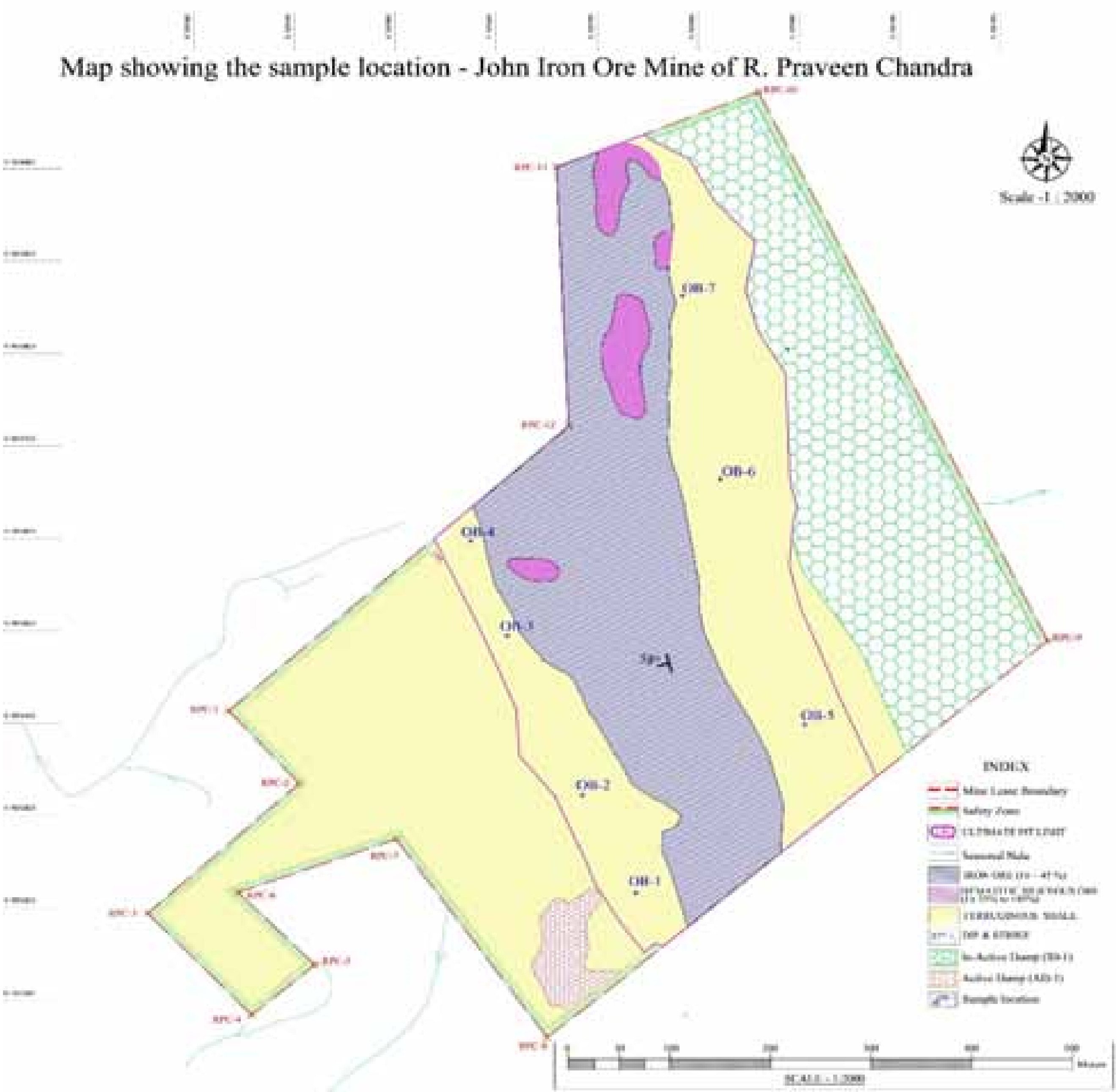
Pursuant to the National Critical Mineral Mission, expedition of the Indian Bureau of Mines, Government of India, the John Iron Ore Mine of R. Praveen Chandra interested in sampling and analysis from the overburden in the mine by collecting seven samples at different locations within the mining lease area (Fig-3) for 69 elements of PGE, REE, and other Critical Elements.

The prospecting of the critical mineral undertaken to study existence, Geochemistry of the formation associated with the potential mineral deposit the Banded Iron Formation/Iron Ore Formation comprised in the mining lease area falling under the Chitradurga Schist Belt of Vanivilas Formation of Dharwar Supergroup. The Vanivilas formation comprised of schistose rocks consisting complex series of chlorite schists, quartzites, carbonate rocks, Manganiferrous clay and banded iron ore formation. Iron formations in the lease area and surrounding the lease area occur in both off-shore volcanic sequence and plattiform volcanic sequence. Stratigraphy succession in Holalkere and Chikkajajur section is as follows. (Source: Dossier of Iron Ore, Geological Survey of India is Acid Volcanics/Intrusive, BHQ/Mn Chert/Phyllite, Limestone/Dolomite, Talya Conglomerate, Schists (Actinolite/Chlorite). The map showing the geology of Karnataka. (Fig-1).

Courtesy by: John Iron Ore mine of R. Praveen Chandra

Figure-2 View of Scientific mining clearly bifurcate Ore & Waste in the pit

The geological sequence of the area focusing the evaluation of the mineral existed and forced to continue the prospecting endorse the following activity.



Courtesy by: John Iron Ore mine of R. Praveen Chandra

Figure-3 Geological map showing sampling location

Table-2 Chemical analysis of Critical Element for total seven samples collected from John Iron Ore Mine of R. Praveen Chandra, Chitradurga, Karnataka.

Sl No	Mineral/Element	Symbol	Sample ID (results in ppm)						
			OB-01	OB-02	OB-03	OB-04	OB-05	OB-06	OB-07
1	Antimony	Sb	0.56	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
2	Beryllium	Be	0.86	<0.5	0.95	<0.5	1.23	0.67	<0.5
3	Bismuth	Bi	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

4	Cadmium	Cd	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
5	Cobalt	Co	29.46	8.52	49.08	5.52	14.03	6.97	14.4
6	Copper	Cu	18	<0.5	66	5	190	90	<0.5
7	Gallium	Ga	8.96	2.92	11.38	5.2	24.55	30.26	2.73
8	Germanium	Ge	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
9	Hafnium	Hf	<0.5	<0.5	<0.5	<0.5	2.23	2.41	<0.5
10	Indium	In	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
11	Lithium	Li	3.44	0.96	2.13	<0.5	0.81	1.77	2.14
12	Molybdenum	Mo	2.87	0.77	0.66	<0.5	<0.5	<0.5	<0.5
13	Niobium	Nb	5.64	<0.5	1.76	<0.5	6.15	7.63	<0.5
14	Nickel	Ni	31	19	87	10	103	35	15
15	Phosphorous	P	462	309	506	122	1249	469	421
16	Potash	K	1293	211	707	501	142	169	544
17	REE								
	i. Lanthanum	La	6.66	3.43	8.97	1.36	30.14	3.23	4.35
	ii. Cerium	Ce	14.64	3.27	14.47	4.17	57.5	25.07	7.8
	iii. Praseodymium	Pr	1.74	<0.5	2.39	<0.5	5.27	0.51	0.65
	iv. Neodymium	Nd	8.26	1.92	10.91	3.16	17.48	3.06	3.52
	v. Promethium	Pm	Radioactive element no permission to test at private Lab						
	vi. Samarium	Sm	1.51	<0.5	2.59	<0.5	2.88	0.66	0.7
	vii. Europium	Eu	0.55	<0.5	0.91	<0.5	0.78	<0.5	<0.5
	viii. Gadolinium	Gd	1.43	<0.5	2.2	<0.5	2.81	<0.5	<0.5
	ix. Terbium	Tb	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
	x. Dysprosium	Dy	1.65	0.74	2.53	<0.5	2.48	1	0.86
	xi. Holmium	Ho	<0.5	<0.5	<0.5	<0.5	0.52	<0.5	<0.5
	xii. Erbium	Er	0.87	0.51	1.59	<0.5	1.43	0.58	0.54
	xiii. Thulium	Tm	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
	xiv. Ytterbium	Yb	0.73	<0.5	1.16	<0.5	1.43	0.61	<0.5
	xv. Lutetium	Lu	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
	xvi. Scandium	Sc	3.61	<0.5	6.4	<0.5	126.39	60.2	<0.5
	xvii. Yttrium	Y	9.35	6.33	15.93	2.43	9.32	4.24	6.74
18	Selenium	Se	<0.5	<0.5	<0.5	<0.5	<0.5	0.79	<0.5
19	Silicon	Si	268042	342316	291060	469904	145279	187905	298684
20	Strontium	Sr	88	29	90	18	10	<5	29
21	Tantalum	Ta	<0.5	<0.5	<0.5	<0.5	0.51	2.23	<0.5
22	Tellurium	Te	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
23	Tin	Sn	<0.5	<0.5	<0.5	<0.5	6.07	<0.5	<0.5
24	Titanium	Ti	1178	134	2852	734	8091	10497	<100
25	Tungsten	W	2.73	1.66	2.24	0.98	1.93	2.06	0.95
26	Vanadium	V	77	51	122	30	342	363	56
27	Zirconium	Zr	35	9	54	19	107	93	7
28	Zinc	Zn	26	18	40	10	139	46	12

Courtesy by: John Iron Ore mine of R. Praveen Chandra

Discussion:

The following elements (Table-3) witnessing its existence as per the analysis report, but the feasibility and economically viability is required to be established in detail.

Table-3 Promising Critical Elements exhibits in the samples as per analysis report

Sl No	Mineral/Element	Symbol	Sample ID (results in ppm)						
			OB-01	OB-02	OB-03	OB-04	OB-05	OB-06	OB-07
7	Gallium	Ga	8.96	2.92	11.38	5.2	24.55	30.26	2.73
17 xvi.	Scandium	Sc	3.61	<0.5	6.4	<0.5	126.39	60.2	<0.5
24	Titanium	Ti	1178	134	2852	734	8091	10497	<100
26	Vanadium	V	77	51	122	30	342	363	56

Courtesy by: John Iron Ore mine of R. Praveen Chandra

The analysis of the samples collected from the different parts of the mines at different geology the Titanium (Ti) Max. 10497ppm (1.05%), Vanadium(V) to 363 ppm (0.036%) and Gallium (Ga) Scandium (Sc) and other are traces in the oxide formation where the BHQ/Phyllite/Chlorite schist is predominant, distributed all along the formation witnessing in the mining lease area.

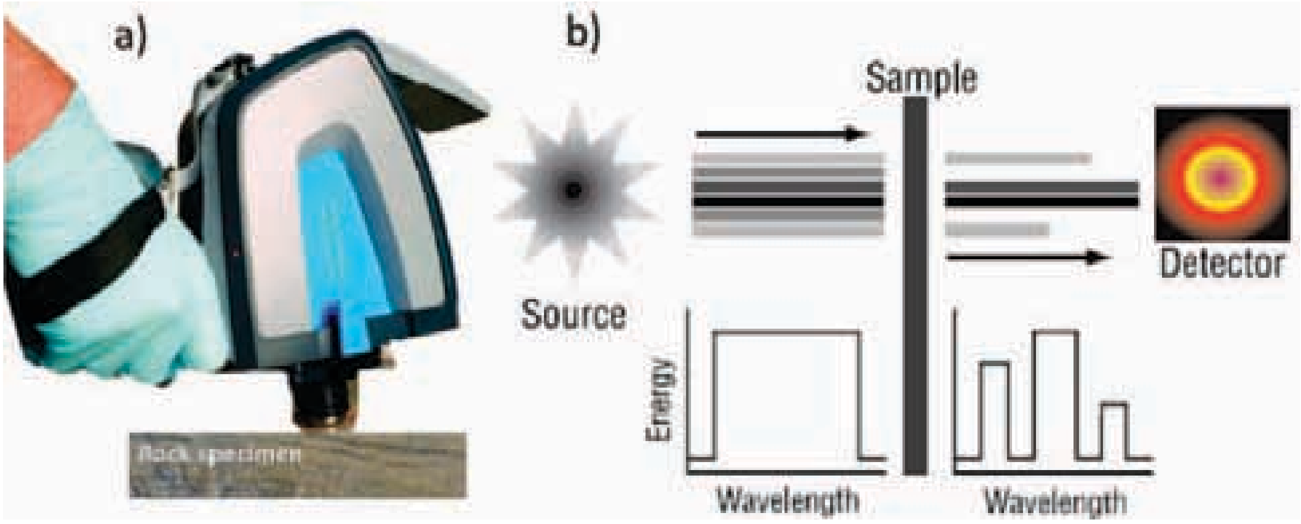
It is worth to spell out on the Portable Techniques for the study of Critical Mineral in a short time and more accurately:

Now a days the more accurate portable techniques are under use for speedy work. The identification of the indicator minerals has major significance in the exploration of the bedrock and the discovery of the other minerals associated to it. During the last half-century, the world has witnessed rapid advancements in analytical instruments for geochemical studies with the introduction of a series of new analytical techniques and technological advancements in allied areas. As a result, there have been significant developments in the accuracy and precision obtainable by even field-portable analytical instruments, such as;

- portable X-Ray Fluorescence spectrometers (pXRF),
- portable X-Ray Diffractometers (pXRD),
- portable near-infrared and short-wave infrared spectrometers (pNIR-SWIR spectrometers) (Fig-4),
- Raman spectrometers,
- portable FTIR spectrometer, (Fig-5),
- LED fluorimeters,
- core scanners,
- portable gamma spectrometers, used for mineral exploration studies.

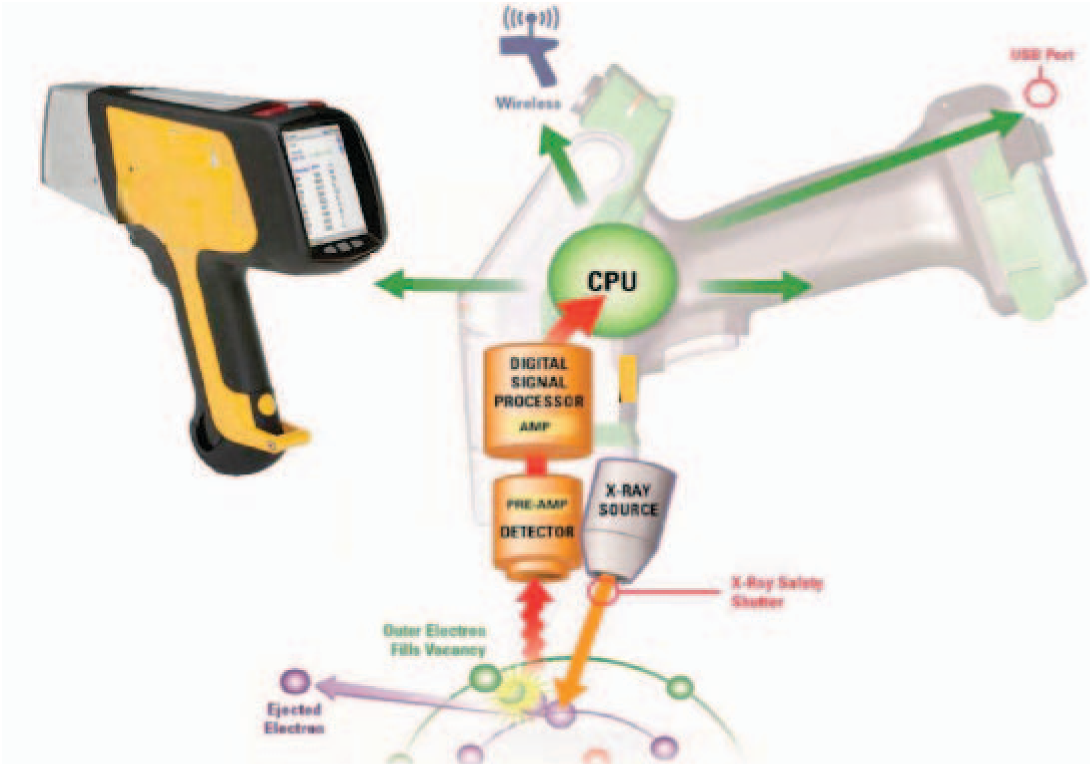
Courtesy by: National Geophysical Research Institute, Hyderabad

Figure-4: A portable UV–Vis–NIR (250–2500 nm range) spectroradiometer for field geology, reproduced from [41], Copyright 2022 Portable Spectroscopy



Courtesy by: National Geophysical Research Institute, Hyderabad

Figure-5: Portable FTIR spectrometer, (b) a schematic diagram of a portable spectrometer



Courtesy by: National Geophysical Research Institute, Hyderabad

Figure-6: Schematic diagram showing the configuration of a typical handheld XRF analyser

Although portable spark optical spectrometers are commercially available, their usefulness for geochemical analysis is not demonstrated yet. With the capability to generate rapid and high-quality data, these analytical techniques have been making the most significant contributions to relatively less expensive geochemical exploration studies leading to new discoveries. Though portable techniques such as pXRF (Fig-6) existed earlier, in recent times, they have become more versatile, incorporating light weight rechargeable batteries, global positioning systems (GPS), wireless computer technology, Bluetooth, remote control, operation capability and have become more accurate and helping the mineral exploration and mining industry in a big way. For example, most exploration geochemists use GPS to establish field/sample locations and these systems are now being integrated into all these field-portable instruments. This article discusses the utility of the information on indicator minerals and pathfinder elements obtained by various portable instruments for identifying different ore deposits both on land and the ocean floor. The basic principles on which these portable instruments work, their strengths and limitations and evaluation of their performance using some practical examples are also presented.

Conclusion:

Since, the Titanium (Ti) is the element used in the manufacture of Surgical instruments, Aerospace technologies, Paint and Chemical industries, Automobiles, Electronic equipment etc., Vanadium will be used in the alloy industries to strengthen the steel etc, and in cumulative the critical minerals are having very vast application in the electronics, military applications and these are the major elements of National security. The chemical analysis reports the Titanium (Ti) Max. 10497ppm (1.05%), Vanadium(V) to 363 ppm (0.036%) and Gallium (Ga) Scandium (Sc) and other are traces in the oxide formation where the BHQ/Phyllite/Chlorite schist is predominant, signifies the efforts of its discovery. The Government of India also making necessary Policy and Regulations and funding initiatives through NMET. Developing / adopting the appropriate processing technology plays an important role in achieving the Atma Nirbharata in critical minerals.

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Feasibility assessment Study of Spherical Wind Turbines (SWTs) for Hilltop Iron Ore Mines in Karnataka

A Technical Evaluation with Regulatory, Environmental, and Forest Clearance Framework

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Abstract

Hilltop iron ore mines in India face growing pressure to reduce diesel dependence and improve sustainability performance under the Indian Bureau of Mines' Sustainable Development Framework guidelines. However, the deployment of conventional wind turbines within mining leases is constrained by limited flat land, safety setbacks, blasting activities, and geotechnical stability requirements. This paper presents a technical and regulatory feasibility study for the application of Spherical Wind Turbines (SWTs) as a decentralized renewable energy solution for hilltop mining operations.

SWTs are compact, omni-directional wind devices capable of operating efficiently under turbulent and multi-directional wind conditions typically encountered along mine ridgelines. Their small footprint, low noise, and reduced clearance requirements make them suitable for auxiliary power applications such as lighting, surveillance, communication systems, and office loads. The study evaluates regional wind potential and estimates energy output for pilot-scale SWT installations in the range of 5–10 kW.

Special emphasis is placed on site selection and foundation safety. Overburden dumps are explicitly excluded due to long-term settlement and stability concerns. Suitable installation locations are identified as reclaimed benches, natural hill ridges within safety zones, and mine infrastructure areas founded on competent in-situ strata. The paper further outlines geotechnical investigation requirements, foundation concepts, safety setbacks, and a regulatory approval pathway involving DGMS concurrence and Mining Plan modification. The proposed approach demonstrates a safe, scalable pathway for integrating wind energy into hilltop mining operations while maintaining full regulatory compliance and operational safety.

1. Introduction

Mining operations depend heavily on diesel generators and grid-based electricity for lighting, communication, and support infrastructure. The Government of India's Climate Action Plan and the Ministry of Mines' Sustainable Development Framework (SDF) 2021 encourage renewable integration in mining. Hilltop iron ore mines in the Ballari–Sandur belt provide a unique advantage:

High elevation

Natural ridgeline wind flow

No large obstructions

However, installing large windmills is not possible due to limited flat land, strict haul-road clearances, blasting schedules, and DGMS-mandated safety distances. Spherical Wind Turbines (SWTs) offer a potential solution.

They require much less land, can operate in turbulent and multi-directional wind flow, and have lower noise and vibration. This makes them suitable for installation in buffer zones, old benches, dumping edges, and reclaimed areas of mining leases. Currently, SWT's have been deployed in decentralized and rural off-grid settings in India and abroad, though documented adoption within active mining operation is minimal or absent. This paper presents a feasibility and proposal-level technical evaluation. The discussed spherical wind turbines are conceptual and proposed in nature. No SWT system has been installed or commissioned at any operating mine site at the time of this study.

Fig 1. *Shows conceptual layout diagram with monitoring parameters*

2. Wind Energy Potential Analysis (2019–2023)

Year	Avg. Wind Speed (m/s)	Power Density (W/m²)
2019	5.3	92
2020	5.6	108
2021	5.9	123
2022	6	132
2023	**6.1**	**138**

Table 1. Annual wind energy potential (2019–2023), Sandur region, based on NIWE dataset. **Source:** NIWE Wind Atlas 2023 & IMD Ballari Station

The hilltop locations consistently maintain above 5 m/s, sufficient for micro-turbine generation. Estimated annual energy for a 5 kW SWT unit:

1.1–1.3 MWh / year

This is sufficient to power:

CCTV surveillance, Bore well pumps (small HP), security lights, office computers, communication towers, street lights inside the mine.

3. Spherical Wind Turbine Technology Overview

SWTs are inspired by O-Wind Technology and utilize a geometric enclosure that captures wind from all directions, unlike conventional HAWTs, which rely on alignment with wind direction.

Advantages of SWTs for mines:

Do not require a yaw mechanism, operate in turbulent wind, require low maintenance, occupy just 3–5 m radius, Lightweight and easy to install, low safety clearance, minimal noise vibration

Parameter	HAWT (Conventional)	SWT (Spherical)
Wind direction sensitivity	High	Omni-directional
Clearance required	>20 m radius	<5 m
Foundation load	High	Moderate
Ability in turbulent wind	Poor	Excellent
Land requirement	Large	Small
Noise	Moderate–High	Low
Ideal use	Open large land	Mines, rooftops, hills

Table 2. Comparison of HAWT/SWT

SWTs are ideal for non-operational benches, buffer zones, reclaimed land, and mine office premises. This study aims to evaluate the technical feasibility, regulatory compliance path, and environmental/forest clearance implications of deploying SWTs in mining buffer zones — and to propose a safe, replicable pilot project pathway.

4. Regulatory Requirements

4.1 DGMS Regulations (MMR 2017)

Required Compliance:

Reg. 116 – Construction near mine workings:

The turbine must not interfere with stability of benches, dumps, or pit slopes.

Reg. 124 – Electrical installations:

Wiring, earthing, lightning protection must meet DGMS standards.

Safe offset distance:

Minimum 50 m from working faces and haul roads. Must not disturb signalling, blasting, or emergency access paths.

4.2 IBM Guidelines

IBM encourages renewable installations in: Reclaimed benches, safety zones, non-operational areas, administrative complexes. SWTs help the mine improve: Sustainable Development Framework compliance, environmental contribution

1. IBM Sustainable Development Framework (SDF), 2016 Issued by: Ministry of Mines

   Purpose: Encourage renewable energy, biodiversity protection, and waste reduction.

   Relevance: SWTs improve the mine's SDF score.

2. IBM Star Rating Program for Mines – 2016 & Updated in 2020 Circular: IBM/SDR/2016 & 2020 revision

   Renewable integration energy efficiency, carbon reduction and installing SWTs

3. MCDR 2021 – Rule 31 (Mine Operations & Sustainable Practices)

   Rule 31(4): The leasee must adopt scientifically advanced and sustainable mining practices. Wind power integration = sustainable practice.

4. IBM Circular on Green Mining Initiative, 2020 Circular No.: Tech/IBM/Green/2020 Issued: 12 August 2020

   Promotes: Renewable energy adoption waste-to-wealth solutions low-carbon mining SWTs directly contribute to green mining.

5. Indian Bureau of Mines Technical Guidelines, Issued: 18 March 2022 Encourages:

   Renewable installations in non-operational zones monitoring of energy usage and integration of decentralized energy systems

   SWTs fall exactly under this guideline.

4.3 Forest Conservation Act (FCA) 1980 – Detailed Process

Only needed if turbine lies in forest land.

STAGE – I CLEARANCE	**STAGE – II** CLEARANCE
Steps:	
1. Submission of Form A	1. Compliance with Stage-I conditions
2. DGPS Survey & KML Mapping	2. CA site fencing and demarcation
3. DFO Inspection & Report	3. Certificate from DCF/DCF
4. Compensatory Afforestation (CA) proposal	4. Final approval from MoEFCC
5. Payment of NPV (Net Present Value)	5.Clearance time: 6–18 months
6. Wildlife Clearance (if applicable)	

Table 3. Stages of Forest Clearance

5. Detailed Feasibility Evaluation

5.1 Site Suitability

Ground:	rocky, stable → good foundation
Elevation:	740–810 m → high wind exposure
Space required:	3–5 m only

Table 4. Site suitability

Buffer ensures safe operation.

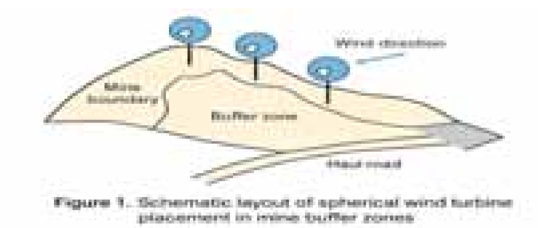

Figure 2. Layout schematic of proposed turbine placement within buffer zone (safe distances shown)

5.3 Site Selection and Foundation Criteria for SWT Installation

The selection of installation locations for Spherical Wind Turbines (SWTs) within a mining lease is governed primarily by geotechnical stability, operational safety, and regulatory compliance. As SWTs are permanent structures subjected to static, dynamic, and wind-induced loads, their foundations must be established on competent and stable strata to ensure long-term performance and safety.

5.3.1 Exclusion of Overburden Dumps

Active and inactive overburden dumps are excluded from consideration due to their heterogeneous material composition, low cohesion, susceptibility to moisture-induced softening, and potential for long-term settlement. The foliated and weathered nature of typical mining overburden, combined with rainfall infiltration and cyclic loading, makes dump material unsuitable for supporting permanent structural foundations. In line with DGMS safety principles, installations on unconsolidated dump material are therefore not considered.

5.3.2 Preferred Installation Locations

Based on technical and regulatory considerations, the following locations within a mining lease are identified as suitable for SWT installation:

a) Reclaimed or Exhausted Benches with Competent In-situ Strata

These benches expose stable geological formations such as banded hematite quartzite (BHQ), banded magnetite quartzite (BMQ), schist, or granite. Such locations offer high bearing capacity, minimal settlement risk, and long-term stability. Since no future blasting is planned in these areas, structural integrity of the turbine foundation can be reliably ensured.

b) Natural Hill Ridges and Safety Zones within the Lease

Natural hill ridges located within statutory safety or buffer zones retain original geological strength and are typically unaffected by mining-induced disturbances. These locations provide excellent wind exposure while satisfying DGMS setback requirements from active workings and haul roads.

c) Mine Infrastructure and Administrative Zones

Areas housing permanent mine infrastructure such as offices, substations, or workshops are already approved for structural loads and are generally founded on competent ground. Installation of pilot-scale SWT units in such zones offers the lowest regulatory and operational risk and is particularly suitable for initial demonstration projects.

5.3.3 Foundation Design Philosophy

Foundation systems for SWT installations shall be designed based on site-specific geotechnical investigations, including borehole logging and plate load tests. Depending on subsurface conditions, isolated reinforced concrete footings, rock-anchored foundations, or micro-pile systems may be adopted. Foundations shall incorporate vibration isolation measures to mitigate the effects of nearby blasting operations.

5.2 Performance Expectation

SWT 5 kW → 1.1–1.3 MWh/yr

Operational reliability: 80–88%

Suitable for continuous small loads

5.3 Operational Use and not suitable for

Operational Use	Not suitable for
Security posts	Crushers
Mining office	Screens
Lighting towers	Heavy motors
Remote cabin power	Conveyor belts
Bore well pump houses	

Table 5. Operational Uses/ not suitable for

6. Cost Analysis

Component	Cost (₹)
5 kW SWT Turbine	2,50,000 – 3,00,000
Foundation + Civil Works	70,000
Cabling + Battery System	90,000
Lightning Protection	15,000
SCADA Monitoring System	40,000
Installation + Labour	30,000
Total Estimated Cost	4,50,000 – 6,00,000
Payback Period:	5–6 years
Operational Life:	12–15 years

Annual Savings:
Grid cost avoided: ~₹1,10,000 per year
Payback period: 5–6 years
Financially feasible for small auxiliary loads.

Table 6. Cost analysis

7. Challenges

7.1 Foundation and geotechnical issues

What it is: Mine benches may have shallow overburden, fractured rock, or variable ground stiffness. Blast-affected zones may have micro-fracturing. Foundations must resist both static and dynamic loads without causing slope instability.

Why it matters: Poor foundation design can cause settlement, tilting, or even slope failure — unacceptable in a mine.

Mitigation: Geotechnical investigation: Boreholes + plate load tests at each proposed hub to determine bearing capacity and settlement behaviour. Isolated shallow foundations: Use spread footings or rock-anchored foundations with vibration isolation from blasting zones.

Monitoring: Install settlement plates and inclinometers to detect movement early.

7.2. Regulatory & compliance challenges

DGMS requires that any new structure inside or adjacent to a mine should not endanger operations (haul roads, escape routes, blasting). They commonly require minimum setbacks and formal approvals.

Why it matters: Without DGMS concurrence you cannot legally install SWT units; DGMS could deny or impose costly conditions post-facto.

Mitigation: Early engagement: Meet DGMS early with a safety case: location maps, bench geometry, blasting schedule, instruments and emergency procedures. Submit instrumentation plans: Include inclinometer/piezometer plans and action thresholds. Design to exceed minimum setbacks: Adopt conservative setbacks (eg. 50–100 m) and buffer zones in the design to smooth approvals.

7.3 Mining Plan / MCDR / IBM approvals

What it is: Adding infrastructure inside a lease often requires a mining-plan modification or mention in PMCP/progressive reclamation plans under MCDR/MCR rules, and IBM oversight.

Why it matters: Non-disclosure or late modification can cause compliance issues during inspections and may lead to penalties.

Mitigation: Document in Mining Plan: Include SWT pilot plan as a modification under Rule (e.g., Rule 32/PMCP).Prepare technical annexes: Provide pilot test methodology, monitoring program, and maintenance SOPs as appendices for IBM. Follow IBM checklists: Use IBM's Rule-12 (or equivalent) application checklist if dispatching power/equipment off-lease.

7.4 Environmental clearance and SPCB conditions

What it is: Project activities that alter land use, generate significant transport movement, or require additional infrastructure may need an EC amendment or SPCB NOC.

Why it matters: EC conditions might limit quantity of material movement, hours of operation, or require extra pollution controls.

Mitigation: EC screening: Check existing EC conditions for the mine; if turbines are within the lease and minor, EC amendment may not be required — still document and get SPCB confirmation. EMP integration: Add SWT-specific EMP (noise, dust during installation) into existing EMP to satisfy regulators.

7.5 Forest & environmental challenges

A. Forest Clearance (FCA) delays, NPV & compensatory afforestation

What it is: If any part of the turbine installation or access route is within forest land, you must secure FCA Stage-I and Stage-II approvals, prepare CA plans, pay NPV, and implement compensatory afforestation.

Why it matters: FCA approvals can take many months; NPV and CA obligations can significantly increase upfront cost and timeline.

Mitigation: Avoid forest land where possible: Prefer non-forest reclaimed benches and revenue land inside lease.

Forest buffer study: If forest overlap is unavoidable, conduct early forest boundary mapping (PARIVESH / FSI) and prepare Form-A with CA proposals and maps.

Parallel processing: Start FCA paperwork in parallel with DGMS and IBM submissions to avoid sequential delays.

Use DMF/NMET funds: Explore funding of CA/mitigation from DMF or national mining funds to avoid heavy upfront costs to the project sponsor.

B. Biodiversity and wildlife impacts

What it is: Siting in or near wildlife corridors or ESZ may require additional clearances and mitigation due to bird collision risk or habitat fragmentation.

Why it matters: Failure to account for wildlife impacts may result in litigation, fines, or project stoppage.

Mitigation: Wildlife assessment: Conduct fauna surveys and collision-risk assessments. Avoid critical habitats: Re-site turbines away from known corridors or nesting sites. Low-impact design: Use low-rotational speed designs, minimal lighting, and avoid long strings of tall turbines.

7.6 Operational & maintenance challenges

A. O&M logistics in remote hilltop locations

What it is: Hilltop mines often have difficult access roads. Routine maintenance (bearings, lubrication, and electronics) requires spare parts and trained technicians.

Why it matters: High downtime, costly part replacement, and increased travel time reduce availability and increase LCOE.

Mitigation: O&M contract with local SLA: Contract vendor with guaranteed response times and local spare parts depot. Training & skilling: Train on-site mine personnel for daily inspections and basic maintenance tasks. Design for maintainability: Select SWT designs with modular parts and remote diagnostics.

7.7 Dust, abrasion and corrosion

What it is: Dust generated by mining, abrasive particles, and chemical attack (if any) can damage moving parts and electronics.

Why it matters: Accelerates component wear and reduces turbine life.

Mitigation: Protective sealing: Use dust-sealed housings and ingress protection (IP-rated enclosures). Regular cleaning schedule: Monthly cleanings during high-dust seasons and after blasting. Air filters & conformal coatings: For control electronics and bearings.

7.8 Battery storage maintenance

What it is: If you include batteries for night or backup power, they require periodic replacement, safe disposal, and thermal management.

Why it matters: Battery failure or mismanagement poses safety and environmental risks.

Mitigation:

Battery selection: Use proven chemistries (LiFePO4) with long cycle life and thermal stability.

Recycling/disposal plan: Contract with certified recyclers.

Thermal control: Install battery shelters with ventilation and temperature monitoring.

7.9 Safety challenges (blasting, slope stability, lightning, electrical)

A. Interaction with blasting & induced vibration

What it is: Blasting causes ground vibration and air blast. If turbines/foundations are too close, long-term micro cracks or misalignment may occur.

Why it matters: May damage turbine alignment, reduce efficiency, or cause structural failure.

Mitigation: Blasting-vibration study: Model expected PPV (peak particle velocity) at turbine foundations for typical blasts and ensure allowable thresholds are not exceeded.

Setbacks: Maintain conservative setbacks (50–100 m or as per DGMS directive). Shock-isolated foundations: Incorporate damping layers or base isolators.

B. Lightning protection & surge management

What it is: Hilltops experience higher lightning incidence; turbines are exposed tall metal structures.

Why it matters: Lightning strikes can destroy electronics, start fires, and cause expensive damage.

Mitigation: Class I lightning protection: Air terminals, down conductors, earthing, and surge arrestors for power/instrumentation circuits.

Lightning risk assessment: Model probable lightning strike rates and size protective systems accordingly.

C. Electrical safety & anti-islanding

What it is: If turbines connect to local grids or micro grids, anti-islanding protection and synchronization are necessary to protect personnel and grid stability.

Why it matters: Unsafe islanding can energize lines unexpectedly during maintenance.

Mitigation: Compliance to CEA / IEC standards: Use certified inverters and protection devices. Local transformer & protection: Install overcurrent, earth-fault, and reverse-power protection.

D. Clear SOPs: For isolation before maintenance with lock-out/tag-out procedures.

Economic & commercial challenges

Higher per-kW CAPEX for micro-wind

What it is: Compared to utility-scale turbines or solar, micro-wind has higher per-kW capital cost and lower economies of scale.

Why it matters: Payback from energy savings alone can be long unless energy replacement is expensive (diesel replacement) or subsidies/grants are available.

Mitigation: Hybridization: Combine SWT with solar PV and battery to increase utilization and reduce per-kWh cost.

Leverage subsidies / grants: Apply for MNRE/state incentives; use DMF/NMET funds for pilot capex. Value non-energy benefits: Quantify avoided diesel transport costs, resilience value, carbon credit potential, and IBM star-rating bonus/benefit.

E. Uncertain market & vendor maturity

What it is: Fewer established suppliers for industrial SWT; after-sales and spare availability may be limited.

Why it matters: Long lead times for parts and uncertain warranties increase lifecycle risk.

Mitigation: Vendor vetting: Select vendors with industrial references, local service networks, and spare inventory commitments.

Procurement terms: Include uptime SLA, performance guarantees, spare parts delivery timelines, buyback/upgrade clauses.

Pilot with multiple vendors: Trial two or three different models to compare real-world reliability.

8. Social & stakeholder challenges

8.1 Local community acceptance and perception

What it is: Communities may fear new installations (visual impact, noise, access restrictions) or see them as a pretext for expanded mining.

Why it matters: Local opposition can cause delays, protests, and negative PR.

Mitigation: Community consultation: Early engagement with village panchayats and stakeholders, explain benefits (job, cheaper materials, electrification).

Local hiring: Offer O&M or transport jobs to locals to build ownership.

Transparency: Publish monitoring results and complaint mechanisms.

8.2 Labour safety & training

What it is: Maintenance personnel and operators must be trained to handle electrical hazards and work at heights.

Why it matters: Untrained work leads to accidents and regulatory issues.

Mitigation: Training program: Certified training on SWT O&M, electrical safety, first aid, and emergency response.

PPE & SOPs: Mandatory PPE, tools, lock-out/tag-out, and permit-to-work systems for all maintenance.

9. Integration & system-level challenges

9.1 Grid/micro grid integration & load matching

What it is: Small wind output is variable; matching with load and storage for reliability is complex.

Why it matters: Without storage or load management, much of production may be unused or wasted.

Mitigation: Energy management system (EMS): Implement EMS to dispatch wind + battery + solar effectively.

Load prioritization: Define critical loads to be served by renewables (lighting, comms, SCADA), and non-critical to grid/diesel.

Battery sizing: Small battery bank to smooth short-term variations; require lifecycle cost analysis.

10. Recommendations

1. Conduct Detailed Micro-Siting Study

Before installation: Perform CFD simulation, identify wind corridors, calculate wake effects, and avoid high-turbulence zones. CFD ensures turbine placement is optimized for peak performance.

2. Establish Safe Offset Distances

Follow DGMS and IBM guidelines:
≥50 m from edge of working benches
≥100 m from blasting zones
≥20 m from haul roads
≥30 m from HT/LT electrical lines

3. Implement Pilot Project of 5–10 kW SWT

Instead of large installations: Start with one or two 5–10 kW units, monitor wind data, power output, vibration validate real benefits before scaling. This reduces financial risk.

4. Adopt Hybrid Renewable System

Combine Solar + SWT because: Solar works in summer wind works during monsoon complementary output ensures 24/7 supply. This prevents idle capacity & increases ROI.

5. Outsource SCADA Remote Monitoring

A remote monitoring system should: Track real-time power generation give vibration alerts give failure alarms monitor battery storage health. Prevents long downtime.

6. Ensure Compliance With All Rules (DGMS, IBM, MoEFCC, CEA).

Prepare a Regulatory Compliance Dossier including:

DGMS permission under MMR 2017

IBM intimation under MCDR 2021 Rule 31(4)

MoEFCC forest clearance (if needed)

Electrical safety approval (CEA 2010)

Local Panchayat/NOC (if outside lease boundary)

This avoids violations and penalties.

7. Set Up AMC (Annual Maintenance Contract) With OEM. This ensures: availability of spares timely servicing trained experts on call long turbine life

Keeps OPEX predictable and low.

1. Start with one test turbine (pilot project)
2. Use CFD wind simulation for micro-siting
3. Install on reclaimed or non-operational benches
4. Maintain 50–100 m distance from active mining
5. Combine with solar panels for hybrid power
6. Use remote monitoring (SCADA)
7. Ensure DGMS & electrical safety compliance

Conclusion

The spherical wind turbine concept is technically sound, environmentally clean, and suitable for auxiliary power generation in hilltop iron ore mines. With proper micro-siting, regulatory compliance, and safety provisions, SWTs can operate efficiently in turbulent hilltop wind conditions. While they cannot replace heavy machinery power demands, their ability to support lighting, communications, security systems, and office loads makes them a practical addition to sustainable mining.

SWT implementation aligns with government policies, IBM's sustainable mining objectives, DGMS safety norms, and can even contribute toward improving a mine's environmental scoring and reputation if implemented in large scale.

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Sustainable Mineral Conservation in Iron Ore Mining: Transitioning to a Circular Economy

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Abstract

The iron ore mining industry faces a critical transition due to declining high-grade ore reserves, stringent environmental regulations, and rising societal expectations. This paper explores strategies for adopting a circular economy model in iron ore mining, focusing on resource efficiency, waste minimization, and material reuse. Key technical processes such as advanced beneficiation, tailings recovery, and energy-efficient technologies are discussed to enable sustainable mineral conservation.

1. Introduction

- Iron ore mining has traditionally followed a linear model of resource extraction, processing, and disposal. However, the depletion of high-grade ores and increasing environmental concerns necessitate a paradigm shift toward a circular economy.
- A circular economy focuses on maximizing resource efficiency, minimizing waste, and reusing materials across the mining value chain. For iron ore mines, this means:
- Utilizing low-grade ores through advanced beneficiation
- Recovering iron values from tailings and slimes
- Reducing waste generation
- Repurposing mineral rejects in downstream industries
- Lowering carbon footprint through energy-efficient technologies

This paper highlights key strategies and technical processes that enable sustainable mineral conservation in iron ore mining.

2. Advancing Circular Economy in Iron Ore Mining: Green Practices for Zero Waste

The need to embrace a circular economy in iron ore mining has become increasingly urgent due to several interconnected challenges. One of the most critical issues is the declining availability of high-grade ore. Traditionally, mining operations relied on hematite reserves with iron content above 64%. However, these high-grade deposits are rapidly depleting, forcing the industry to process low- to medium-grade ores with iron content ranging from 45% to 58%. This shift demands more advanced beneficiation techniques and improved resource efficiency to sustain production levels.

Environmental regulations have also become stricter, especially regarding tailings disposal and emissions. Conventional mining practices generate large volumes of waste and consume significant energy, making compliance difficult without innovative solutions. At the same time, societal expectations are evolving—communities and stakeholders now demand sustainable mining practices that minimize ecological impact and ensure long-term resource stewardship.

Another major concern is the carbon footprint of traditional beneficiation processes, which are energy-intensive and contribute significantly to greenhouse gas emissions. With global climate commitments and ESG (Environmental, Social, and Governance) pressures increasing, sustainability is no longer optional. Mining companies are expected to reduce carbon emissions, improve material recovery, and demonstrate responsible operations to regulators and local communities.

A **circular economy approach** directly addresses these challenges by promoting **zero waste principles**, resource efficiency, material reuse, and energy optimization. By integrating green mining practices—such as advanced beneficiation, tailings reprocessing, water recycling, and renewable energy utilization—companies can transform waste into valuable resources, reduce environmental impact, and align operations with global sustainability goals.

3. Circular Economy Principles in Mining

The mining industry is increasingly embracing the principles of a circular economy to ensure sustainability and long-term resource security. One of the core aspects of this approach is resource efficiency, which focuses on maximizing the recovery of valuable minerals such as iron from both ore and waste streams. By improving beneficiation techniques and adopting advanced separation technologies, mining operations can significantly reduce losses and make better use of extracted resources. Equally important is waste minimization, aimed at reducing the generation of tailings and slimes through innovative processes. Traditional mining often results in large volumes of waste, but modern practices emphasize reprocessing and utilizing these by-products, thereby lowering environmental impact and improving overall productivity.

Another key principle is material reuse, which involves repurposing mineral rejects and other residual materials for applications in construction and allied industries. This not only diverts waste from landfills but also creates new value chains, contributing to a more circular and sustainable economy. Finally, energy optimization plays a critical role in reducing the carbon footprint of mining operations. By implementing low-carbon technologies, improving energy efficiency, and integrating renewable energy sources, the industry can move toward cleaner production methods while maintaining competitiveness. Together, these strategies represent a transformative shift from the traditional linear model of “take, make, dispose” to a circular system that prioritizes **resource conservation, environmental stewardship, and economic resilience.**

4. Technical Strategies for Sustainable Mineral Conservation

4.1 Advanced Beneficiation of Low-Grade Ores

Reverse Flotation for Upgrading Low-Grade Iron Ore

Reverse flotation is an advanced beneficiation technique widely used to improve the quality of low-grade iron ore. The process begins by grinding the ore into fine particles and conditioning it to create an environment suitable for selective separation. In this method, amine-based collectors are introduced, which preferentially attach to silica or quartz particles present in the ore. These silica particles become hydrophobic and float to the surface, forming a froth that can be removed. Meanwhile, the valuable iron-bearing minerals such as hematite and magnetite remain hydrophilic and sink to the bottom, allowing for their recovery. This selective flotation significantly enhances the iron content of the final product while reducing impurities like SiO_2, resulting in a higher-grade concentrate suitable for steelmaking.

Circular Economy Benefits: Reverse flotation not only improves ore quality but also aligns with the principles of a circular economy. By upgrading low-grade iron ore that would otherwise be considered waste, the process transforms an underutilized resource into a marketable product. This reduces dependency on high-grade reserves, helping conserve natural resources and extend their lifespan. Additionally, by minimizing waste generation and utilizing materials that would typically be discarded, reverse flotation contributes to sustainable mining practices. The approach supports resource efficiency, lowers environmental impact, and promotes economic viability in the iron and steel industry.

Reduction Roasting for Upgrading Low-Grade Iron Ore

Reduction roasting is a thermal treatment process designed to improve the quality of low-grade iron ores, particularly those that are highly siliceous or contain goethite. In this technique, the ore is heated to temperatures typically ranging from 600°C to 900°C in a controlled reducing atmosphere. During roasting, the iron-bearing mineral hematite undergoes a phase transformation into magnetite. This change is crucial because magnetite exhibits strong magnetic properties, enabling efficient separation from gangue minerals through magnetic separation techniques. The result is an upgraded iron concentrate with significantly higher Fe content, making previously low-value ore suitable for steel production.

Sustainability Advantages: Reduction roasting offers notable sustainability benefits in the context of modern mining and resource utilization. By making highly siliceous and goethitic ores usable, this process reduces reliance on conventional beneficiation methods alone, which often struggle with such ore types. It also enhances overall iron recovery from resources that were once considered waste, thereby minimizing the need for extensive mining of high-grade deposits. This approach supports the principles of resource efficiency and waste reduction, contributing to a more sustainable and circular mining economy. Ultimately, reduction roasting helps conserve natural reserves, lowers environmental impact, and ensures better utilization of available mineral resources.

4.2 Recovery of Iron from Tailings and Slimes

WHIMS

Wet High-Intensity Magnetic Separation is an advanced mineral processing technique primarily used for recovering iron from ultra-fine particles and slimes, typically smaller than 45 microns, which are often considered waste in conventional processes. This method operates in a wet environment under a strong magnetic field, allowing magnetic minerals such as hematite and magnetite to be separated from non-magnetic gangue. WHIMS is particularly effective for low-grade ores, where traditional beneficiation methods struggle to achieve high recovery rates. By extracting additional iron from slimes, WHIMS significantly enhances resource utilization and reduces material loss. Moreover, it contributes to environmental sustainability by lowering the load on tailing dams, thereby minimizing the ecological footprint of mining operations. This process not only improves overall yield but also offers economic benefits by converting what would otherwise be waste into a valuable product.

Utilization of Iron Ore Tailings (IOT): Key Circular Practices

4.2.1 IOT in Construction Materials

Iron ore tailings (IOT), a by-product of mining, can be repurposed in construction to reduce environmental impact and promote circular practices. They can replace natural sand or be used in backfill, concrete aggregates, bricks, blocks, tiles, and road embankments. This reduces pressure on river sand mining, conserves ecosystems, and minimizes land needed for tailings storage. Integrating IOT into construction materials supports sustainability, cost efficiency, and long-term ecological balance.

4.2.2 Pelletisation of Tailings

Ultra-fine iron ore particles (slimes) can be converted into value-added pellets through pelletisation. The process involves dewatering, adding binders, and forming uniform pellets for use in DRI and EAF steelmaking. This reduces waste, minimizes dust, lowers tailing pond accumulation, and supports sustainable mining by enhancing resource recovery and reducing environmental impact.

4.3 Waste Reduction and Repurposing

Mine waste materials can be effectively repurposed to support sustainable mining and construction activities. One key approach is utilizing waste in cement and brick manufacturing, which reduces the need for virgin raw materials and minimizes disposal challenges. Additionally, dry beneficiation techniques are increasingly adopted in regions facing water scarcity, as they eliminate the need for large volumes of water and prevent slime generation, making them ideal for arid mining environments. Overburden and waste rock can also be reused for practical applications such as road construction, mine haul road maintenance, embankments, and tailing dam strengthening. This reuse minimizes the requirement for external borrow material, lowers environmental impact, and enhances the overall efficiency of mining operations. Collectively, these practices contribute to resource conservation, cost reduction, and improved sustainability in the mining sector.

4.4 Energy-Efficient Technologies

Mining operations consume significant energy for drilling, hauling, crushing, and material handling. To address rising energy costs and sustainability requirements, companies are adopting a mix of technologies aimed at improving efficiency and reducing environmental impact.

Solar panels and solar-powered lights at JSW Mines – Harnessing renewable energy for sustainable mining operations

- **Renewable Energy Integration:** Solar power is increasingly used in remote mine sites where grid access is limited. Photovoltaic (PV) systems can supply electricity for lighting, pumping, and auxiliary operations. When combined with battery storage, solar installations provide reliable power even during non-sunny hours. This reduces diesel generator usage, lowers greenhouse gas emissions, and cuts long-term energy costs.
- **Advanced Material Handling Systems:** Conveying systems are major energy consumers in mining. Pipe conveyors represent a significant improvement over conventional belt conveyors. Their tubular design allows for steep inclines and curved paths, reducing the need for multiple transfer points and associated energy losses. They also minimize spillage and dust, improving environmental performance and reducing cleanup costs. For long-distance transport, pipe conveyors can replace truck haulage, which otherwise consumes large amounts of diesel fuel.

Down The Hill Pipe Conveyor at JSW Mines – Efficient and eco-friendly material transport.

- **Other Efficiency Measures:**

  High-efficiency motors, variable frequency drives (VFDs), and energy recovery systems in ventilation are also widely implemented. These technologies optimize power usage across different processes, contributing to overall operational efficiency.

  By combining renewable energy sources, innovative material handling solutions, and process optimization, mines can significantly reduce energy consumption while meeting sustainability goals.

- **Electrified Mining Equipment for a Greener Future**

  The mining industry is undergoing a significant transformation as companies seek to reduce carbon emissions and improve operational efficiency. One of the most promising developments is the shift from diesel-powered machinery to electrified equipment. This transition not only addresses environmental concerns but also offers tangible economic and safety benefits.

Why Electrification Matters:

Diesel engines have traditionally powered haul trucks, loaders, and drilling rigs, contributing to high greenhouse gas emissions and increased ventilation requirements in underground mines. Electrification eliminates tailpipe emissions,

- reducing the mine's carbon footprint and improving air quality for workers. Lower heat generation also minimizes cooling demands, further cutting energy consumption.

Key Advantages of Electrified Equipment:

- **Energy Efficiency:** Electric motors convert energy more efficiently than internal combustion engines, reducing overall power consumption.
- **Reduced Operating Costs:** Electricity is often cheaper and more stable in price compared to diesel fuel, leading to long-term savings.
- **Lower Maintenance:** Electric systems have fewer moving parts, resulting in reduced wear and maintenance downtime.

Improved Safety: Better air quality and less noise enhance working conditions, particularly in underground environments.

Current Applications and Future Outlook: Battery-electric haul trucks and loaders are already being deployed in several large-scale mines. Hybrid systems combining battery and trolley assist are also gaining traction for open-pit operations. As battery technology advances and charging infrastructure improves, full electrification of mining fleets is expected to become a standard practice, aligning with global decarbonization goals.

5. Environmental and Economic Benefits

Reduced Land Footprint

Recovering iron from tailings reduces the load on tailings dams, minimizing land use and closure liabilities. Tailings reprocessing enhances resource recovery, cuts costs, and mitigates land degradation and water pollution, leading to a smaller ecological footprint.

Lower Carbon Emissions

Beneficiating low-grade ore reduces waste hauling and transport emissions. Reusing tailings in construction avoids the carbon impact of river sand mining, significantly lowering the industry's overall carbon footprint.

Water Conservation

Dry processing minimizes water use, while thickened tailings and filtration systems enable water recovery and recycling. These practices create a closed-loop system, conserving resources and reducing environmental impact.

6. Alignment with SDGs and National Policies

Adopting a circular economy in mining is more than an operational improvement—it is a strategic approach that aligns with global and national sustainability objectives. At the international level, it supports key **United Nations Sustainable Development Goals: SDG 12** by promoting responsible consumption through efficient resource utilization and waste reduction, **SDG 13** by lowering carbon emissions and optimizing energy use, and **SDG 15** by reducing land degradation and fostering ecological restoration. Nationally, these principles resonate with the **National Mineral Policy 2019**, which advocates zero-waste mining and resource recovery, and help companies comply with **IBM Star Rating** Parameters focused on environmental stewardship and resource efficiency. Furthermore, circular mining practices contribute to the vision of **Viksit Bharat @2047**, ensuring resource security, sustainable industrial growth, and environmental protection—critical pillars for India's transformation into a developed nation. By embracing these strategies, mining operations not only meet regulatory and societal expectations but also strengthen their sustainability credentials and create long-term value for stakeholders.

7. Steps toward Circular Economy and IRMA Standards

Adopting circular economy principles in mining such as resource efficiency, waste reduction, and material recovery directly supports compliance with IRMA standards. IRMA emphasizes responsible resource management, environmental protection, and continuous improvement, all of which align closely with circular economy strategies.

Key Connections

- **Waste Minimization:** Circular practices reduce tailings and promote material reuse, meeting IRMA's environmental performance criteria.
- **Energy Efficiency:** Incorporating renewable energy and battery-powered equipment

supports IRMA's climate and energy requirements.

- **Responsible Closure Planning:** Circular economy encourages designing mines for post-closure reuse, aligning with IRMA's mine closure chapter.

- **Stakeholder Engagement:** Circular models often involve community participation in recycling and reclamation, fulfilling IRMA's social responsibility standards

8. Conclusion

Transitioning to a circular economy is essential for sustainable and competitive mining. By adopting advanced beneficiation, tailings recovery, and energy-efficient technologies, the industry can conserve minerals, reduce waste, and minimize land and water footprints. These practices lower environmental impact, improve compliance, and strengthen sustainability credentials. Circular mining creates long-term value for companies, communities, and ecosystems, positioning India as a global leader in responsible mining.

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Sustainable Mining and Green Technologies: A Pathway to Decarbonizing India's Mineral Economy

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Abstract:

This article explores how integrating sustainable mining practices and green technologies can help reduce carbon emissions in India's mining sector. As a major emitter of greenhouse gases, India faces the challenge of balancing industrial growth with environmental protection. Green mining focuses on reducing environmental impact, ensuring worker and community safety, and promoting responsible, long-term operations. By adopting these practices, India can advance its climate goals and lead in sustainable resource extraction. Sustainable mining combines environmental care, economic feasibility, and social responsibility to create a more eco-friendly and socially conscious mining industry.

1. Introduction:

India, the world's second-largest coal and fourth-largest iron ore producer, is central to global mineral supply but faces significant environmental challenges from conventional mining. As the third-largest greenhouse gas emitter, the country is under increasing pressure to decarbonize its energy-intensive mining sector. In response, leading mining companies have committed to reducing emissions by 30–40% over the next decade and achieving net-zero Scope 3 emissions by 2050. This transition is being driven by the adoption of green technologies, climate-smart practices, digital tools such as AI and IoT, and strengthened public-private partnerships, positioning India toward more sustainable and technologically advanced mining.

2. Impact of Mining Activities on the Environment:

The mining sector is widely seen as a major cause of environmental degradation due to its significant ecological footprint that exacerbates ecological degradation. Mining operations account for substantial **Scope 1 and Scope 3 emissions**, primarily from:

- Diesel-powered haul trucks and generators
- Explosives used in blasting operations
- Emissions from transportation and mineral processing

While minerals are vital for industrial growth, their extraction often results in serious environmental and social impacts. Mining can cause deforestation, biodiversity loss, land degradation, and pollution of air, water, and soil, disrupting ecosystems. Socially, it often displaces tribal and indigenous communities without fair compensation, leading to conflicts and unrest. Each stage of mining, from exploration to closure, carries risks that, if not managed responsibly, can cause lasting harm to both the environment and local communities.

3. Legal and Regulatory Framework for Environmentally Sustainable Mining in India:

The Ministry of Environment, Forest and Climate Change (MoEF&CC) is the key authority regulating India's mining sector, guided by the Environment Protection Act (1986, amended 2006) and the Forest Conservation Act (1980). These laws mandate Environmental Impact Assessments (EIA) and empower the government to protect forests and prevent ecological damage. The Central Pollution Control Board (CPCB) enforces the Water Act (1974), Air Act (1981), and CRZ rules, while state departments and Pollution Control Boards monitor compliance locally. Together, these frameworks focus on assessing regional carrying capacity and minimizing environmental impacts. Complementing this, initiatives like the Star Rating System, National Mineral Policy 2019, and Production Linked Incentive (PLI) Scheme promote sustainable mining, technological advancement, and reduced dependence on mineral imports for green technologies.

4. Key Findings:

The mining industry in India serves as the backbone of its industrial economy, facilitating rapid urbanization, infrastructure development, and the transition toward renewable energy. With vast reserves of coal, iron ore, bauxite, and critical minerals like lithium and rare earth elements, India is positioned as one of the leading global mining hubs.

- **Economic Contribution:** The mining sector contributes 2.5% to India's GDP, with potential to increase significantly through modernization and reforms. It provides direct employment to over 700,000 workers, with an extended ecosystem supporting millions indirectly.
- **Market Size & Growth:** In 2023, the mining market was valued at Rs. 1,045,000 crore and is projected to grow at a CAGR of 6% through 2030. Coal remains the dominant segment, accounting for over 55% of the market, while critical minerals are set to become the fastest-growing category.
- **Trends Shaping the Industry:**
  - ◊ Increasing private participation and FDI due to policy reforms like the National Mineral Policy (2019) and amendments to the MMDR Act.
  - ◊ Adoption of smart mining technologies, including AI, IoT, and automation, to improve efficiency and reduce environmental impacts.
  - ◊ Focus on sustainable mining practices and ESG compliance in response to global environmental concerns.

5. Sustainable Mining Practices & Green mining technologies:

India's drive for sustainable mining is fueled by its net-zero emissions pledge by 2070, stricter regulations, and rising stakeholder expectations. Industry bodies like FIMI and CII are promoting environmental impact assessments, eco-certifications, and sustainable practices. Mining, which contributes up to 7% of GHG emissions, is undergoing a green shift through technologies like electric equipment, dust suppression systems, water recycling, and dry tailings disposal. Heavy diesel machinery alone emits around 400 million tons of CO_2 annually, prompting a transition to electric alternatives that reduce both emissions and operational costs. An astounding 46% of these emissions are produced by excavators in the 10 t-plus categories, with the mining industry accounting for up to 7% of total GHG emissions. These collective efforts are steering India's mining sector toward a greener, more future-ready model.

5.1 Sustainable Mining Methods

5.1.1 Low-Impact Extraction Techniques

Low-impact mining methods such as precision drilling and selective extraction can reduce land disturbance, dust, and noise by 30–50% while cutting costs by 10–20%. Countries like Canada are leading in adopting these approaches, particularly in underground gold and copper mining, proving that efficiency and environmental responsibility can go hand in hand.

5.1.2 Waste Reduction and Circular Economy Management

Circular economy practices in mining such as recycling tailings and waste rock for construction and reclamation- reduce environmental impact while creating value. Methods like dry stacking significantly cut water use and tailings risks, achieving up to 40% less landfill waste and 50% lower waste volumes, while improving safety and enabling future land reuse.

5.1.3 Water Conservation and Treatment Systems

Water conservation is central to sustainable mining, with closed-loop systems reducing freshwater use through continuous recycling. Advanced filtration, constructed wetlands, and bioremediation further treat water effectively while protecting ecosystems and supporting biodiversity. These approaches are used in countries like Chile and Canada, have achieved up to 90% water reuse, helping reduce environmental risks, ensure regulatory compliance, and build community trust.

5.1.4 Energy Efficiency and Carbon Footprint Reduction

Energy efficiency and renewable integration are reshaping mining by cutting emissions and reducing reliance on fossil fuels. The use of solar, wind, and hydropower—along with electrified equipment and smart energy systems has enabled some mines, particularly in Africa and Australia, to meet up to 80% of their energy needs from renewables.

5.1.5 Progressive Mine Rehabilitation & Biodiversity Conservation

Land rehabilitation and ecosystem restoration are central to responsible mining, with progressive reclamation reducing long-term impacts. Reforestation with native species, soil stabilization, and real-time monitoring using drones and remote sensing help restore biodiversity and prevent erosion. Countries like Australia and South Africa have rehabilitated over 50% of mined land before closure, demonstrating the effectiveness of proactive restoration.

5.1.6 Digital Traceability, Transparency & Ethical Sourcing

Digital traceability and transparency are transforming mining by ensuring ethical sourcing and supply-chain accountability. Blockchain, AI, and satellite monitoring enable end-to-end tracking, improve compliance by up to 30%, reduce illegal mining, and support global sustainability standards.

5.1.7 Community Engagement, Social License, and Local Benefits

Community engagement and social license are vital to sustainable mining. By involving local and Indigenous communities in decision-making, investing in infrastructure, and supporting skills development and local businesses, mining companies build trust, promote economic resilience, and ensure long-term social and economic benefits for host communities.

5.2 Technology Advancements Enabling Sustainable Mining Practice

5.2.1 Remote Sensing & Satellite Monitoring

Remote sensing and satellite monitoring enable real-time tracking of land, vegetation, and water in mining areas. Using AI-driven tools, drones, and multispectral imagery, companies can ensure compliance, detect degradation or illegal mining early, and support transparent, sustainable operations.

5.2.2 AI-Based Environmental Monitoring & Advisory

AI-based environmental monitoring systems are transforming mining by enabling real-time, data-driven sustainability management. Using IoT sensors and predictive analytics, these systems optimize energy and water use, reduce emissions and waste, and enhance exploration and processing efficiency—minimizing environmental impact while improving operational performance.

5.2.3 Blockchain for Supply Chain Traceability

Blockchain is enhancing transparency and ethical sourcing in mining by securely tracking minerals from extraction to delivery. By ensuring ESG compliance and supply-chain accountability, successful pilots in Africa and South America show how blockchain builds trust and prevents exploitation.

5.2.4 Resource and Fleet Management Tools

Digital fleet management systems are transforming mining logistics by enabling real-time tracking, route optimization, and equipment health monitoring. These tools reduce fuel use, emissions, downtime, and maintenance costs, supporting safer, more efficient, and sustainable mining operations.

6. Mining Companies Going Green:

- **Polluter Pays Principle:** Odisha and Jharkhand have implemented GIS-based and web-based dispatch systems.
- **Equipment Electrification:** NMDC and Coal India are piloting electric and hydrogen-powered haul trucks, loaders, and drill rigs; replacing one diesel truck can cut over **3,000 tonnes of CO_2 annually**.
- **Energy-Efficient Technologies:** MOIL uses solar lighting, variable frequency drives (VFDs), and efficient compressors, achieving 8-10% annual energy savings.
- **Sustainability Reporting:** Companies like Hindustan Zinc, JSW Steel, and Tata Steel publish detailed sustainability reports, tracking metrics like water neutrality, carbon reduction, and biodiversity efforts- boosting transparency and investor trust.

6.1 Best practices done by JSW Steel Limited:

- Scientific Reclamation: Mines in Karnataka, Odisha, etc., rehabilitated per ICFRE and government guidelines.

Gabion Check Dam

Toe Wall & Garland drain

Geo-coir matting

- Water Efficiency: Targeting 2.21 m^3/tonne specific water consumption by 2030.
- **Digital Mining:** Tablets and digital systems have been implemented to optimize fleet/ loading, boosting productivity and lowering environmental impact.

◊ ***Mine Integration System:*** The excavation and hauling process involves defining the work area and material, allocating equipment and manpower, generating and monitoring trips with real-time trips with weighbridge data, and completing post-operation checks with performance analysis and reporting.

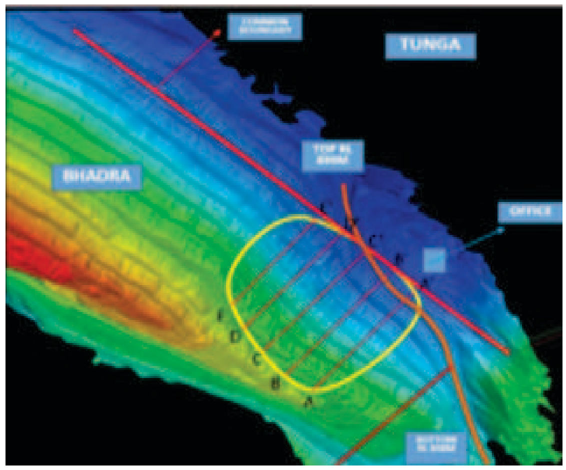
◊ 

Reactore Software

◊ ***Fuel Management System:*** A digital fuel management system integrated with SAP and MIS enables real-time tracking of fuel issuance, consumption, and inventory, ensures cost and usage transparency, prevents unauthorized transactions, and improves operational efficiency through fuel-performance analysis.

Fuel Management System

◊ ***Maptek 3d Laser Scanner:*** The Maptek XR3 MkII 3D Laser Scanner provides fast, high-precision 3D surveying for mines, enabling accurate modelling, volume calculations, safer remote data capture, and improved planning and decision-making.



Maptek 3d Laser Scanner

◊ ***Mysetu EHS&S:*** MySetu EHS&S is a digital platform for real-time management of Environment, Health, Safety, and Sustainability, enabling incident reporting, compliance tracking, environmental monitoring, and safety audits through mobile access and customizable dashboards.

Mysetu EHS&S

- ESG Alignment: Roadmap aligned with UN SDGs.
- **Dust control measures:** Engineered water sprinklers, wet drilling, dust suppression system at crusher & screen plants is being practiced at the mine site.

Engineered water sprinklers *Wet Drilling* *Mist Canon*

- **Pipe Conveyor (Vijayanagar):** JSW has installed 24 km pipe conveyor from Nandihalli Yard to JSW Steel Limited plant, Operating 24×7 with a capacity of 3,500 TPH at 5 m/s, reduces ~8,335 t CO_2/year, cuts dust, improves safety, and saves fuel, prevents mineral spillage, supports DHPC connectivity from multiple leases, and plays a key role in reducing the overall carbon footprint of mining operations.


Transportation of Iron Ore through Pipe Conveyor

Table 1: Emission Reduction via Pipe Conveyor Technology

Transport Mode	Energy Use	Annual CO_2 Emission (Tonnes)
Road (Tipper Trucks)	Diesel fuel (~2 km/L)	9,447
Pipe Conveyor	Electricity 3.5 kWh/t	1,112

CO_2 Savings: 9,447 – 1,112 = 8,335 CO_2 (Tonnes)

6.2 Best practices done by NMDC Limited:

- **Renewable Energy:** NMDC sourced ~40% of its power from renewables in FY 2022–23, including wind and solar projects.
- **Emission Reduction:** Cut GHG emissions by 24% over the past decade through Scope 1, 2 &3 tracking.
- **Green Transport:** A 15 MTPA slurry pipeline to reduce road transport and emissions.
- **Digital Innovation:** Digital Twin technology implemented for real-time monitoring in Chhattisgarh mines.
- **Water Recycling:** Reuses 80% of water in beneficiation plants.
- **Operational Efficiency:** Advanced fleet management and automated systems enhance recovery and reduce losses.

6.3 Best practices done by Hindustan Zinc:

- **Drone Surveillance:** Monitors and ensures compliance with the Sustainable Development Framework (SDF).
- **Renewable Energy & EVs**: 40% renewable energy use; electric vehicles in underground mines.
- **Green Fleet**: India's first BEVs in underground mining, plus EV trucks, scooters, and LNG vehicles to cut Scope 3 emissions.

- **Solar Power**: 40 MW installed at mining sites.
- **Water Management**: Zero Liquid Discharge (ZLD), rainwater harvesting, rooftop runoff recharge, recycling, and 60 MLD sewage treatment.
- **EcoZen Zinc**: Asia's first low-carbon zinc brand, 75% below global average carbon footprint.

6.4 Best practices done by Tata Steel:

- **Noamundi Mine (Jharkhand):** Biodiversity parks, rainwater harvesting, air quality monitoring, electrified ore transport, drip irrigation, afforestation; five-star rating by Indian Bureau of Mines.
- **Sustainable Technologies**: Mine-to-mill optimization & slag recycling to reduce waste and improve efficiency.
- **Effluent Treatment**: Sukinda Chromite Mine's 108 MLD ETP treats 100% effluent, reclaiming 90-95% for reuse.
- **Water Management**: TSML collaborates with TERI and FluxGen for water audits; targets zero groundwater use and 30% reduction in surface water intake by 2030.

6.5 Best practices done by Vedanta:

- **Drone Surveillance**: Ensures compliance with India's Sustainable Development Framework (SDF).
- **Smart Mining**: AI-based ore sorting and drone exploration.
- **Carbon Reduction Target**: 25% cut in Scope 1 & 2 emissions by 2030.
- **Low-Emission Smelting**: GHG emissions reduced by 20% at zinc mines.
- **Dry Tailings System** (Zawar): >90% water recovery, lower environmental risks, easier land rehabilitation.

7. Common Challenges in Implementing Sustainable Mining Technologies:

- **High Capital and Operational Costs-** Sustainable mining technologies demand high upfront capital investment and entail significant maintenance costs, particularly challenging for smaller or remote mining sites where operational resources and technical support are limited.
- **Technical Complexity & Skill Gaps-** A shortage of tech-savvy mining professionals and the need for specialized skills in areas like AI, drone operations, and blockchain hinder the effective adoption of sustainable mining technologies.
- **Integration with Legacy Infrastructure-** Many older mines lack digital infrastructure, leading to compatibility issues with outdated equipment and legacy processes.
- **Data-Related Issues- Inconsistent or poor-quality data, combined with data overload and limited real-time analytics, hampers the performance and efficiency of advanced mining technologies.**
- **Regulatory and Standardization Gaps-** Varying global ESG regulations and the absence of standardized reporting and traceability frameworks create compliance challenges and hinder consistent sustainability performance across the mining sector.

- **Social and Community Challenges-** Building community trust in sensitive regions is challenging, as unequal benefit distribution and cultural differences can lead to conflicts and resistance to mining activities.
- **Adoption Barriers for Small and Remote Operators-** Limited funding, technical skills, and connectivity, along with infrastructure and power constraints in remote areas, hinder the adoption of sustainable mining technologies.
- **Cybersecurity and Trust Issues-** Digital traceability systems are vulnerable to data breaches and rely on input that can potentially be manipulated.
- **Environmental and Geological Limitations-** Some ecological methods may be unsuitable for certain terrains or ores, and natural conditions can hinder restoration efforts.
- **Resistance to Change- Organizational inertia and worker resistance can delay the adoption of new digital technologies.**

8. Conclusion:

India's mining sector is at a pivotal moment, with its future hinging on the integration of sustainability, technological innovation, and resource efficiency. By adopting green technologies, embracing digital transformation, and fostering public-private partnerships, the industry can transition from a carbon-intensive model to one aligned with climate goals. Leading companies are already demonstrating how sustainable practices can reduce emissions, conserve water, and lower operational costs. With strong policy support and collaborative efforts, green mining has the potential to reshape India's mineral economy and establish it as a global leader in responsible resource extraction.

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Challenges Envisaged During Ore Reserve Estimation of Underground Gold Mine at Hutti: A case study of Strike Reef

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Abstract:

The world class Hutti Gold Mine is located in the northern part of Hutti-Maski Schist Belt. The gold quartz-sulphide mineralisation is localised mostly within the chlorite-biotite-carbonate schist that occur as tabular zones within the metabasalts and at the contacts of metabasalts with the acid volcanic rocks. There are nine significant well defined parallel to sub-parallel tabular auriferous reefs localised along narrow zones of highly sheared chlorite-biotite-carbonate schist. These reefs exhibit different ore characteristics yielding variation in average width and grade.

As it is understood that in Archaean type of lode deposit, the occurrence of gold mineralization is not uniform unlike other minerals, which is true in Hutti Gold Mines also. The occurrence of gold mineralization is erratic in nature. This factor creates significant challenges in declaring an accurate grade of the stoping block. The estimation of ore-reserve is done through classical Longitudinal Vertical (L–V) section method and Datamine Resource Module software. But each method has limitations in determining grade with full certainty. Therefore, the precise grade of a stoping block can only be reliably reconciled after mining; until then, the grade remains a projection based on the available data. A case study of reserve estimation in a stoping of Strike Reef is discussed in this paper.

Introduction:

The Hutti Gold Mine is a potential working mine of M/s Hutti Gold Mines Co. Ltd.(HGML), A Government of Karnataka Undertaking has the unique distinction of being the only producer of primary gold in the country. HGML has been active in the exploration, development and exploitation of gold deposits occurring in Karnataka.

The Hutti deposit is located at the north western periphery of the Hutti greenstone belt. All the auriferous lodes occur within the metavolcanics dominantly composed of massive, fine to medium grained, pillowed metabasalt and subordinate widths of Acid volcanic bands of rhyolitic composition, which occur intermittently as concordant bodies. The gold quartz-sulphide mineralisation is localised mostly within the chlorite-biotite-carbonate schist that occur as tabular zones within the metabasalts and at the contacts of metabasalts with the acid volcanic rocks.

Nine significant well defined parallel to sub-parallel tabular auriferous reefs viz. Main, Prospect, Oakley's, Middle, Zone-I, Village, Strike, Strike (Foot-wall) and New East reefs are localised along narrow zones of highly sheared chlorite-biotite-carbonate schist.The general strike of the mineralised zones is N 20^0 W to S 20^0E with a general dip of 60^0 to 70^0 due west (Fig.1).

It is well proved that in Archaean type of lode deposit, the occurrence of gold mineralization is erratic in nature. This fact makes it challenging to declare precise grade of the stoping block. This feature is common in Strike Reef also.

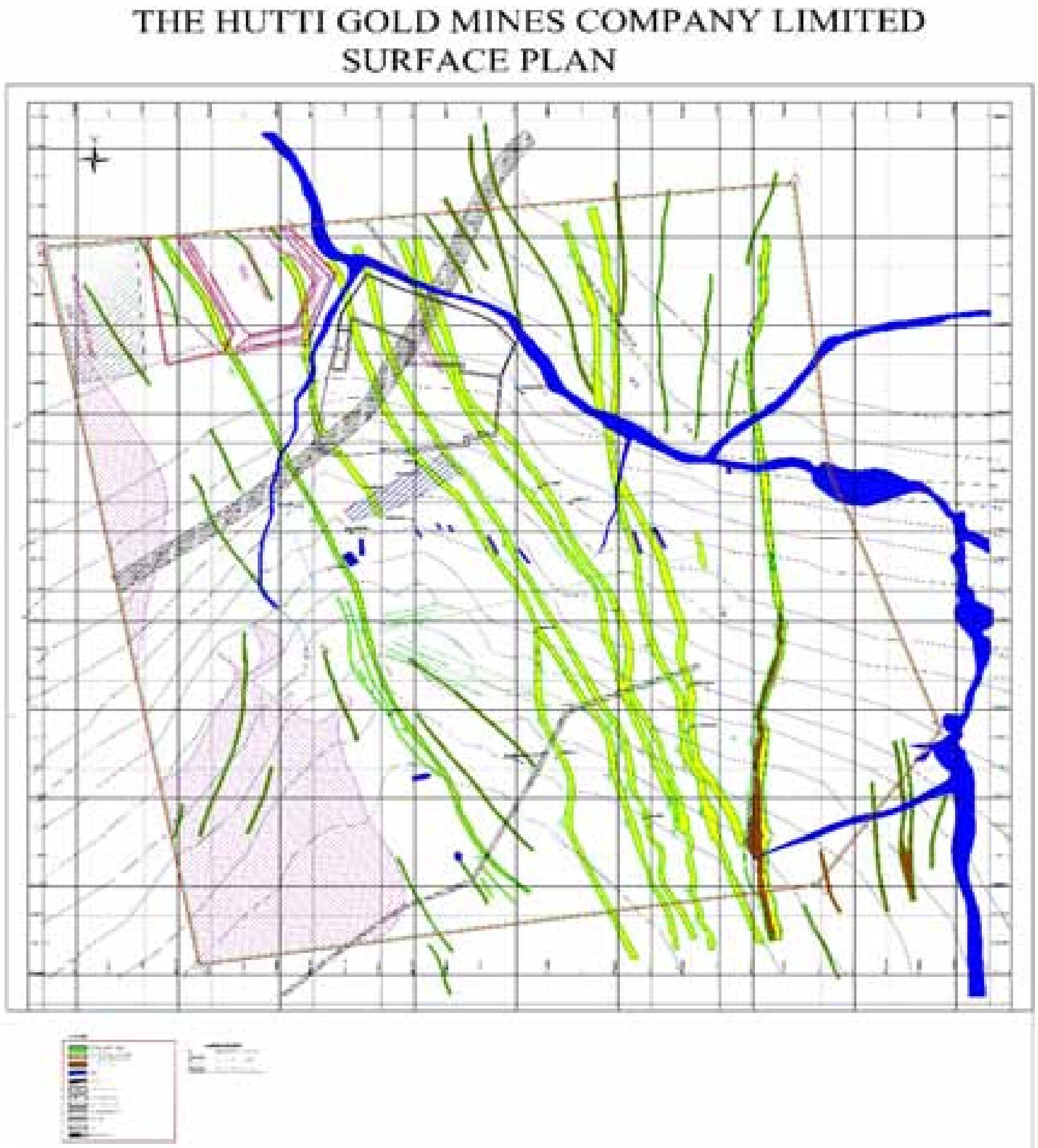


Fig.-1

A case study of Strike Reef

At Hutti Gold Mine ore reserves were estimated at an cut-off grade of 2.0 grams/tonne. A stopping block from **SR 24th L (781m) to 26th Level (841m)** has been selected to discuss the challenges encountered in assessing ore reserves using the classical **L–V section method** and the **Datamine Resource Model.**

Parameters considered for reserve estimation of SR 24-26th L S/L Stope:

- Geological sampling was carried out at regular 2-meter intervals in the ore drives and at 50cm intervals along both the north and south walls of the exploratory cross cuts during on-lode development of SR 24th Level and SR 26th Level as well as in the secondary stope development points of SR 24th Drill Level, SR 26th Top Sublevel, and SR 26th Bottom Sublevel.
- The primary and secondary development which is taken within the ore body follows the ore trend and the sample values as collected above are its guiding factor.
- The zone towards hang-wall and foot-wall of an ore drive up to which sample values are 2g/t and above are considered within the payable zone (a limit demarcated in each ore drive of proposed stoping block having values more than the cut-off grade) and accordingly width of the payable ore body is evaluated.
- However, at places where the sample values within the drives are less than 2.00 g/t is also considered as payable.
- Bulk density of 2.83 g/m3 is considered for all calculation purpose.

A) Estimation of ore reserve by classical L-V Section Method (Table-1.1)

	24th L - 24thD/L				**24th D/L -26th TSL**		
	length (m)	**Avg. Width (m)**	**Avg. Grade (g/t)**		**length (m)**	**Avg. Width (m)**	**Avg. Grade (g/t)**
Drives	186	3.25	9.96	**Drives**	180	3.32	12.82
X-cuts	213.4	5.70	8.20	**X-cuts**	247.1	5.58	7.19
Total		**8.95**	**9.07**	**Total**		**8.90**	**9.83**
	26th TSL - 26th BSL				**26th BSL - 26th L**		
	length (m)	**Avg. Width (m)**	**Avg. Grade (g/t)**		**length (m)**	**Avg. Width (m)**	**Avg. Grade (g/t)**
Drives	180	3.15	12.90	**Drives**	180	3.16	14.55
X-cuts	243.2	4.74	5.77	**X-cuts**	374	4.67	7.75
Total		**7.89**	**9.43**	**Total**		**7.84**	**10.43**

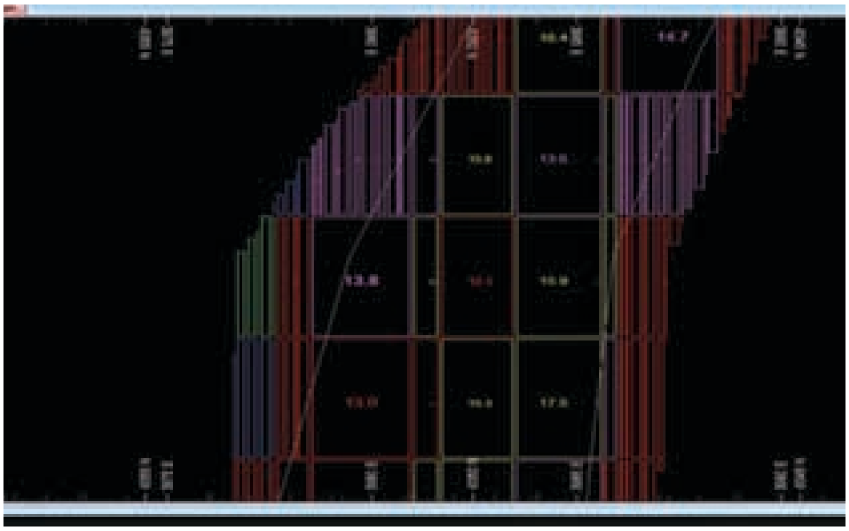
Reserve Estimated between SR 24th L - 26th L (Table- 1.2**)**

Level	**Strike length (m)**	**Width (m)**	**Spg. Gravity**	**Tonnes (T)**	**Avg. Grade (g/t)**	**Gold (Gms)**
24th L - 24D/L	90	8.95	2.83	22808	9.07	206856
24th D/L - 26th TSL	90	8.90	2.83	22664	9.83	222693
26th TSL - 26th BSL	90	7.89	2.83	20096	9.43	189493
26th BSL - 26th L	90	7.84	2.83	35923	10.43	374657
Total				**101492**	**9.79**	**993698**

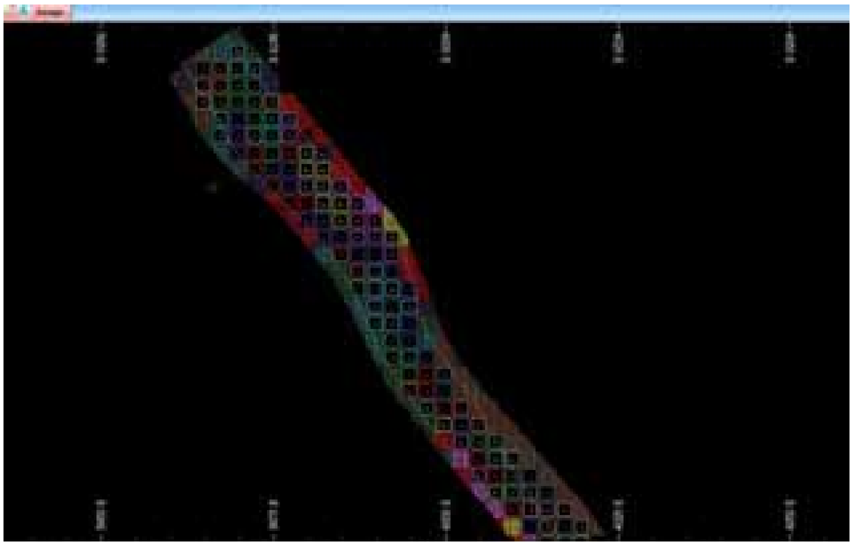
The Reserves estimated through L-V section method: 1,01,492 Tonnes @ 9.79 g/t.

B) Ore Reserve Estimation using DATAMINE Software

3D Model of Ore Body showing SR24L to SR26L ***(Fig.-2)***



*Block Model showing Cross Section representing Assay Values of Entire Stoping Block (**Fig.-3**)*



Block Model Showing Horizontal View.(Fig.-4)

Reserves estimated using DATAMINE software (**Tabel-2**)

Category (grade range in g/t)	Tonnes (T)	AU (g/t)
[0,1]	53	0.94
[1.01,1.49]	1302	1.31
[1.5,1.99]	3522	1.76
[2,3.49]	12336	2.77
[3.5,4.99]	13733	4.23
[5,6.99]	17242	5.99
[7,9.99]	22172	8.48
[10,12.99]	23568	11.53
[13,14.99]	10748	13.93
[15,CEILING]	13776	17.07
Total	**118689**	**8.84**

The Reserves estimated using Datamine software: 1,18,689 Tonnes @ 8.84 g/t

Discussion:

The results derived by classical L-V section method indicated 16% variation in tonnage and 10% more grade (Table1.1& 1.2) as compared to ore estimated using Datamine software (**Table- 2**).

The observed variation may be attributed to inherent limitations in both methods, as detailed below:

Classical Method	Datamine software
1. Consideration of Primary Sampling Data	
• Primary sampling data obtained from underground development (drives, raises, winzes, etc.) are considered only within the stoping block. • The reserve estimation is limited strictly between two defined levels. • Geological interpretation is manual. • The grade continuity between the levels cannot be assessed properly.	• Primary sampling data are digitally captured and constrained within a 3D stoping block using wireframes. • The software considers all valid samples spatially within the modelled ore zone. • Sampling influence is distributed in three dimensions rather than just between two levels. • This approach ensures better spatial representation of grade continuity
2. Determination of Ore Body Width	
• The width of the ore body is determined manually by the geologist by demarcating the payable limit of 2.0/t. paya. • The ore zone is demarcated up to the payable limit, commonly defined by a cut-off grade (e.g., 2 g/t Au). • Decisions are depend on visual interpretation of assay values • Variability in interpretation between geologists may affect consistency.	• All assay values within the payable limit are plotted digitally. • The ore body width is defined objectively using grade shells or wireframes. • Software tools help maintain uniformity and reduce personal bias. • The resulting ore geometry is more precise and reproducible.

3. Top Cut Determination (Nugget Effect Control)	
• The top cut value is determined graphically by plotting assay values. • Extremely high grades are manually capped to avoid overestimation due to the nugget effect. • This process is subjective and dependent on the experience of the geologist.	• Statistical techniques such as histograms, cumulative frequency plots, log probability plots, and coefficient of variation are used. • The top cut value is derived scientifically and consistently. • This reduces bias and improves confidence in grade estimation
4. Grade Assignment and Reserve Estimation	
• Only the assay values from the top level drive and bottom level drive are used. • The grades between two levels are averaged, assuming uniform distribution. • Vertical and lateral grade variations are not fully captured. • Reserve estimation is relatively simple but less accurate.	• A 3D wireframe model of the ore body is created **(Fig.-2).** • The dip, strike, and cell size of the block model are defined. • The software assigns grades to individual blocks using nearest neighbourhood assuming uniformity in the lithological contacts with consistent mineral setup**(Fig.3)** • Grade variation is modelled realistically from top to bottom and across the ore body. • This leads more reliable reserve estimate than classical method **(Fig.4)**.
5.Tonnage Estimation	
• Only overall tonnage can be estimated. • No clear segregation of ore based on grade ranges (Table-1.2). • Mine planning and economic evaluation are limited due to lack of grade-wise detail.	• Grade-wise tonnage estimation is possible (e.g., <2 g/t, 2–4 g/t, >4 g/t)(Table-2). • Enables preparation of detailed tables showing tonnage, average grade, and metal content for different grade classes(Table-2). • Highly useful for mine scheduling, selective mining, and economic analysis.

Conclusion:

In the classical method due to some human errors in demarcating the payable zones and its estimation cause variation in the estimated tonnage as compared to tonnage estimated through software. In both the classical and software-based methods, the variation in grade estimation is around 10% which is acceptable in such erratic gold mineralized stoping blocks. However, even this grade cannot be considered precise, because both methods assume that the lithological contacts along with their corresponding sampling derived grades continue uniformly from the top level to the bottom level. In reality, due to erratic nature of the deposit, these assumptions often do not hold true.

Hence, we would like to conclude that there is no noticeable variation in the results derived from both the methods. But precise grade of the deposit cannot be assessed, which can only be reconciled after the mining until then, the grade remains a projection based on the available data. The historic data have proven positive correlation between the projected grade and the actual grade.

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Change in Mines Layout by introducing New Ramps for Fuel Efficiency and Reduction in Carbon Emission at Rajashree Cement Limestone Mine

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Abstract:

India's journey toward Viksit Bharat 2047 calls for industries to embrace sustainability without compromising growth. In open-pit mining, haulage remains the single largest fuel consumer and emission source. This article presents a practical engineering intervention at Rajashree Cement Limestone Mine - introducing diagonal ramps to reduce haulage lead (horizontal distance between loading and unloading), thereby improving fuel efficiency, lowering carbon emissions, and enhancing safety. Using mine planning tools and performance analytics, the ramp redesign achieved lead reduction from 1,950 m to 1,500 m per cycle, saving ~1,65,000 litters of diesel annually, and cutting ~442 metric tons of CO_2 per year -a strong example of Green Mining in action.

Introduction:

Sustainable growth in mining requires engineering-lead optimizations that reduce environmental impact while maintaining productivity. Among these, ramp design in open-pit mines directly influences haulage efficiency, cycle time, fuel burn, tyre wear, and safety. At Rajashree Cement Limestone Mine, lead distances had steadily increased as the pit expanded, necessitating a layout rethink to improve haulage economics and emissions performance.

The solution: introducing diagonal ramps to connect benches more directly, shortening haul routes and minimizing unnecessary elevation gain—delivering lower HSD consumption, reduced emissions, and safer, faster cycles.

Technical Aspects: -

Problem Statement:

Rajashree Cement Limestone Mine (RCLM) is facing continuous increase in lead distance which directly affecting fuel consumption, cycle time, and equipment wear.

In larger aspect increase in mining cost force to rethink and reevaluate design of mining pit. In open-pit mining, longer horizontal leads mean trucks travel farther between loading and dumping points, increasing operational costs.

- *Impact*: In RCLM a 100-meter increase in lead directly raising fuel consumption by 0.28 Liters per cycle on existing gradient and on payload of 92.5 MT.

- *Optimization Strategy*: By preparing new ramps reduce horizontal lead by 10–30%, depending on pit geometry and bench layout.

1. Fuel Consumption

Fuel is the largest operating cost in haulage. Currently 45-47 % of overall cost is in head of HSD only. Aim to reduce fuel consumption and conserve natural resources.

2. Emission Control

Diesel combustion emits CO_2, NOx, and particulate matter. Each Liter of diesel burned emits ~2.6 kg of CO_2. Reduce air pollution and supports ESG compliance

3. Ramp Geometry

Ramp design influences haulage efficiency and safety. Reduce overall travel time and also minimize unnecessary elevation gain.

- *Design Tools*: Mine planning software like Surpac, and DATAMINE help us to draw and design pit layout with proposing new ramps and simulate multiple ramp geometries to find the most fuel-efficient path. Spectra-insights a tool used by UltraTech help us to monitor and review gradient, width etc of the ramp to co correction if required.

4. Gradient Optimization

Ramp gradient affects traction, speed, and fuel burn.

Ideal Range: 1 in 16 is optimal for most haul trucks, balancing speed and safety.

Discussions: -

- Environmental Benefits
  - Up to 5-6% reduction in fuel consumption
  - Lower greenhouse gas emissions and particulate matter
- Economic Gains
  - Reduced fuel and maintenance costs
  - Extended tyre life

Methodologies: -

The various steps followed and benefits of each process is given in below Table.1,

Step	What to Do	How it Helps
1.	Study the area using survey maps/levelling to understand slopes and heights.	Identifies the shortest, safest alignment
2.	Design the ramp (diagonal alignment) in planning software	Shorter ramp → less fuel and reduced cycle time
3.	Compare options via simulations	Selects the most efficient design before execution
4.	Build with safety (correct slope, width, berms)	Ensures dumper stability and reduce risk
5.	Observe & improve using MINEOPTIMA360 (Fleet Management Software)	Continuous optimization of flow, fuel use, and road condition

Table.1 – Methodology adopted for haul road development

Ramp Preparation:

Bench Height : 9 meters

- Ramp Length : 144 meters
- Width : 37mtr
- Area blasted : 47,952 m^3

Road Width Planned for One Way Traffic:

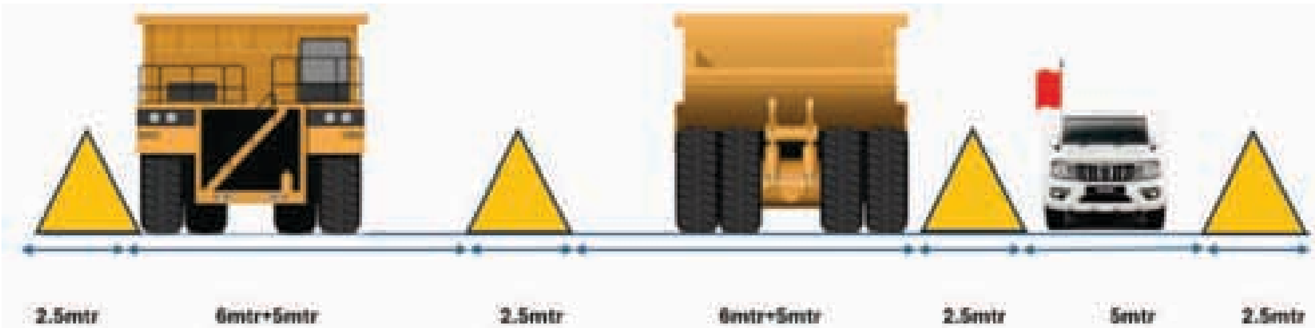

Fig.1 – Pictorial representation of Haul Road width

- Berm+ One Way + Berm+ One Way+ Berm + LMV road+ Berm
- 2.5+(6+5) +2.5+(6+5) +2.5+5+2.5 =37mtr
- One way: width of widest machine plying (6mtr)+5mtr
- Berm width: 2.5 m
- Dumper width: 6 m
- LMV road: 5 m

Ramp Layout: - Built new ramp in SE of mine interconnecting benches 2A, 3rd, 4th & 5th diagonally, resulting Lead distance reduction from loading to Crusher unloading area. Before and after diagonal ramp image showing route, map and lead distance is given in below Fig.2 and Fig.3.

Location of New Ramp: 2nd Bench to 5th Bench diagonally

Coordinates: 732668.9 m E, 1894507.7 m N to 733135.5 m E, 1894152.7 m N

Fig.2 – Before image of haul roads

Fig.3 - After image of haul roads

Benefits Achieved: - Lead Distance Reduction

- Earlier lead: 1,950 m
- After ramps: 1,500 m
- Lead saved per cycle (round trip assumption): 900 m
  (450 m one-way reduction × 2 = 900 m per cycle)

Fuel Saving — (scenario)

- HSD consumption for CAT 777 per Hour : 45 litres
- HSD consumption per 100mtr : 0.28 litres
- HSD saved per trip : 9*0.288 = 2.52 litres
- Trips per Hour : 4
- HSD saved per hour : 10.08 litres
- Hours per day (3shift*5 hours) : 15Hours
- Fuel saved per day : 15*10.08 = 151.2 litres
- Fuel saved with 3 dumpers : 3*151.2 =453.6 litres
- Fuel saved per year : 1.65 L litres
- Cost saving per year : ₹132 Lakh

Emission Reduction Calculation: -

Annual CO2 reduction is calculated considering the below mentioned parameters and the resultant is given in Table.2.

1. Carbon content in Diesel & CO_2 formation ratio
   - Diesel typically contains about 0.73 kg of carbon per kg of fuel, and the ratio for converting carbon to CO_2 is based on molecular weights: CO_2/C = 44/12≈ 3.67.
2. CO_2 per liter of Diesel
   - Standard emission factor: ≈ 2.68 kg CO_2 per liter of diesel (assuming complete combustion).
3. Emission factor confirmation
   - U.S. EPA and other agencies report similar values (≈ 2.64–2.68 kg CO_2 per liter).

Parameter	Value
Carbon content in Diesel	0.73 kg per Liter
CO_2 formation ratio ($C \rightarrow CO_2$)	44/12 ≈ 3.67
CO_2 per Liter of Diesel	0.73 × 3.67 ≈ 2.68 kg
Daily CO_2 reduction	453.6 × 2.68 ≈ 1215.64 kg (≈1.215 metric tons)
Annual CO_2 reduction	4,42,200 kg (≈442 metric tons)

Table.2 – Calculation showing CO2 reduction quantity

Conclusion:

"1 Tree absorb ~3 metric tonnes of CO_2 over its lifespan (varies based on age and species). By reducing 442 metric tonnes of CO_2 every year, is equals to planting 147 trees approximately".

Ramp design is a simple yet powerful solution for sustainable mining. It reduces fuel consumption, lowers emissions, and enhances safety—all while improving operational efficiency. This practice should be integrated into mine planning, safety audits, and training programs to ensure long-term impact. By adopting such improvements, the mining industry can actively contribute to the national mission of a Viksit Bharat.

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Creating Shared Value: Strategic CSR Interventions by Vedanta in Chitradurga District

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Abstract

Corporate Social Responsibility (CSR) today plays a critical role in bridging development gaps and fostering inclusive growth. Vedanta Sesa Goa, through its Sesa Goa Iron Ore operations in Karnataka, has adopted a strategic and community-centric CSR approach in Chitradurga district. This paper outlines the planning framework, implementation methodology, key thematic interventions, and long-term development outcomes of Vedanta's CSR initiatives. It highlights how structured partnerships, need-based planning, and sustainable execution have enabled meaningful social impact and contributed to holistic regional development.

1. Introduction

Corporate Social Responsibility has transitioned from being a voluntary philanthropic activity to a strategic development instrument aligned with national priorities and global sustainability goals. In this evolving landscape, corporates are expected not only to contribute resources but also to bring in efficiency, innovation, and long-term vision to development initiatives.

Vedanta Group, one of India's leading natural resources conglomerates, places community development at the core of its operations. Through Sesa Goa Iron Ore – Karnataka, Vedanta has been actively implementing CSR interventions in Chitradurga district with the objective of creating sustainable social impact and enabling inclusive growth. The CSR initiatives are designed to address local development challenges while strengthening community institutions and promoting self-reliance.

This paper presents Vedanta's CSR journey in Chitradurga, focusing on the strategic planning process, implementation mechanisms, key projects across sectors, and the long-term developmental impact created through these interventions.

2. Regional Context: Chitradurga District

Chitradurga district, located in central Karnataka, is characterized by a semi-arid climate and predominantly agrarian economy. The district faces several socio-economic challenges, including water scarcity, limited livelihood diversification, gaps in education and healthcare infrastructure, and nutritional concerns among vulnerable populations. Despite government efforts, issues such as school dropouts, unemployment among youth, migration for livelihoods, and inadequate access to quality health and sanitation facilities persist in rural areas. Addressing these multidimensional challenges requires integrated development interventions that go beyond short-term solutions. Vedanta's CSR strategy in

Chitradurga is designed keeping this regional context in mind, with a focus on addressing root causes and enabling sustainable development through community participation and institutional convergence.

3. CSR Vision and Philosophy

Vedanta's CSR philosophy is guided by the principle of "Creating Shared Value", where business growth and community well-being progress together. Our corporate ethos is deeply rooted in Corporate Social Responsibility (CSR), aimed at fostering a sustainable, inclusive, and diverse future. We adopt a holistic approach to our operations, prioritizing community development, employee well-being, and environmental sustainability. Our comprehensive CSR initiatives span education, healthcare, livelihoods, skill-building, women empowerment, community development, environmental conservation, and promotion of sports & culture. These initiatives are strategically designed to uplift the socio-economic fabric of the communities we serve. All CSR initiatives are aligned with Schedule VII of the Companies Act, 2013, and are implemented with a strong emphasis on measurable outcomes and impact.

4. CSR Planning and Execution Framework

1. Need Assessment and Baseline Studies:

   CSR planning begins with comprehensive need assessments conducted through:

   - Baseline surveys
   - Community consultations
   - Gram Sabha interactions
   - Engagement with district administration and line departments

   This participatory approach ensures that interventions are need-based, locally relevant, and community-driven.

2. Identification of Thematic Focus Areas

   Based on assessments, key focus areas are identified:

   - Children Wellbeing &Education
   - Health Care
   - Agriculture & Livelihood
   - Skilling
   - Women Empowerment

3. Stakeholder Engagement and Partnerships

   Effective partnerships form the backbone of Vedanta's CSR implementation. Collaboration is undertaken with:

   - District Administration
   - Women and Child Development Department
   - Education and Health Departments
   - NGOs and technical partners
   - Community-based organizations

   Such convergence avoids duplication of efforts and enhances scale and sustainability.

5. Key CSR Interventions and Projects

5.1 Education:

Over the past few years, Vedanta Sesa Goa has adopted a holistic approach to enhancing educational opportunities, benefiting children from pre-primary through higher education. Our CSR initiatives encompass a variety of programs aimed at supporting school infrastructure and promoting accessible education. These initiatives include Nandghars, Anganwadi 17 renovations, providing school buses, constructing toilets and dining halls, and offering scholarships. By focusing on these critical areas, we aim to reduce dropout rates and ensure that all children have equitable access to education, regardless of the challenges faced by their families or communities. Our commitment to education reflects our belief that every child deserves the opportunity to learn and thrive in a supportive environment.

The «Back to School» program is an annual initiative designed to alleviate the financial burden on families and ensure equitable access to education for all children. In the previous year 7700+ students were supported from 54 surrounding schools. By providing comprehensive school kits containing notebooks, instrument boxes, pens, pencils, school bags, steel water bottles, and other essential supplies, the program significantly reduces the stress and worry associated with the cost of education. For children from economically weaker backgrounds, who may otherwise struggle to afford these items, the initiative plays a crucial role in enabling them to pursue their education without financial constrain.

Fig.1 Back to School Program

- o The installation of computer labs in 5 schools and science labs in two schools in Chitradurga, bridges the gap in access to modern educational tools and equipment, benefiting over 800 students.
- o In the past 2 years awarded 500+ scholarships to deserving students aligning with Sustainable Development Goal 4, quality education. The scholarship is awarded to SSLC, PUC and Graduation students on need cum merit basis.
- o Understanding the challenges faced by students in rural areas, we have introduced a school bus service that ensures 230 students from 8 villages can attend high school without fail. This initiative aims to overcome commuting difficulties and promote consistent access to education, supporting academic continuity and enhancing opportunities for students in remote communities.

- o Over the past three years, as part of our CSR initiative, Sesa goa has constructed and developed classrooms, dining halls, compound walls, toilet blocks, and school grounds in 20+ schools and one college in last three years. This effort has significantly reduced dropout rates and enhanced safety within these schools. Our goal is to transform these schools into model institutions by providing comprehensive facilities that meet high standards, ensuring a conducive environment for learning and growth.

5.2 Health care:

Our commitment to community healthcare, is aligned with the sustainable development goal of Good Health and Wellbeing. Project Aarogya was born out of sincere care for the communities we operate in and desire to support the development of rural India. The Mobile Health Unit project plays a crucial role in enhancing healthcare and accessibility for 18 remote villages lacking Government Primary Health Centres (PHCs) or Community Health Centres (CHCs). The Mobile Health Van provides healthcare at the doorstep, camps and consultation services addressing the problems of inaccessibility, inability to afford and non-availability of basic primary health care. Previous year more than 12,000+ people across our operational availed the services. To further meet community needs, the project organizes quarterly health camps focusing on specialized areas such as organised multispecialty mega health camps comprising, Dental, Eye, Orthopaedics, ENT, Paediatrics, Gynaecologist, Physiotherapist, etc. benefitting over 2000+ people from the villages.

Fig 2. Breast Feeding Awareness Program

5.3 Agriculture and livelihood:

Our initiative in agriculture and animal husbandry, the Alternative Livelihood Opportunity Project (ALOP) have emerged as crucial interventions aimed at transforming the landscape of rural livelihoods. ALOP seeks to empower farmers with climate-resilient and sustainable agricultural practices, providing them with viable alternatives to traditional methods that are increasingly vulnerable to climate variability. By fostering diversification and innovation in agriculture, this project not only aims to enhance productivity and income but also to safeguard the socio-economic well-being of rural communities, thereby creating a more inclusive path to agricultural growth.

Fig 3. Harvesting Crops providing under ALOP

ALOP is a five-year project which is being implemented in the community by our partner BAIF a Nationally known NGO who has been impacting rural lives through its livelihood and climate-resilient programmes for more than 55 years. The main objective of the project is to create opportunities for gainful self-employment for rural families by ensuring sustainable livelihood. The project focuses on providing training and resources to local communities to help them with sustainable livelihood opportunities and improve their socio-economic wellbeing. It comprises initiatives such as watershed management, optimum utilisation of local natural resources, agricultural development, cattle management, and women 10 empowerment to achieve overall sustainable growth of the community. The components of the holistic development program were chalked out carefully by analysing data of every village.

Key Interventions & Impact includes:

- o Crop Diversification
- o Organic Farming
- o Micro enterprise development
- o Livestock Management
- o Capacity Building
- o Millet promotion
- o Soil & Water management

5.4 Skilling & Women Empowerment:

Vedanta Sesa Goa has established 4 computer centres and 5 tailoring centres offering transformative courses to over 500+ students in remote areas. These centres provide training in programs such as Diploma in Computer Applications (DCA), Tally & GST, web designing, and more. We aim to bridge the digital divide and empower local communities with the necessary tools and knowledge to thrive in today's technology-driven job market. In the past 3 years 500+ youths have been trained the computer courses. Alongside technical skills, participants undergo rigorous soft skills development, enhancing their employability and readiness for the job market. Furthermore, entrepreneurship development programs are integrated, culminating in certifications approved by the National Skill Development Corporation.

Fig 4. Certificate Distribution Ceremony

We were able to open doors for opportunity for hundreds of young aspirants by connecting them directly with credible employers. 20+ Companies and 500+ youth attended the Mela. Around 150+ youth received placement letters.

Fig. 5. Job Mela

Employee Volunteerism

Total 1,100+ units of blood were donated through the camps held in FY '25 & '26, and 3,000+ families were benefitted through the drives held both within the company premises and in the communities surrounding the operations. The initiative, under Sesa Goa's Project 'Aarogya' is aimed at meeting the critical need of blood for the communities, through contributing the 'Gift of Life', and is aligned with the UN SDG-3 'Good Health & Well-being'.

Fig.6. Blood Donation Camp

Strategic Development Outcomes

Vedanta's CSR interventions aim to move beyond activity-based outputs to long-term development outcomes. The strategic focus has resulted in creation of durable community assets, strengthening of local institutions, behavioural change through awareness and participation and enhanced community resilience and self-reliance. CSR initiatives are designed to complement government schemes and fill critical gaps, thereby acting as catalysts for sustainable development.

Governance, Monitoring, and Accountability

Strong governance mechanisms ensure transparency and effectiveness which include regular field monitoring and reviews, outcome-based reporting frameworks, third-party evaluations for select projects and documentation of best practices and learnings. These mechanisms enable continuous improvement and ensure optimal utilization of CSR resources.

Conclusion

Vedanta Sesa Goa Iron Ore – Karnataka's CSR initiatives in Chitradurga demonstrate how a structured, participatory, and strategic approach can create meaningful and sustainable social impact. By aligning community needs with institutional partnerships and long-term vision, Vedanta has been able to contribute significantly to the district's socio-economic development. The experience reinforces the role of CSR as a powerful development enabler and reflects Vedanta's commitment to building inclusive, sustainable and empowered communities. Through continued collaboration and innovation, Vedanta remains dedicated to driving positive change and creating shared value for society at large.

A Comprehensive approach towards systematic and scientific mining by using drone technology: A Sustainable outlook and A Regulatory compliance perspective

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Abstract

Drones are creating revolution in the field of mining by improving safety, efficiency, and accuracy through aerial surveying, real-time monitoring, and data collection and the drone technology has been adopted to mitigate risks and streamline operations across the entire mining lifecycle, from exploration to reclamation. They enable faster, safer, and more cost-effective operations by conducting tasks like site mapping, stockpile volume calculations, and inspections in hazardous areas, reducing human risk and providing high-resolution data for better planning and resource management.

Keywords- *Geology, Mapping, Mining, Lithology, Indian bureau of mines, Mineral Conservation and Development Rules, Mine survey, Mineral exploration, Reclamation, Land use and landcover.*

Introduction

Drones offer cost-effective, safe, and quick aerial surveys for data collection and are very useful for industries like mining, which requires constant monitoring of mining operations, which are typically in remote locations and hard to access places, often make human accessibility difficult. This, in turn leads to either delay in decision making and lack of insufficient information also adversely affect in efficiency of mining.

As drone technology evolves, becomes more affordable and regulations get more defined, Surveyors and engineers can use the data captured from drones to make reports and forecasts about the development of the mines. In mines, drones can provide valuable information about the condition of the above ground area, thus improving the workers safety in the process.

As a part of Sustainable mining, submission of digital aerial drone images to Indian Bureau of Mines (IBM) is a key compliance under Rule 34A (often referred to as Rule 34(a) in the context of major 2021 amendments) of the **Mineral Conservation and Development Rules (MCDR), 2017** supports **scientific and systematic mining operations**, better supervision, and adherence to environmental and mine planning norms.

The key ways how the Rule 34A contributes to sustainable mining include:

1. Precision Monitoring and Compliance

- **Enforcement of Boundaries:** By requiring drone surveys up to 100 meters outside lease boundaries, the rule helps authorities detect and prevent illegal mining and encroachment into sensitive areas.

- **Scientific Mining:** Digital elevation models (DEM) and Ortho mosaic images allow for highly accurate volume calculations and verification that mining is following the approved, scientific Mining Plan.

2. Environmental Protection and Closure

- **Reclamation Oversight:** The visual data is critical for monitoring «reclamation and rehabilitation» activities. It ensures that miners are progressively restoring the land as planned rather than leaving hazards behind.
- **Mine Closure Planning:** Time-series digital data helps in the better planning of mine closure activities, ensuring the site is returned to a sustainable state at the end of its life cycle.

3. Integration with Star Rating Systems

- **Verification of Sustainability:** Rule 34A works in tandem with **Rule 35**, which mandates a «Star Rating» for mines based on sustainable practices.
- **Objective Evidence:** The digital images submitted under Rule 34A serve as physical evidence to verify a miner's self-assessment for their Star Rating, rewarding those who follow eco-friendly and socially responsible protocols.

4. Enhanced Transparency and Safety

- **Transparency:** The shift to digital reporting reduces human error and manual manipulation of data, providing a transparent record for the Indian Bureau of Mines (IBM) and state governments.
- **Operational Safety:** High-resolution images help identify structural risks, such as unstable slopes or subsidence, which might be missed by ground-level inspections, thereby enhancing worker safety.

Key roles and Applications of Drone technology in the mining sector are as fallows;

1. Geological mapping and Interpretation.
2. Mine monitoring and Planning
3. Stockpile measurement and Volume calculations
4. Monitoring the progress of R&R works on waste dump site
5. Plantation and vegetation interpretation on waste dump site

1. Geological mapping and Interpretation.

Interpretation of lithology from drone data relies primarily on **analysing the spectral properties, texture, colour variations, and structural features** captured by various drone-mounted sensors. This information, often integrated with field observations and advanced software, allows Geologists to identify and map different rock types (lithological units).

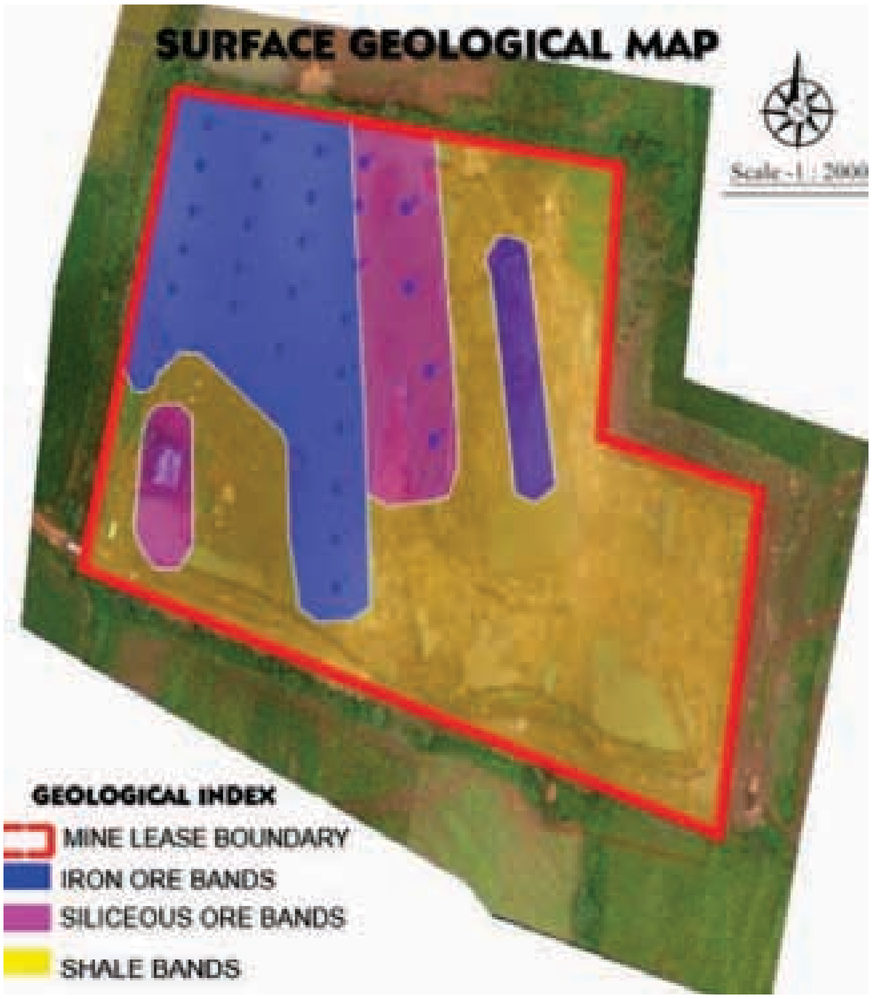

Fig:1 Surface Geological map prepared using ortho mosaic map

2.Mine Monitoring and Planning

A mine consists of numerous moving components requiring systematic analysis and adjustments to achieve maximum efficiency and safety. Mining drones are highly effective in the following areas:

Identify Deviation in Mine Working and Dumping-Working and dumping deviation» refers to discrepancies between planned site operations (like excavation, material movement, and waste disposal) and the actual execution, which can be identified using data and imagery captured by drones. Drones help monitor progress, ensure compliance with design plans, and track material volumes.

Types of Deviations Identified: Drone imagery and data analysis can pinpoint various «working and dumping» deviations, including:

- **Unauthorized Dumping:** Drones can survey large areas efficiently, identifying illegal or unapproved waste dumping sites that deviate from designated disposal zones.
- **Incorrect Grading/Earthwork:** Deviations from planned elevation contours can indicate improper grading, which might lead to drainage problems, erosion, or stability issues.

- **Haulage road design -**These roads are responsible for the transportation of mining materials from the worksite. The heavy traffic and equipment mean road conditions need to be assessed constantly. The data collected is also helpful in determining if improvements need to be made to the site infrastructure.

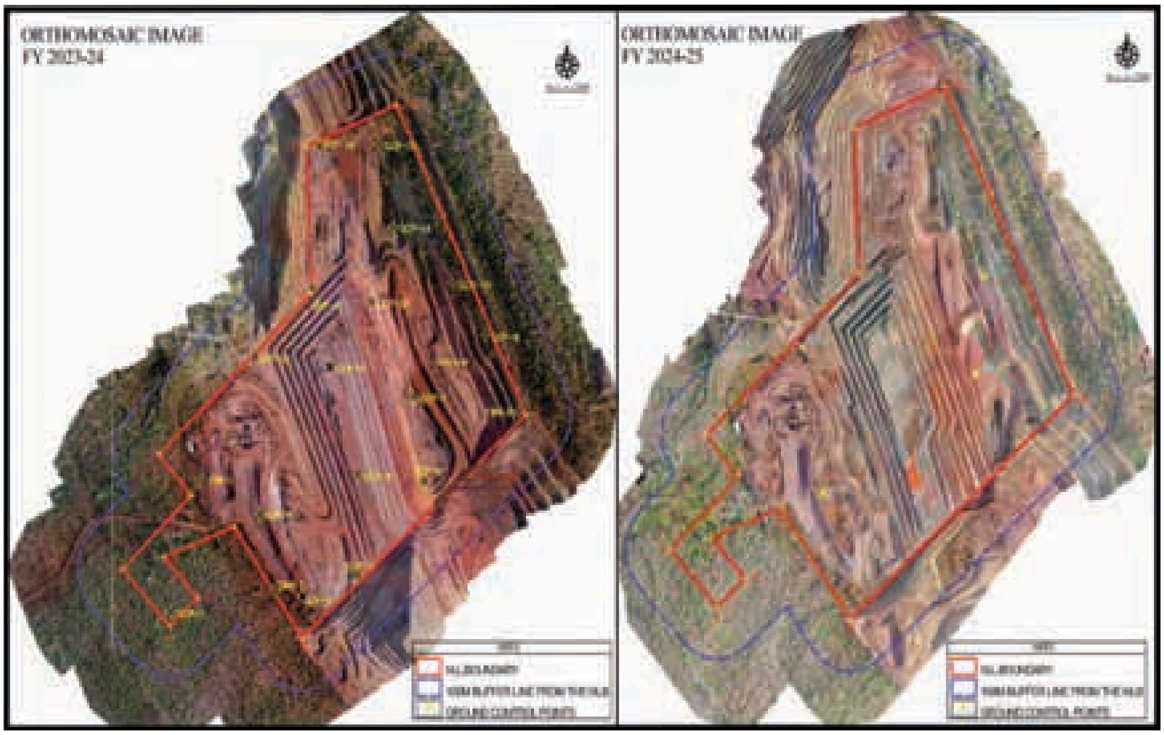

Fig:2 Comparison of the dump and benches movement using Ortho mosaic images of Two different Periods (i.e., FY 2023-24 and FY-2024-25)

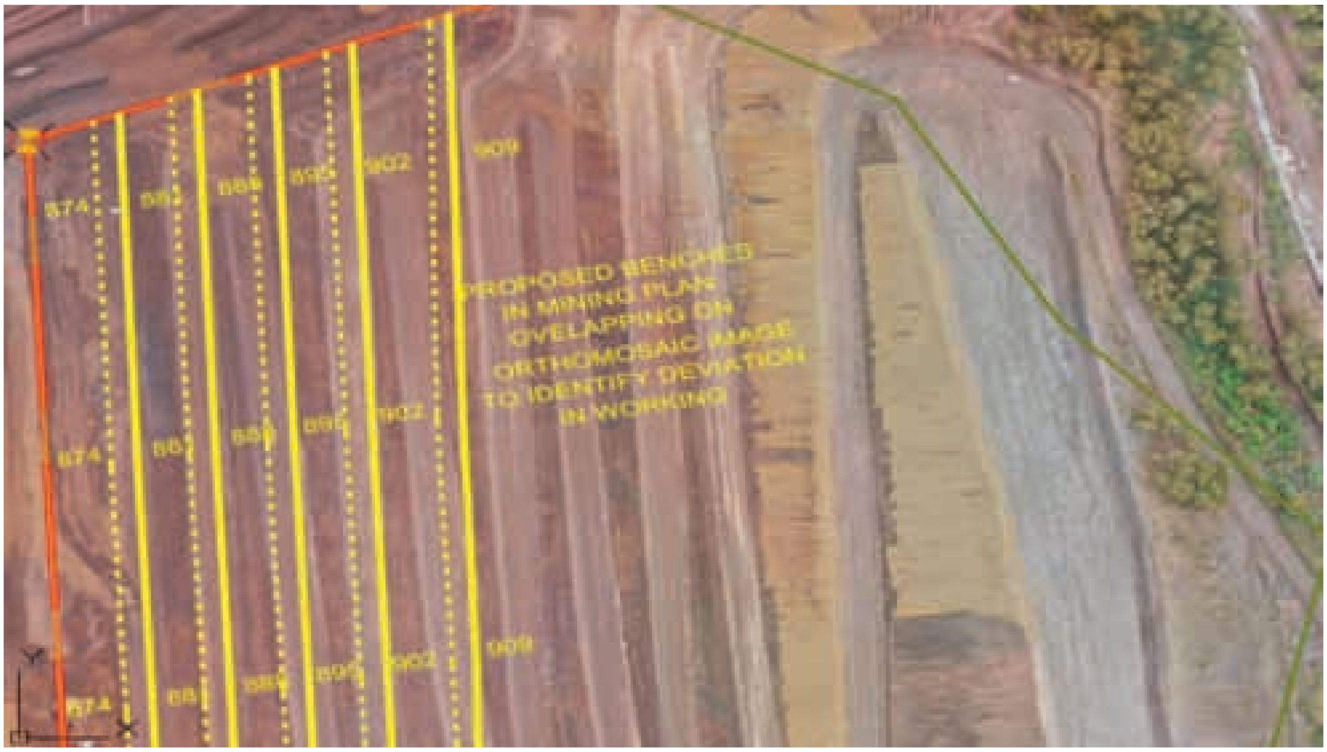

Fig:3 A Picture shows comparison b/w proposed benches in mining plan v/s Actual benches on ortho mosaic image

3.Stockpile measurement and Volume calculations

Volumetric measurement is the process of calculating how much material in a stockpile of ore, overburden, or other mining materials due to the sheer size of stockpiles, it's challenging to get accurate volume reports using manual methods. However, the integration of a mine drone allows for quick deployment with inexpensive and reliable volume data.

Tracking variations in stockpiles using drones is cost-effective and helps to get accurate information and using advanced volume measurement software, mine drone data can be processed and presented to create a 3D model. The algorithms behind these apps calculate based on the volume between the base layer to the surface.

Fig:4 Panoramic view of stock piles demarked on Ortho mosaic image

4.Monitoring the progress of R&R works on waste dump site

Drones provide an efficient, accurate, and safe way to monitor the work progress of Reclamation and Rehabilitation (R&R) project, drones are an invaluable tool for monitoring R&R works (environmental structures both natural features and built infrastructure that interacts with the environment) by providing accurate, high-resolution data that is difficult, dangerous, or time-consuming to collect manually. They are widely used for assessment, management, and regulatory compliance. drones inspect environmental structures like check dams, retaining wall, Garland drains, Vertical drainages and Silt settling tanks in line with waste dumps.

drones detect structural issues such as cracks, corrosion, and material degradation from a safe distance, often using specialized cameras and sensors to identify hidden problems before they escalate into major failures on waste.

Fig:5 Monitoring the progress of R&R work by using drone image

5.Plantation and vegetation interpretation on waste dump sites.

Drones are used for plantation and vegetation interpretation on waste dumps by capturing high-resolution images to create vegetation maps. These models are used to assess plant health and growth, quantify vegetation cover, and monitor changes over time. which helps in effective site management and the planning of successful restoration efforts.

Key Monitoring Applications

- **Tree Counting and Density Assessment**: High-resolution imagery from drones enables the identification and counting of individual trees to verify the success of planting efforts and assess stand density.
- **Health and Growth Monitoring**: Drones equipped with multispectral or thermal sensors can detect early signs of disease, pest infestations, or water stress by analysing changes in vegetation indices (e.g., NDVI, NDRE) before they are visible to the human eye. This allows for timely intervention and adaptive management strategies.
- **Erosion and Stability Assessment**: Digital Elevation Models (DEM) derived from drone data are used to monitor soil erosion, land subsidence, and terrain changes, helping to plan stabilization measures in degraded areas.

- **Species Identification and Mapping**: Detailed spatial data can help identify and map different tree species, as well as detect the presence of invasive plants, to ensure the planned biodiversity goals are met.

Fig:6 Identification of changes in vegetation cover using two different years of drone images (i.e., FY 2023-24 and 2024-25).

Conclusion

Drones have become an **essential component of modern mining operations,** the use of drones in the mining industry has evolved from a niche tool to an indispensable asset, fundamentally transforming operations by significantly enhancing **safety, efficiency, and data accuracy** across the entire mine life cycle. Drones are now standard practice, offering substantial advantages over traditional, manual methods. The future of drones in mining involves increased integration with other advanced technologies, such as AI-powered data analytics, machine learning, and autonomous flight systems. This will lead to more productive maintenance, fully automated routine inspections, and deeper data interpretation, more efficient, data-driven, and environmentally responsible industry.

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The Role of MCDR in Advancing Sustainable Mining Practices

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Introduction

India's Mining sector supports strategic Industries including Steel, Energy, Infrastructure, and Defence. However, years of extraction have led to resource depletion, land degradation, and environmental challenges, demanding a shift toward sustainability. Today, sustainability in mining is not confined only to the responsible extraction of minerals but also includes ecological preservation, social accountability, occupational safety, and efficient resource utilization. The MCDR, governed under the Mines and Minerals (Development and Regulation) Act, 1957, has evolved from a compliance-centric framework to a sustainability-oriented regulatory ecosystem integrating scientific exploration, responsible mining, technology adoption, and transparent reporting.

Evolution of India's Mineral Regulatory Framework: MCDR

As early as the mid-20th century, rapid economic growth led an exceptional demand on mineral resources. However, unregulated extraction during that period led to resource wastage, unsafe mining conditions, and environmental degradation. Recognizing the need to balance mineral utilization with long-term national interests, the Government of India progressively established regulatory mechanisms to ensure scientific and systematic mining. The Mines and Minerals (Development and Regulation) Act, 1957 laid the legislative foundation for mineral governance in the country. However, it soon became evident that broader legal provisions were insufficient without detailed operational rules that directly guided mining practices at the field level. This prompted the introduction of the Minerals Conservation and Development Rules (MCDR) in 1988, aimed at conservation of minerals, proper mine planning, and protection of the environment. Over the years, advancements in technology, increased environmental awareness, and global sustainability commitments demanded further refinement of the regulatory framework. This led to the comprehensive revision and enforcement of MCDR 2017, strengthening requirements for exploration, resource classification, scientific extraction, waste management, land reclamation, and digital reporting. With the introduction of initiatives such as Star Rating, Progressive Mine Closure Plan (PMCP), and online monitoring through IBM portals, sustainability evolved from a desirable concept into a mandatory compliance requirement. The MCDR Rules have been amended including, 2021, 2024 and 2025 serve as the regulatory framework for ensuring sustainable mining practices in India. These rules apply to all minerals except coal, lignite, petroleum, natural gas, and minor minerals, thereby emphasizing broad mineral conservation and environmental management across most mining operations.

Sustainable Development Framework

The Chapter V of the MCDR, consisting of Rules 35 to 44, specifically addresses sustainable mining practices. This chapter introduces the "Star Rating of Mines" system under Rule 35, which evaluates mines on parameters such as safety, mineral conservation, environmental management, and resource utilization. The star rating incentivizes mines to adopt best practices promoting sustainability. Other rules in this chapter mandate systematic reclamation and backfilling, progressive mine closure, environmental monitoring, proper waste management, and mandatory submission of environmental and technical reports. Recent amendments have also integrated modern technologies like drone surveys for enhanced digital mapping, accurate monitoring, and transparency. Collectively, these rules enforce a comprehensive approach to sustainable development, balancing economic mining activities with environmental protection and social responsibility, making MCDR a critical tool in India's mining governance.

Role of Geologists in Sustainable Mining

Geologists play a vital role in achieving the sustainability objectives mandated by the MCDR, serving as the primary scientific guides in understanding and managing mineral resources. They ensure accurate exploration, resource estimation, and block modelling to optimize ore extraction while minimizing dilution and waste. Through geotechnical and hydrogeological assessments, geologists support safe mine planning, slope stability and long-term environmental performance. They are also responsible for continuous compliance monitoring by conducting production reconciliation, updating statutory plans, and submitting precise digital returns through IBM portals. In alignment with the Star Rating framework, geologists evaluate environmental impact, waste management, and progressive reclamation measures, ensuring that best practices in conservation are integrated throughout the mine life cycle. By bridging data-driven decision-making with regulatory requirements, geologists contribute significantly to transforming mining into a more responsible, resource-efficient, and sustainable industry.

Implementation of Best Sustainable Practices at JSW Mines

Here at JSW Mines has demonstrated how MCDR provisions can proactively transform mining sustainability through technology adoption and environmental stewardship. The implementation of **mandatory drone surveys through the latest technologies** has enhanced volumetric accuracy, boundary compliance, and digital mine mapping — enabling transparent reporting through IBM portals and reducing discrepancies in production accounting.

Waste management has significantly improved through **dedicated and scientifically designed dump decks**, ensuring proper segregation of overburden materials facilitating future re-handling for improved resource utilization.

Figure 1 Digital Mine Mapping

To maintain long-term slope stability and ecological restoration, JSW Mines has adopted **eco-engineering measures** such as coir matting, geo-textile installation, native plantation, and **vermicompost, organic manuring** to enhance soil fertility and promote sustainable vegetation growth.

Figure 3 Dump Area Stabilization through Geo-Textile

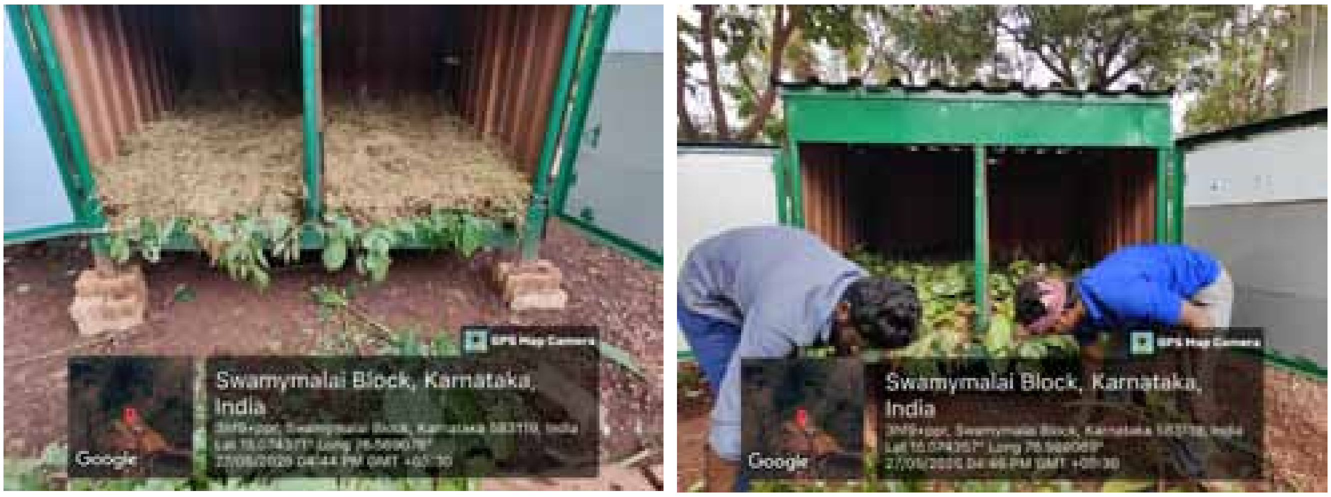

Figure 4 Vermi Compost – Transforming waste into plant power

Mine **digitization initiatives** — including automated survey data through drone survey, digital statutory plan updates, and **continuous environmental monitoring systems** — have strengthened regulatory compliance and real-time sustainability performance tracking.

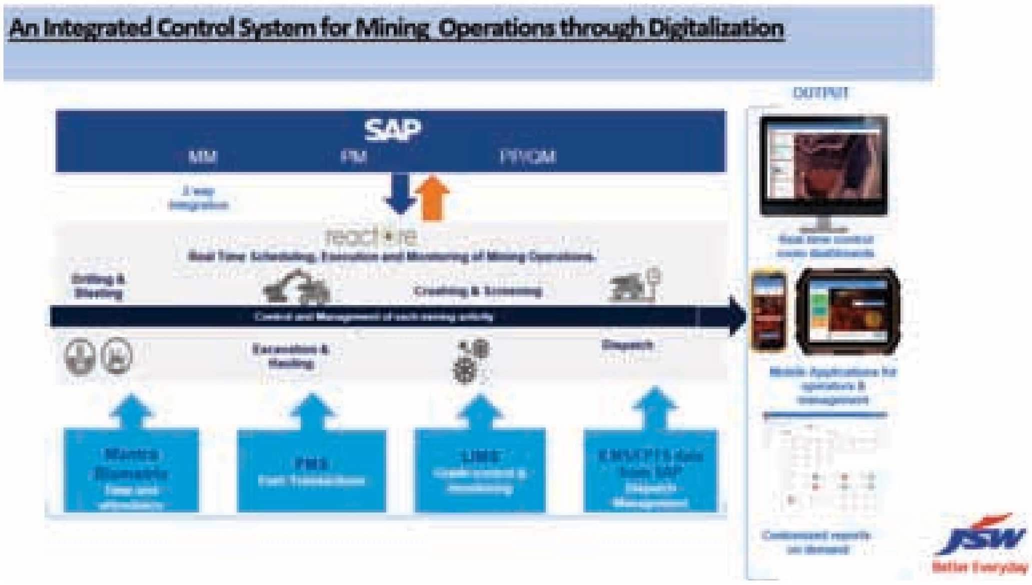

Figure 5 Integrated Control System for Mining Operations through Digitization

Figure 6: Eco-Friendly mode of Transportation: Reduction in Co_2 emission (3.86 Kgs/Ton) by Transportation

*The mine also embraces **environment-friendly transportation solutions such as pipe conveyor systems**, significantly reducing diesel consumption and contributing to lower CO_2 emissions and a cleaner working environment.*

Beyond statutory requirements, JSW Mines actively contributes to social welfare through **resettlement & rehabilitation infrastructure, CSR initiatives**, and livelihood development programs, thereby reinforcing both environmental and social dimensions of the MCDR Star Rating framework. Together, these initiatives position JSW Mines as a leading example of how scientific mining, community well-being, and regulatory compliance collectively drive sustainability in the Indian mining sector. These measurable improvements have not only elevated operational efficiency and environmental performance but have also enabled **JSW Mines** to consistently achieve **Five-Star ratings** under the MCDR framework — positioning the organization as a benchmark for responsible and sustainable mining in India.

Figure 7 Project Vision Correction: Cataract Operation

Figure 8 Room to Read Program for School Children's

Figure 9 Glimpse of Environmental Day Celebration

Figure 10 Solar Photo volatile system installed in Mining premises which acts as a power supply for the Wi-Fi trolleys

Conclusion

Sustainable mining aims to integrate environmental management, resource optimization, and socio-economic development across the entire mine lifecycle. Core strategies include systematic waste segregation, tailings reprocessing, and scientifically planned land reclamation using geo-engineering and native species reforestation. Environmental performance is achieved through emission control systems, water recycling circuits, and adoption of low-carbon technologies, complemented by renewable energy integration to reduce greenhouse gas intensity. Advanced techniques such as blast optimization and real-time fleet management systems optimizing energy use, and minimizing surface disruption. On the social front, sustainability mandates structured stakeholder engagement, community development programs, and equitable benefit-sharing mechanisms aligned with regulatory frameworks. Collectively, these measures operationalize a balance between mineral extraction, ecological integrity, and social responsibility, ensuring long-term resource security and compliance with global sustainability standards.

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Critical Minerals - The Backbone of India's Energy Transition and Sustainable Mining

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Abstract:

The Global timeline to discover (Mainly Lithium) the commercial production is around 7-10 years, wherein India's target is four years with the mission mode approach. The Global players have adopted different approaches and brought in reforms to boost their lithium production.

Australia being the world's leading producer with 52% of global supply share and with hard rock mining expertise have brought in rapid commercialization through clear regulations and private sector leadership.

Chile being the lowest cost ($5,000/ tonne) producer adopting brine extraction (Atacama Desert) have planned for proper sustainable water management by environmental innovation in water scarce region and adopting PPP Model.

China being the refining superpower with 60% of global refining capacity with complete vertical integration having strategic supply chain control and value chain dominance through midstream focus and long term planning.

The United States by bringing policy driven transformation through inflation reduction Act ($369B), mandate domestic processing, acceleration in Nevada lithium projects. Through this bold policy reshapes, economics and attracts private capital at scale.

In view of the above details, it is evident that self-regulation through transparent mining practices, ESG compliance, and faster environmental clearances can improve investor confidence and project timelines in India's critical minerals sector. Policy reforms such as liberalized exploration norms, public-private partnerships, and overseas mineral asset acquisitions can reduce import dependence and strengthen supply security. Technological innovation in exploration, mineral processing, recycling, and substitution can help India move up the value chain, making it a competitive and reliable player in the global critical minerals market.

The transition to a low-carbon economy has amplified the strategic importance of critical minerals, such as lithium, cobalt, nickel, copper, graphite, and rare earth elements, which are essential for batteries, solar PV, wind turbines, and electric mobility technologies. India's ambitious renewable energy targets and electric vehicle adoption necessitate a sustainable and resilient domestic supply of these minerals. This paper evaluates India's critical mineral resources, highlighting domestic reserves, projected demand, and current import dependency. Advanced extraction and processing technologies—including bioleaching, molecular recognition *technology (MRT), deep eutectic solvents, electro dialytic separation, and secondary recovery from tailings and e-waste—are analyzed for efficiency, economic feasibility, and environmental performance. Sustainable mining practices such as low-impact mechanized operations, water recycling, dry tailings stacking, and biodiversity restoration are examined for their social and environmental benefits. Policy frameworks, regulatory reforms, and circular economy strategies are emphasized as enablers for responsible resource management.*

Initiatives such as the National Critical Minerals Mission (NCMM) and collaborative models among industry, academia, and government demonstrate the importance of integrating technological innovation with governance measures. Lifecycle assessment, techno-economic analysis, and social impact evaluations provide insights into environmentally and socially sustainable critical mineral development. Recommendations include incentivizing private sector participation, strengthening domestic refining infrastructure, fostering international cooperation, and implementing pilot projects for secondary resource recovery. The paper illustrates that the integration of advanced technologies with robust policy and governance frameworks can secure India's critical mineral supply chain, support energy transition, and promote sustainable industrial growth.

1. Introduction:

Critical minerals and rare earth elements (REEs) form the backbone of modern technological, energy, and defence systems. As the world transitions to a low-carbon future and advances in digital and defence technologies accelerate, the demand for these minerals has surged. However, their supply chains remain concentrated in a few countries, posing risks to economic stability and national security.

India, as a rapidly developing Country with ambitious renewable energy, defence indigenization, and digital economy goals, remains heavily dependent on imports for many critical minerals. This dependency presents a strategic vulnerability. Ensuring access, affordability, and security of critical mineral supply is therefore essential to India's economic resilience, strategic autonomy, and long-term national security. Recognising this, India has recently adopted a comprehensive policy framework and regulatory shifts to build resilience and move toward greater selfreliance.

2. Strategic Importance of Critical Minerals:

Critical minerals such as lithium, cobalt, nickel, rare earths (like neodymium, dysprosium), graphite, and others are indispensable for:

- **Clean energy technologies** (solar PV, wind turbines, electric vehicles, batteries)
- **Defence applications** (jet engines, missile systems, night vision devices)
- **Electronics and semiconductors**
- **Telecommunications and aerospace**
- **Advanced manufacturing and AI**

India's targets—500 GW of non-fossil fuel energy by 2030, 30% EV penetration by 2030, and indigenized defence production—cannot be achieved without secure and resilient supply chains of critical minerals.

3. India's Dependency and National Security Implications:

India imports nearly 85–90% of its lithium, cobalt, and REE needs, largely from China and other geopolitically sensitive regions. This dependence creates multiple risks:

- **Strategic vulnerability** in defence and high-tech manufacturing
- **Price volatility and supply disruptions** due to geopolitical tensions
- **Slowdown of renewable and EV transitions**
- **Lack of bargaining power** in global markets

Without domestic exploration, value chain development, or diversification of sources, India risks becoming a passive consumer in a resource-constrained global order.

4. Recent Government Initiatives and Developments:

To address these risks, the Government of India has initiated major steps in 2023–25:

National Critical Minerals Mission (NCMM), 2025

- Budget: □16,300 crore (initial allocation).
- Objectives: Integrated development from exploration to recycling across 24 identified minerals.
- Focus on import substitution, domestic capability, and strategic stockpiling.

Exploration and Mining Push

Legislative Reforms

- **Mines and Minerals (Development and Regulation) Amendment Act, 2023**:
- Introduced auction regime for critical minerals
- Expanded Centre's powers to auction deep-seated, strategic minerals
- Removed restrictions on certain atomic minerals (like lithium, beryllium) for commercial use

Fiscal Incentives and Circular Economy

- Zero/minimal customs duty on lithium ores, cobalt powder, battery scrap, etc.
- □1,500 crore PLI-type scheme for **critical mineral recycling**
- Guidelines for recovery from mine tailings, overburden, and industrial waste
- Initiatives for magnet and battery manufacturing under "Make in India"

5. Regulatory Reforms Needed:

Despite strong momentum, several regulatory and structural challenges persist. Key reforms required include:

- **Streamlined environmental, land-use, and permitting clearances:** reduce delays in permitting critical mineral mining and processing, especially in ecologically sensitive or legally complex regions, while balancing environmental and social safeguards.

- **Transparent, stable royalty/tax regimes** and price assurance or off-take agreements to derisk investment, especially for private and foreign firms.
- **Overseas strategic partnerships:** Enabling Indian firms to explore, mine, process abroad, and secure supply chains (both raw mineral and refined products). Legal frameworks must allow overseas investment, with incentives and protections.
- **Technology and infrastructure capacity building:** Setting up domestic refining, magnet production, processing, downstream value addition; establishing Centres of Excellence; supporting R&D for alternative materials & extraction technologies.
- **Circular economy and secondary sourcing:** More aggressive policies for recycling, reuse, recovery from tailings, mine waste, agricultural and industrial byproducts. Regulatory clarity on ownership of mine waste, rights to process byproducts, liability issues.
- **Strategic reserves / buffer stocks:** Establishing government stockpiles of critical minerals to buffer against supply shocks.
- **Governance, transparency & stakeholder engagement:** While some recent moves (e.g. exempting public hearings in certain cases of critical mineral mining in view of strategic reasons) raise concerns, balancing security with democratic accountability and community rights remains important.

6. Challenges and Gaps:

- **Technical capacity deficits** in exploration and deep mining
- **Lack of domestic processing/refining units**
- **Community and environmental resistance** in mineral-rich areas
- **Limited private sector participation** due to risks and capital intensity
- **Geopolitical competition** for access to foreign mineral assets

7. Policy Recommendations:

To achieve national security and economic resilience through critical mineral security, India must:

- **Institutionalize the NCMM** as a statutory body with cross-sector coordination authority
- **Strengthen strategic diplomacy** with mineral-rich countries (e.g., through QUAD, BRICS)
- **Incentivize private and joint ventures** for both domestic and overseas exploration
- **Establish refining and downstream facilities** with public-private R&D support
- **Ensure responsible mining practices** with ESG compliance and community partnerships
- **Invest in talent and technology development** for long-term capability building
- **Create a transparent mineral data platform** for investors and planners.

8. Conclusion:

India possesses significant critical mineral reserves — including lithium (recently found in Jammu & Kashmir and Rajasthan), rare earth elements (especially in monazite sands along coastal Andhra Pradesh, Kerala, Tamil Nadu and Odisha), graphite, copper, nickel and phosphate rocks — and has identified a list of 30 critical minerals essential for the energy transition and advanced technologies. However, despite these endowments, India's actual production and value-chain participation remain limited: it produces only about less than 1 % of global rare earth output and is heavily dependent on imports for key battery and permanent-magnet minerals such as lithium, cobalt, nickel and high-purity rare earths.

The country also lacks large-scale processing and refining capacity for these minerals, meaning most raw materials are shipped abroad for further conversion into advanced products, and it imports large volumes of magnets and battery-grade materials from countries like China. India has taken steps to address this through policy reforms, block auctions under the Mines & Minerals (Development & Regulation) Act, and initiatives like the National Critical Minerals Mission with substantial funding to boost exploration, processing, recycling and overseas asset acquisition.

In contrast, global leaders in critical minerals - particularly China, Australia and Indonesia have a greater command dominant positions in both mining and processing. China alone controls the vast majority of global processing capacity (over ~90 % of rare earths and graphite processing, ~80 % of cobalt, and significant shares of lithium chemicals), enabling it to set market terms and export policies that can reverberate globally. Countries like Australia lead in lithium mine production, while Indonesia is a top nickel ore producer. This concentration of production and refining makes India's supply chain vulnerable to geopolitical risks and external shocks, and highlights major concerns for India: import dependence, limited downstream infrastructure, regulatory and investment gaps, and low domestic value capture in the high-tech segments of the critical minerals market. Addressing these issues is central to strengthening India's strategic autonomy in clean energy, defense and high technology sectors.

The Sustainable critical mineral extraction is central to India's energy security and climate goals. A mix of **advanced technologies, circular economy principles, and strong policy frameworks** can enable India to meet its growing demand while minimizing environmental impacts. Collaborative R&D, pilot demonstrations, and incentives for green technologies will be crucial in the coming decade.

Note:

We at Karnataka State Minerals Corporation Limited, have carried out complete chemical analysis for all radicals of adequate number of representative iron ore samples from our iron ore leases as per the Circular No: M- 11022(MP)/2/2022-CCOM-MDR-IBM_HQ Dated: 28.08.2025 from the office of the Controller General (I/C), Indian Bureau of Mines.

The circular issued by the Indian Bureau of Mines mandates comprehensive analysis of all radicals, underscoring the Government of India's strong focus on critical minerals. This initiative reflects a strategic approach to strengthen mineral characterization and data reliability. By emphasizing detailed analysis, the government aims to support sustainable extraction, value addition, and self-reliance. The move is a significant step toward achieving key milestones in India's critical minerals roadmap.

Companies play a crucial role in achieving this objective by aligning their exploration, testing, and reporting practices with the Indian Bureau of Mines' guidelines. By investing in advanced analytical capabilities and ensuring compliance, industry participants strengthen the critical minerals value chain. Their proactive support accelerates resource development, enhances transparency, and directly contributes to the Government of India's mission of securing critical minerals for sustainable growth.

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Soil Microbial Diversity and Its Role in Ecological Restoration of Mining Areas

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Abstract

Mining activities significantly disturb soil systems by altering physicochemical properties, removing fertile topsoil, and introducing heavy metal contamination, leading to a decline in soil fertility and biological integrity. Soil microbial diversity is highly sensitive to such disturbances and serves as a reliable indicator of soil health and ecosystem recovery. Microorganisms play a critical role in nutrient cycling, organic matter decomposition, soil aggregation, and metal immobilization, thereby facilitating vegetation establishment and ecological restoration. This article evaluates soil microbial diversity in mining and reclaimed areas and assesses the effectiveness of environmental protection measures on flora, fauna, and overall ecological balance. The findings demonstrate that scientifically planned reclamation measures—such as topsoil management, erosion control structures, organic amendments, and afforestation—significantly enhance microbial recovery and contribute to the long-term sustainability of mine-degraded landscapes.

Keywords: *Soil microbial diversity, mining, reclamation, ecological restoration, soil health*

1. Introduction

Soil ecosystems host an extraordinarily high diversity of microorganisms, far exceeding the diversity of higher plants and animals. A single gram of soil may contain billions of microorganisms representing thousands of species; however, less than one percent of these microorganisms are culturable using conventional laboratory techniques. Soil microbial diversity encompasses genetic, taxonomic, and functional diversity, all of which regulate essential ecosystem processes such as nutrient cycling, organic matter decomposition, and soil structure formation.

Mining activities cause severe soil degradation through large-scale land disturbance, removal of topsoil, alteration of soil pH, compaction, and accumulation of heavy metals. These changes result in a substantial decline in microbial diversity and activity, thereby impairing soil productivity and ecosystem resilience. Understanding soil microbial diversity in mining landscapes is therefore essential for evaluating soil health, assessing reclamation success, and guiding sustainable mine closure and ecological restoration strategies.

2. Assessment of Soil Profile within Mine Leases and outside mine lease area

Soil samples were collected from 21 locations within and outside the SMIORE mining lease area to assess soil quality and microbial status across active, inactive, and stabilized mine dumps. The mining lease covers an area of 1,860.10 ha, comprising multiple operational pits and waste dumps.

Reclamation and rehabilitation (R&R) measures implemented under the approved R&R Plan include the construction of retaining walls, garland drains, geo-textile (coir mat) stabilization, afforestation, surface water management structures involving check dams and gulley plugs, silt settling tanks and rainwater harvesting pits. Retaining walls and drainage structures effectively control erosion and stabilize waste dumps, while coir mat application enhances slope stability and promotes natural vegetation colonization.

Afforestation using native dry deciduous species has improved land stability and facilitated ecological succession. Water harvesting and grade stabilization structures have significantly reduced surface runoff and soil loss, thereby improved soil moisture regimes and creating favourable conditions for microbial activity and recovery.

Soil samples were collected at a depth of 30 cm, 60 cm and 90 cm at each sampling location. The soil samples were collected in a neat and clean airtight polythene bag and properly packed. All the soil samples collected from three different depths were homogenized and then they were analyzed for their various nutrient parameters.

The pH and Electrical Conductivity (EC) of soil samples were determined by the methods described by Jackson (1973). Organic Carbon content was determined by adopting chromic acid wet digestion method (Walkley and Black, 1934), nitrogen was estimated by alkaline permanganate method (Subbiah and Asija, 1956) and available phosphorus was estimated by Bray-I method (Bray and Kurtz, 1945). The potassium contents in the extract were determined by using flame photometer (Standford and English, 1949), calcium, magnesium and Sulphur contents were estimated by the standard method (Jackson, 1973; Lindsay and Norvell, 1978). The results of the soil nutrient parameters of all the ten study locations were compared with the standard soil classification.

The soil microbial load viz., Bacteria, Fungi, Actinomycetes and AM fungi was determined from 20 different soil samples of selected sampling locations. Serial dilution and plating techniques as described by Parkinson et al. (1971) was adopted for enumerating the population of Bacteria, Fungi and Actinomycetes. The AM fungal spore population was estimated by using wet sieving and decanting technique (Gerdemann and Nicholson, 1963). Root colonization by the AM fungi was done by using root clearing and staining techniques (Phillips and Hayman, 1970; Koske and Gemma, 1989) and data on percent root colonization of AM fungi was also estimated by using gridline intersect method (McGonigle et al., 1990).

Sample No.	pH		EC (dS/m)		Organic Carbon (%)		Available Nitrogen (kg/ha)		Available Phosphorus (kg/ha)		Available Potassium (kg/ha)		Calcium (mg/kg)		Magnesium (mg/kg)	
	Nov. 22	Jul. 23	Nov. 22	Jul. 23	Nov. 22	Jul. 23	Nov. 22	Jul. 23	Nov. 22	Jul. 23	Nov. 22	Jul. 23	Nov. 22	Jul.23	Nov. 22	Jul.23
1.	6.68	7.50	0.186	0.196	0.470	0.840	114	325.0	8.23	30.56	79.00	99.00	860	1122.0	360	195.0
2.	6.26	6.80	0.196	0.110	0.410	0.800	213	305.0	7.62	13.97	110.0	90.0	758	762.0	280	170.0
3.	6.38	6.89	0.230	0.890	0.370	0.420	250	230.0	9.32	10.74	128.0	77.0	689	641.0	241	182.0
4.	7.12	7.81	0.189	0.154	0.290	0.460	109	216.0	5.89	18.69	108.0	116.0	725	1323.0	300	195.0
5.	7.39	7.26	0.235	0.114	0.490	0.230	125	165.0	7.55	9.87	110.0	84.0	715	481.0	218	134.0
6.	7.49	7.92	0.225	0.227	0.180	1.490	120	403.0	6.96	33.97	105.0	419.0	635	2725.0	260	255.0

Sample No.	pH		EC (dS/m)		Organic Carbon (%)		Available Nitrogen (kg/ha)		Available Phosphorus (kg/ha)		Available Potassium (kg/ha)		Calcium (mg/kg)		Magnesium (mg/kg)	
	Nov. 22	Jul. 23	Nov. 22	Jul. 23	Nov. 22	Jul. 23	Nov. 22	Jul. 23	Nov. 22	Jul. 23	Nov. 22	Jul. 23	Nov. 22	Jul.23	Nov. 22	Jul.23
7.	6.79	6.90	0.248	0.102	0.120	0.940	162	350.0	7.28	14.84	79.50	128.0	475	842.0	240	109.0
8.	6.76	7.41	0.263	0.128	2.350	0.590	190	297.0	8.36	18.51	110.5	135.0	682	902.0	255	158.0
9.	7.38	7.08	0.244	0.800	1.990	0.310	128	193.0	7.26	11.44	125.0	65.0	596	461.0	230	73.0
10.	7.10	7.12	0.157	0.118	0.152	0.460	180	246.0	8.05	13.45	105.0	113.0	638	601.0	240	61.0
11.	7.36	7.94	0.110	0.223	0.125	1.640	156	442.0	7.63	20.87	116.0	314.0	758	2244.0	380	316.0
12.	6.76	7.68	0.105	0.321	0.186	0.800	140	314.0	9.36	30.65	115.0	264.0	586	1603.0	289	231.0
13.	6.31	7.48	0.103	0.249	0.680	0.900	180	336.0	10.88	23.93	145.0	273.0	489	1483.0	307	146.0
14.	6.94	7.16	0.101	0.240	10.83	2.060	140	470.0	7.58	20.26	160.0	301.0	522	1683.0	268	134.0
15.	6.71	7.18	0.230	0.349	0.098	2.710	125	543.0	6.28	23.58	138.0	290.0	408	2946.0	288	231.0
16.	6.41	7.13	0.152	0.246	2.003	2.010	215	431.0	7.38	36.33	140.0	396.0	759	1924.0	315	219.0
17.	7.38	7.20	0.333	0.169	1.258	1.280	260	356.0	9.42	12.49	129.0	196.0	628	1283.0	263	170.0
18.	6.25	7.06	0.279	0.204	0.380	1.240	180	347.0	7.62	15.11	156.0	298.0	708	1463.0	244	219.0
19.	6.46	7.10	0.209	0.157	0.079	0.650	240	297.0	9.52	12.84	110.0	117.0	635	1142.0	315	134.0
20.	6.35	6.91	0.344	0.226	1.740	2.250	220	524.0	7.48	14.06	148.0	357.0	704	1603.0	296	146.0
21.	6.73	6.88	0.229	0.272	0.845	3.050	185	563.0	11.25	21.13	135.0	569.0	729	2144.0	305	304.0
Min	**6.25**	**6.80**	**0.101**	**0.102**	**0.079**	**0.230**	**109**	**165.0**	**5.89**	**9.87**	**79.00**	**65.0**	**408.00**	**461.0**	**218.00**	**61.0**
Max	**7.49**	**7.94**	**0.344**	**0.890**	**10.83**	**3.050**	**260**	**563.0**	**11.25**	**36.33**	**160.00**	**569.0**	**860.00**	**2946.0**	**380.00**	**316.0**
Mean	**6.81**	**7.26**	**0.208**	**0.262**	**1.193**	**1.200**	**172.95**	**329.67**	**8.14**	**17.82**	**122.00**	**223.86**	**652.33**	**1399.24**	**280.67**	**180.10**

3. Role of Soil Microbial Diversity in Mining Areas

Soil microbial diversity plays a pivotal role in mine land restoration by improving nutrient availability, enhancing organic matter decomposition, stabilizing soil structure, and reducing heavy metal bioavailability through immobilization and transformation processes. Microbial communities facilitate revegetation, improve soil fertility, and serve as sensitive indicators of reclamation success.

However, microbial recovery in mining areas is often slow and constrained by residual contamination, repeated disturbances, low organic matter content, and dominance of metal-tolerant opportunistic microorganisms. These limitations highlight the need for long-term monitoring and adaptive management to ensure sustained ecological recovery.

Beneficial microbes such as VAM Fungi and Plant Growth Promoting Rhizobacteria (PGPR) viz., Azospirillum and Azotobacter, Phosphate Solubilizing Bacteria (PSB) and Actinomycetes sampled and estimated from the soil in and around the SMIORE mine revealed that their population generally varied both among the sampling interval as well as among the sampling locations. In general, natural forest outside the mining lease area recorded relatively high root colonization percent, spore density and soil population of PGPRs compared to afforested dumps. This is attributable to evident disturbances in land use cover on account of mining in the study areas. Also, seasonal influence was quite evident in the beneficial microbial population as evident variation was observed in beneficial soil microbial population between both winter and monsoon.

5. Advantages and Disadvantages of Soil Microbial Diversity

5.1 Advantages of Soil Microbial Diversity

Soil microbial diversity provides multiple ecological and functional benefits essential for soil health and ecosystem stability. Diverse microbial communities enhance nutrient cycling by decomposing organic matter and mobilizing essential nutrients such as nitrogen, phosphorus, and sulfur. Microbial activity promotes soil aggregation, improving aeration, water infiltration, and resistance to erosion.

Beneficial microorganisms - including nitrogen-fixing bacteria, mycorrhizal fungi, and plant growth-promoting rhizobacteria - enhance nutrient uptake, stimulate root development, and improve plant productivity. High microbial diversity naturally suppresses soil-borne pathogens through competition, antibiosis, and predation.

Diverse microbial communities increase soil resilience to environmental stresses such as drought, mining disturbances, pollution, and land degradation. Soil microorganisms also regulate carbon cycling and sequestration, contributing to climate change mitigation. Additionally, certain microbes degrade organic pollutants and immobilize heavy metals, thereby improving soil quality and supporting sustainable land use and ecological restoration.

5.2 Disadvantages of Soil Microbial Diversity

Despite its benefits, soil microbial diversity may also present certain challenges. Increased diversity can include harmful microorganisms such as plant pathogens or toxin-producing species that negatively affect crops and soil health. During organic matter decomposition, microbes may temporarily immobilize nutrients, reducing their availability to plants.

Some microbial processes contribute to greenhouse gas emissions, including methane (CH_4) and nitrous oxide (N_2O), which influence climate change. Intensive microbial activity under unfavorable conditions may lead to soil acidification or accelerated nutrient leaching. Highly diverse microbial communities can also result in complex and unpredictable soil processes, complicating soil management. If ecological balance is disturbed, microbial diversity may facilitate the persistence and spread of soil-borne diseases.

6. Conclusion

The use of mycorrhizal fungi, particularly the VAM, as bio-fertilizers play an important role in enhancing the uptake of nutrients (Phosphorus, Zinc and other essential elements) and water for establishment of seedlings/saplings on degraded lands including mined out areas and OB dumps. The use of VAM fungi along with PGPR bio-fertilizers is known to have profound influence on the development of good vegetation growth in reclamation and rehabilitation of mine spoils. Hence, the biological reclamation of mining areas employing native tree species bio-inoculated with VAM fungi and PGPR bio-fertilizers (Rhizobium, Azospirillum, Azotobacter and Phosphobacterium) is highly recommendable.

Mining-induced soil degradation results in a significant decline in soil microbial diversity and ecosystem functioning. The implementation of scientifically designed reclamation measures substantially improves soil conditions and promotes gradual recovery of microbial communities. Soil microbial diversity emerges as a reliable indicator of soil health and ecological restoration success in mining areas. Sustained monitoring, use of native vegetation, organic amendments, and integrated land and water management practices are essential to ensure long-term stability and sustainability of post-mining ecosystems.

Banded Magnetite Quartzite (BMQ) 2050 – "The Future Mining in Sandur Schist Belt"

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ABSTRACT

The Sandur Schist Belt hosts extensive Banded Magnetite Quartzite (BMQ), an Archaean Banded Iron Formation composed of alternating magnetite and quartz bands. These deep-seated formations lie below BHQ and haematitic ore, making present extraction difficult due to boundary limitations and the extreme hardness of BMQ. Its strong magnetic properties aid exploration, but advanced crushing and beneficiation technology is required for economic use. With high-grade haematitic ore (+35% Fe) expected to deplete within the next 50 years, future mining may increasingly depend on magnetite-rich BMQ. Technological improvements and integrated boundary access will be crucial for unlocking these resources sustainably.

INTRODUCTION

The Sandur Schist Belt of Ballari District, Karnataka, stands as one of the most significant greenstone belts within the Dharwar Craton, renowned for its extensive Iron and Manganese ore deposits. Among its key iron-bearing formations, Banded Haematite Quartzite (BHQ) and Banded Magnetite Quartzite (BMQ) form an integral part of the region's geological and economic framework. BMQ, a major Archaean Banded Iron Formation (BIF), preserves early Earth processes through its characteristic alternating magnetite and quartz bands, originally deposited as chemical sediments in a marine environment. These formations have since undergone metamorphism, deformation, tight folding and foliation, reflecting the intense tectonic history of the Sandur region.

BMQ is characterized by alternating dark and light bands—the dark layers composed mainly of magnetite (an iron oxide mineral) and the light layers of quartz or chert. These rhythmic bands were originally deposited as chemical sediments in a marine basin, where iron and silica precipitated alternately from seawater. Over time, the rocks underwent metamorphism and deformation, resulting in the compact, finely banded quartzites observed today. The BMQ often shows tight folding and foliation, indicating multiple tectonic events in the Sandur region.

In the field, BMQ occurs as hard, compact ridges with metallic lustre and weathered haematitic surfaces, often containing accessory minerals such as biotite, amphibole and carbonates. Its strong magnetic properties make it easily traceable during geophysical exploration. Despite its economic value, BMQ remains largely inaccessible due to its position beneath BHQ and unexhausted haematitic ore, combined with lease-boundary restrictions and the need for advanced crushing and beneficiation technology.

Economically, BMQ represents a long-term iron ore resource, especially in regions such as Donimalai, Haraginadoni, Ramanamalai and Copper Mountain. While fresh BMQ requires magnetic separation to produce high-grade concentrates, its weathered zones may yield usable haematitic ore. Scientifically, these formations offer insights into ancient marine environments and early oxygenation events.

Beyond its economic value, BMQ of the Sandur Schist Belt provides insight into ancient Earth environments, representing one of the earliest records of oxygen build-up and iron precipitation in the oceans. Preserving and studying these formations not only supports mineral exploration but also enhances understanding the geological history.

Looking ahead, as high-grade haematitic ore (+35% Fe) may be depleted within the next 50 years, the importance of magnetite-rich formations such as BMQ will inevitably increase. Advancements in mining technology, integrated boundary access and government support through auctioning or common-boundary working will be essential to ensure sustainable utilization of these deep-seated resources in the future.

Case Study: Potential of Banded Magnetite Quartzite (BMQ) in the Sandur Schist Belt

The geological succession is typically comprises lateritic cover at the top, followed by high-grade haematitic iron ore, underlain by Banded Haematite Quartzite (BHQ) and deeper Banded Magnetite Quartzite (BMQ). The BMQ occurs as thick, compact and steeply dipping bands, often showing tight folding and foliation due to intense deformation associated with regional tectonism.

Fig No-1: Photographs showing core drill sample: Dark bands colour refers to presence of Magnetic ore and light colour bands refers to silica content

Field observations indicate that BMQ in the Ramanamalai & Swamimalai Range is encountered at depths of approximately 100–200 m below surface, beneath partially exhausted haematitic ore zones. Due to its position below economically viable ore and the presence of lease boundary limitations, the BMQ horizon remains largely unexploited at present. Similarly petrographic study carried out for BHQ formation of M/s. VESCO reveals some presence of magnetite content.

Grade and Mineralogical Characteristics

The BMQ is characterized by alternating magnetite-rich and quartz-rich bands. Representative analytical data indicate average iron content in the range of 28–32% Fe, with silica content of about 45–55%.

Weathered zones of BMQ locally show partial oxidation of magnetite to haematite, resulting in marginally upgraded iron values. However, fresh BMQ remains hard, compact and unsuitable for direct use as ROM ore without suitable processing.

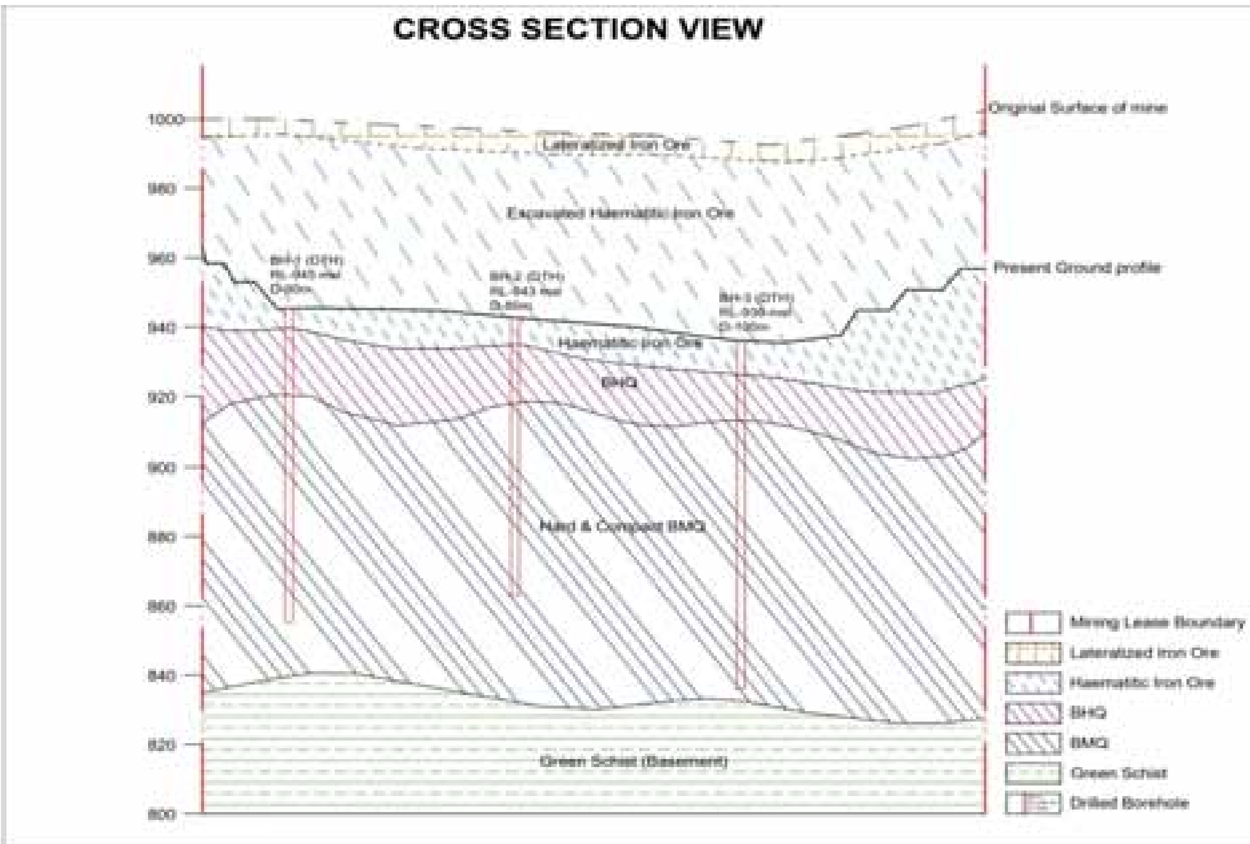

Fig No-2: Cross sectional view showing occurrence of BMQ

The cross-section shows the deposit from about 1000m RL at surface to about 840m RL at depth, highlighting the significant vertical separation between the active haematite zone and the underlying BMQ.

The lateritic cover and original surface occur near 1000m RL, underlain by the haematitic ore zone (60–65% Fe), which is presently mined and extends down to around 930 to 940m RL, with surface drilling.Below this, a weathered BHQ zone of about 20 to 25m thickness occurs around 900m RL, forming a transition layer. The hard and compact BMQ lies below this level and continues downward up to about 840m RL, remains unexploited due to depth & hardness.

Example of Boreholes data drilled with chemical analysis

Hole No: BH-1

RL: 945.00 m msl (bottom pit)

Depth: 90.00 mtrs

Depth (m)	Lithology	Radicals				Remarks
		Fe %	FeO %	SiO_2 %	Al_2O_3 %	
0.00–6.00	Haematitic powdery ore with silica	58.00	-	-	-	HIO (+35% Fe)
6.00–5.00	BHQ	34.00 – 42.00	-	-	-	
55.00-90.00	Hard & compact BMQ	37.00 – 43.00	6.00 – 15.00	35.00 – 42.00	-	MIO (+15%Fe)
Borehole ended in BMQ formation						

Hole No: BH-2

RL: 943.00 m msl (bottom pit)

Depth: 80.00 mtrs

Depth (m)	Lithology	Radicals				Remarks
		Fe %	FeO %	SiO_2 %	Al_2O_3 %	
0.00-10.00	Haematitic powdery ore	63.00 – 65.00	-	1.50	1.70	HIO (+35% Fe)
10.00–45.00	BHQ	30.00 – 50.00	-	-	-	
45.00–80.00	Hard & compact BMQ	20.00 – 43.00	7.00 – 12.00	34.00 – 50.00	-	MIO (+15%Fe)
Borehole ended in BMQ formation						

Hole No: BH-3

RL: 936.00 m msl (bottom pit)

Depth: 100.00 mtrs

Depth (m)	Lithology	Radicals				Remarks
		Fe %	FeO %	SiO_2 %	Al_2O_3 %	
0.00-15.00	Haematitic ore	63.00 – 66.00	-	1.50	1.60	HIO (+35% Fe)
15.00-38.00	BHQ	28.00 – 50.00	-	-	-	
38.00–100.0	Hard & compact BMQ	36.00 – 42.00	5.00 – 20.00	36.00 – 43.00	-	MIO (+15%Fe)
Borehole ended in BMQ formation						

Threshold value for Magnetite Iron ore is minimum 15% Fe & for Haematitic Iron ore is +35% Fe

CONCLUSION

The BMQ of the Sandur Schist Belt is a valuable yet currently inaccessible iron-bearing resource lying beneath BHQ and haematitic ore zones. While present mining and technological limitations restrict its extraction. Future depletion of high-grade ores will increase reliance on magnetite-rich BMQ.

In the long-term scenario, after the next 50 years, most of the accessible haematitic iron ore with a cut-off grade of +35% Fe may become completely exhausted. With future advancements in mining and mineral-processing technology, the industry may become capable of economically working low-grade iron ore below 35% Fe. Otherwise, if technology does not advance sufficiently, future mining may be forced to depend predominantly on magnetite-rich formations such as BMQ. Thus, developing suitable technology and ensuring coordinated boundary access—such as auctioning adjacent mining areas for common-boundary working—will be crucial for reaching and utilizing the deep-seated BMQ resources in the future.

As per the notification issued by the Ministry of Mines on 25 April 2018, the threshold value for Haematite Iron ore is fixed at 35% min' Fe, whereas for Magnetite Iron ore it is 15% min' Fe. This difference reflects the higher beneficiation potential of magnetite ores, which can be economically upgraded through magnetic separation despite their lower in-situ iron content. In contrast, haematitic ores require a higher natural grade to remain viable due to comparatively limited scope for beneficiation.

Therefore, while haematite dominates present-day mining due to its higher threshold value, magnetite-rich formations such as BMQ gain strategic importance in the long-term, especially when high-grade haematitic resources above 35% Fe become exhausted. The lower threshold for magnetite supports future reliance on BMQ as a sustainable iron ore source, provided suitable mining and processing technologies are developed.

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Critical Minerals: The Backbone of India's Energy Transition

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The rich geological diversity of the Indian shield positions the country as a potential leader in critical minerals. Critical minerals are non-fuel raw materials essential for renewable energy systems, electric vehicles, semiconductors, defense technologies, aerospace, telecommunications, and advanced manufacturing.

Classification of Critical Minerals:

Nations classify raw materials or critical minerals based on their economic priorities, industrial requirements technological development, national security needs, and natural resource endowment. Aligning with these global considerations, the Ministry of Mines (MoM), Government of India, has identified 30 minerals as critical, i.e. antimony, beryllium, bismuth, cobalt, copper, gallium, germanium, graphite, hafnium, indium, lithium, molybdenum, niobium, nickel, PGE, phosphorous, potash, rare earth elements (REEs), rhenium, silicon, strontium, tantalum, tellurium, tin, titanium, tungsten, vanadium, zirconium, selenium and cadmium. From powering electric vehicles to strengthening defence and aerospace systems, critical minerals underpin virtually every aspect of technological and industrial progress. If India aims to lead globally in clean energy, digital innovation, and strategic autonomy, securing reliable access to critical minerals must become a national priority. India's target of achieving net-zero emissions by 2070 requires a large-scale transition toward renewable energy, electric mobility, and advanced energy-storage systems sectors that heavily depend on lithium, cobalt, nickel, copper, and rare earth elements. In essence, critical minerals are the foundational building blocks of a modern and self-reliant India.

Exploration :

The role of geologists / mining engineers / metallurgists is vital in exploring and developing critical mineral deposits, which hold immense significance for economic growth and national security. Mineral exploration typically progresses through three key stages such as reconnaissance, preliminary exploration, and detailed exploration. As the target area becomes more focused, the intensity and precision of work increase. These stages rely on thorough geological studies, geochemical and geophysical surveys, and systematic rock sampling. With advancements in modern analytical instrumentation, geochemical analysis has become more accurate, with improved detection limits and reliability. Sampling for critical minerals presents unique challenges, especially due to the occurrence of erratic high values that can affect average grade estimations. Therefore, geological mapping and interpretation of structural features, combined with careful assessment of geochemical data, are essential for identifying prospective mineralized zones. Geochemical surveys provide quantitative information on the distribution of elements in both surface and sub-surface materials, which is then compared to background values to identify anomalies. Common sampling methods i.e., soil, stream-sediment, and rock sampling are designed to capture key geochemical indicators of mineralization.

Modern analytical instrumentations enhance the accuracy and detection limits of these surveys marking a significant advancement in geo-chemical analysis and exploration methodologies. Geo-statistical studies are crucial for understanding the frequency distribution of sample values in estimating deposit grades with varying levels of confidence. Variographic studies further aid in understanding the structural characteristics and spatial continuity of ore bodies, which is significant for effective reserve estimation. In India, mineral reserves classifications follow the UNFC system. Which, designing an effective exploration program requires balancing cost with accuracy and coverage. Systematic sampling, detailed geological mapping geometry of the ore shoots and structured planning form the backbone of any successful exploration strategy. Above all, skilled exploration team remain indispensable; their expertise, combined with modern analytical, IT tools, modern mining & metallurgy enables them to navigate the complex challenges of critical mineral exploration & mining feasibility.

Resources:

Major global REE deposits

Country	Source Rock	Rare Earth Resources (million tons)	Rare Earth Production in 2024 (tones)	Grade (REO), (%)
USA	Carbonatite & Alkaline Complex	1.9	45	8.248
Australia	Carbonatite	5.7	13	7.91
China	Iron-oxide –Copper-Gold	44	270	6
Vietnam	Granite	3.5	-	5.22
Brazil	Carbonatite	21	-	5
South Africa	Carbonatite	-	-	2.32
Tanzania	Carbonatite	-	-	2.24
Canada	Alkaline Intrusion	-	-	1.16
India	Monazite (BSM Ore)	6.9	2.9	0.057

Case Studies :

Amareshwar Lithium Deposit

The Amareshwar region Raichur Dist., Karnataka in the Parampur schist belt Raichur Dist., Karnataka of the Dharwar Craton, Southern India, is a promising site for Li exploration. The region hosts pegmatite bodies intruded at the boundary of amphibolites and granitoids, that contains spodumene ($LiAlSi3O8$). These pegmatites are composite, zoned, and primarily composed of quartz, plagioclase, k-feldspar, spodumene, and muscovite. Satellite surveys and existing data were used to identify potential spodumene-bearing areas. Band-ratio and RGB composite techniques on ASTER data were employed to delineate these regions.

Integration of these maps with lithological, structural, and geochemical data from the National Geoscience Data Repository (NGDR) improved the accuracy of spodumene identification. Validation with Geological Survey of India (GSI) maps, which also marked Li-pegmatites, showed strong alignment, confirming the effectiveness of the generated maps. These findings proved invaluable for fieldwork where the presence of the spodumene bearing pegmatite bodies were identified. The accuracy of the pre-field maps was thus tested and it proved helpful in exploration targeting and can guide future exploration in the region. Further, R&D work is in Progress (Abir Banerjee, Sakthi Saravanan Chinnasamy & Prabhakar Sangurmath : 2025)

Kalyadi Cu-Co deposit

Cobalt (Co), a critical and strategic metal due to its unique physiochemical properties such as high melting point, exceptional mechanical strength at high temperature and excellent corrosion resistant properties. As part of its ambitious plan to achieve net zero emissions by 2070, the Government of India aims to transition the majority of the vehicles to EVs, significantly reducing dependence on fossil fuels and lowering carbon entissions in the transportation sector. None of these goals will be achievable without a consistent supply of Co and other elements which are essential for battery production.

Belligutti hill, situated near Kalyadi village within the Kalyadi Schist belt (KSB) of the Westen Dharwar Craton in Karnataka, India, is historically known for significant copper production and previous studies have reported the presence of significant Co. The economic potential of Co in the Kalyadi deposits was assessed using detailed petrographic analysis, EPMA, Raman spectroscopy and ICP-MS from the samples collected from mine dumps and tailings Petrographic analysis identified sulfide-bearing phases, mainly pyrite and chalcopyrite, occurring along the foliation and within quartz-carbonate veins. EPMA results indicate two modes of cobalt (Co) occurrence: as an independent Co mineral and through isomorphic substitution within pyrite. Co concentrations in pyrite range from 0.5 to 6.3 wt.%. Elemental mapping and correlation analyses suggest that Co substitutes for Fe in pyrite through isomorphic replacement. Raman spectroscopy confirmed the presence of siegenite as the independent Co mineral, based on its distinctive spectral signature. ICP-MS analysis of separated sulfide concentrates from mine tailings revealed notable cobalt content, reaching up to 1.1 wt.%.

With further studies to assess whether Co can be extracted economically from pyrite and sulfide tailings, the Kalyadi deposits could become a viable Co bearing mining site, contributing to meeting the increasing demand for Co. Further, R&D works are in progress (Pratush Kar, Abir Banerjee, Sakthi Saravanan Chinnasamy, V. N. Vasudev, Prabhakar Sangurmath : 2025)

The significance of critical minerals in supporting India's economic growth and environmental goals highlights exploration as a crucial endeavor for ensuring a stable supply chain and fostering sustainable development in a rapidly evolving global market.To build the nation of our dreams, atom by atom, wire by wire, chip by chip, India must strengthen its focus on critical minerals. At present, the country imports most of these strategic resources. To achieve true self-reliance, it is essential to prioritize domestic, intensive, and detailed exploration, along with developing strong mining and refining capacities for critical minerals. Such an approach will reduce India's vulnerability to global supply shocks and foster long-term resource security. The lengthy and demanding process of prospecting, exploration, developing & establishing critical mineral mines in India require serious and timely attention at every level of decision-making. Strengthening these efforts will be instrumental in securing the mineral foundation of a modern, sustainable, and technologically empowered India.

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Note: The views expressed in this article are solely those of the author and do not necessarily reflect the opinions of the organization with which he is currently or were previously associated.

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A Comprehensive CSR Case Study of R. Praveen Chandra, ERM Group

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Abstract

John Iron Ore Mine, Unit of ERM Group under the stewardship of Shri R. Praveen Chandra, represents a benchmark model of responsible mining aligned with India's Viksit Bharat 2047 vision. Located in Chitradurga District, Karnataka, the mine has embedded Corporate Social Responsibility (CSR) into its core business strategy for over 15 years, with structured interventions in healthcare, education, water security, sanitation, infrastructure development, and environmental stewardship across villages.

Guided by the philosophy of seeking harmony between People, Society, Environment, and Sustainable Development, the CSR framework functions as a business-led development model that enhances regulatory compliance, strengthens social license to operate, and mitigates operational risks. This paper documents the CSR governance architecture, implementation mechanisms, impact metrics, and strategic alignment with the United Nations Sustainable Development Goals (SDGs), Indian Bureau of Mines (IBM) Star Rating framework, and the Viksit Bharat 2047 agenda.

The mine's recognition with a 5-Star Rating by the Indian Bureau of Mines for the periods 2016–2022 and 2023–24 underscores the effectiveness of integrating green mining practices with inclusive community development. This case study provides technical insights and replicable lessons for mining professionals, policymakers, and sustainability practitioners seeking scalable models of responsible mineral development.

1. Introduction

1.1 Mining Context and CSR Imperative

India's mining sector generates substantial economic value while presenting complex environmental and social challenges. The iron ore mining region of Chitradurga District in Karnataka represents a critical convergence point between resource extraction and community welfare. Under Section 135 of the Companies Act 2013, listed mining enterprises are mandated to allocate a minimum of 2% of average net profits toward CSR activities [1].

1.2 ERM Group Philosophy

The CSR philosophy articulates: *«Every act of humans has an impact on the environment. Through our mining operations, we strive to minimize negative environmental effects without disrupting the social and economic fabric of local communities.»* This commitment reflects understanding that long-term business success requires risk mitigation, stakeholder confidence, and creation of measurable community value.

1.3 CSR Vision, Mission, and Strategic Framework

Vision: To be a socially committed organization engaged in building vibrant communities in harmony with nature, aiming to become the most admired company in India.

Mission: Through sustainable measures and community participation, actively contribute to social, economic, and environmental development of communities, thereby creating value for the nation.

Implementation Approach: CSR initiatives follow a holistic logic framework model encompassing INPUT (resources, partnerships) → OUTPUT (programs delivered) → OUTCOME (behavior changes, infrastructure ready) → IMPACT (sustained social-economic development). All projects undergo assessments measuring health indicators, literacy levels, livelihood status, population demographics, and economic conditions. Programs are identified participatorily through consultation with Gram Panchayats and village communities. The CSR Committee oversees quarterly progress reviews, budget allocation, and strategic alignment with national development agendas.

2. Healthcare Initiatives: Extending Primary and Secondary Care

2.1 Mobile Health Clinic: Fifteen Years of Primary Healthcare Delivery

Commissioned in 2009, the Mobile Health Clinic represents the most comprehensive and continuous healthcare intervention. Operating as a fully air-conditioned facility, the clinic rotates bi-weekly across approximately 10 operational villages.

Cumulative Impact (2009–2025): Over 1,50,000 patient consultations; sustained annual service delivery; consistent community trust and utilization reflecting service credibility.

2.2 Emergency Ambulance Services

A fully equipped ambulance donated to the Community Health Centre at Sirigere (2009) has facilitated over 2,500 emergency patient transportations.

Figure 1: *Mobile Health Clinic, Mobile TB Screening Equipment support through Rotary Foundation, and nutrition kit distribution to tuberculosis patients.*

2.3 COVID-19 Pandemic Response: Emergency Mobilization

During 2020–2022, ERM Group demonstrated exceptional CSR commitment through extraordinary pandemic relief:

Figure 2: *COVID care centre and oxygen generation plant.*

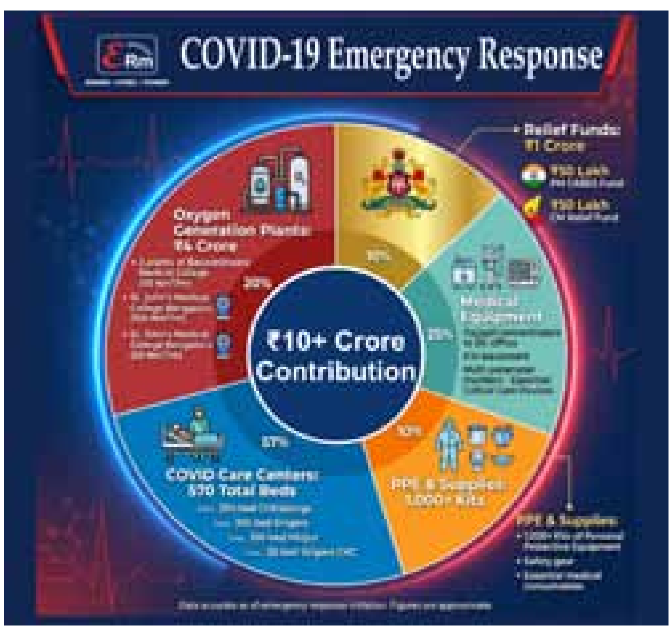

Figure 2a: *COVID-19 Emergency Response highlighting ERM Group's contribution.*

Sponsorship of Dialysis Charges:

Sponsoring Up to 200 dialysis sessions per month for patients from economically weaker sections in Chitradurga district through Rotary Trust

Chitradurga.

Specialized Health Camps:

Health screening and awareness camps are organized in collaboration with Vasan Eye Care and Basaveshwara Medical College & Hospital, Chitradurga.

Financial Assistance for Health Needs:

Financial aid is provided to deserving patients to support their medical treatment and related expenses

Ration Support for TB Patients – Sirigere PHC
Essential ration items have been distributed to patients undergoing Tuberculosis treatment at the Sirigere Primary Health Care Centre, supporting nutritional needs and improving treatment adherence.

Contribution to Rotary Foundation – Mobile TB Screening Equipment
Financial assistance has been provided to the Davangere Rotary Foundation towards the procurement of mobile TB screening equipment, strengthening early detection and community-level TB control efforts.

3. Education: Building India's Future

3.1 Infrastructure Modernization and Digital Integration

Education investments target quality improvement across 15+ government schools through:

Structural Investments:

- Construction of new classrooms (10+ schools)
- Gender-segregated toilet blocks (13+ facilities across schools and health centers)
- Science laboratory infrastructure development
- Dining halls for mid-day meal service
- Ranga Mandira (cultural performance halls)
- Anganwadi centers for early childhood development
- School compound walls for safety

Digital Education Integration:

- Smart classroom technology deployed in 12 government higher primary schools (2024–2025): D. Medikeripura, Tanigehalli, Megalahalli, Chikkenahalli, Kagalagere, Muthugaduru, Alagavadi, Bommavanagathihalli, Bommanhalli, Sirigere, Kadleguddu, Sasalu and Institution of Agricultural Technologists, Chitradurga.
- Teaching aids and visual learning materials
- RO-treated drinking water systems in school compounds.

3.2 Digital Access and Learning Continuity

Computer Education Program: Free computer classes across 4+ villages (D. Medikeripura, Kagalagere, Tanigehalli) targeting classes V–VII. Over 2,000 students trained since program inception in advanced computer skills and fundamentals.

COVID-19 Emergency Response:

- 1,000 pre-loaded tablets distributed to 10th Standard students containing comprehensive SSLC (Secondary School Leaving Certificate) study materials aligned with Karnataka state curriculum
- 500+ copies of Prajavani and Deccan Herald newspapers distributed daily with study materials for board examination preparation.

3.3 Transportation Access

Two school buses operational since 2008 (second bus inaugurated 2024–2025) to provide safe, reliable transportation for 350+ students daily from surrounding villages, addressing rural access barriers to quality education.

3.4 Financial and Vulnerable Population Support

- Merit-based scholarships for 40–50 higher education students annually
- Financial assistance preventing educational discontinuation for poor students
- Career guidance and professional skill training coordination
- Adoption of Ashray Dhama (destitute home in Seebara): support for 25–30 children annually including food, education, and welfare

Figure 3: *Smart Classrooms, Computer education, and school bus services supporting rural education.*

4. Water Security and Sanitation: Essential Infrastructure for Life

4.1 Drinking Water: Reverse Osmosis Plants and Pipelines

Water security is critical in semi-arid Chitradurga District experiencing increased rainfall variability and groundwater stress. John Mine has established six operational RO (Reverse Osmosis) treatment plants with complementary pipeline networks:


RO Drinking Water Facilities: Coverage & Impact

RO Facility Location	Capacity (LPH)	Villages / Institutions Served	Households / Beneficiaries Served	Operational Since	Operational Since
Tanigehalli	1,000 LPH	Tanigehalli	800 households	2013 - Ongoing	2013 – Ongoing
Kagalagere	1,000 LPH	Kagalagere	600 households	2013 - Ongoing	2013 – Ongoing
B. Durga	1,000 LPH	B. Durga	400 households	2017 - Ongoing	2017 – Ongoing
D. Medikeripura	1,000 LPH	D. Medikeripura	1,200 households	2012 - Ongoing	2012 – Ongoing
Mutugaduru AK Hatti	500 LPH	Mutugaduru	500 households	2025 - 2026	2025 – 2026
Sasalu	250 LPH	Sasalu Community Health Centre	Multiple beneficiaries	2024 - 2025	2024 – 2025
KGF	250 LPH	School of Mines, KGF		2024 - 2025	2024 – 2025

Details of RO Drinking Water Facilities Established and Maintained for Rural Communities and Institutions

Figure 4- *Village-wise Reverse Osmosis (RO) Drinking Water Facilities Established under CSR Initiatives.*

Note: In addition to the above, small and compact RO plants have been donated to schools and government offices.

Additional Infrastructure:

- Underground water storage tank (2.0 lakh liter capacity at Kadlegudda)
- Mini storage tanks at D. Medikeripura (2023–2024)
- RO filter installed at Sasalu Railway Station (2023–2024)
- Water pipeline distribution networks spanning 7+ villages (Megalahalli, Kadleguddu, Nayakarahatti)

Impact Metrics:

- Beneficiary population: 4,500+ individuals
- Families benefited: 1,500+ over ten-year operation period
- Water quality standards: WHO-compliant, quarterly monitoring

- Community management model: Nominal user charges ensuring financial sustainability and community ownership
- Annual maintenance investment: ₹5+ lakhs for operational sustainability

4.2 Sanitation and Open Defecation Free (ODF) Initiatives

Under alignment with the national Swachh Bharat Mission, John Mine has constructed:

Individual Household Toilets: 367 household toilets in D. Medikeripura (achieving ODF status 2015); estimated 500+ household toilets across operational villages employing two-pit pour-flush technology with proper waste management and user behavior change communication.

Institutional Sanitation Facilities: Government schools: D. Medikeripura, Megalahalli, Tanigehalli, Kagalagere, Chikkenahalli, Alagawadi, Chitradurga, B. Durga, Hireguntanuru, Health centers: Muttugaduru. Etc...

Behavior Change Communication:

- Every year Swachhata Pakhwada Celebrations in Schools and mine.
- Hygiene awareness workshops across villages.
- Menstrual hygiene kit distribution to school girls.
- Personal hygiene training emphasizing handwashing and waste segregation.

4.3 Watershed Development and Water Conservation

Recognizing mining-induced hydrological stress, John Mine has undertaken:

- De-silting of water tanks at D. Medikeripura, Megalahalli, Sirigere, Shantivana, and Megalahalli villages (desilting of Megalahalli Lake repeated 2023–2024)
- Construction of check dams and water harvesting structures
- Groundwater recharge pit development
- Collaborative efforts with District Water Resource Department
- Utility tank construction at Hireguntanuru

Figure 5: *RO drinking water plants, lake desilting activities, and Swachhata Pakhwada celebrations.*

5. Infrastructure Development: Connectivity and Community Assets

5.1 Road and Internal Connectivity Networks

Between 2013 and 2024, over 12 km of concrete and asphalted road infrastructure has been developed across operational villages. Key interventions include 3.2 km of concrete roads at D. Medikeripura, 2.8 km at Megalahalli, 2.1 km at Muthugaduru, and 1.8 km at Tanigehalli. In addition, asphalted road networks were laid at Sasalu, while damaged stretches at Kadleguddu were repaired and re-asphalted during 2022–2023. A 190-meter drainage system was constructed at Hireguntanuru during 2023–2024. Collectively, these infrastructure investments have significantly improved agricultural produce transport, ensured timely emergency medical access, and enhanced overall commercial and social mobility within the region.

6. Environmental Stewardship and Biodiversity Conservation

6.1 Environmental Monitoring and Compliance

John Iron Ore Mine, is an ISO 9001:2015 (Quality Management), 14001:2015 (Environmental Management), 45001:2018 (Occupational Health & Safety), and SA 8000:2014 (Social Accountability) certified — commitment to operational excellence and responsible practices.

Wildlife-Railway Alert System Installation
An advanced alert system has been installed under our CSR initiative to prevent wildlife-railway accidents in the Londa Range, Belgaum.

6.2 Zoo Adoption and Wildlife Conservation

- **Cumulative Zoo Support:** Three-year comprehensive adoption and welfare support extended to all animals at Adumalleshwara Mini Zoo, Chitradurga, covering nutrition, healthcare, habitat maintenance, and visitor facility improvements.
- **Hospital Construction:** Medical facilities for zoo animals constructed and maintained.
- **Environmental Education:** Awareness programs on bird species and environmental protection distributed to schools.

- **Construction of Visitor pathway** with interlocking pavers and kerb stones at Adumalleshwara Mini Zoo, Jogimatti, Chitradurga.

Figure 6: *Asphalted roads, classroom construction, and visitor pathway development at Chitradurga.*

Conclusion

John Iron Ore Mine demonstrates that mining, when implemented with a strong CSR foundation and environmental stewardship, can be both economically viable and socially transformative. Over a period of time the mine has established and sustained a comprehensive set of CSR programs in health, education, water and sanitation, infrastructure, and environment, thereby positively impacting the lives of thousands of people.

The Mobile Health Clinic and Ambulance services have improved health access and outcomes for vulnerable populations. Educational infrastructure, digital learning tools, and scholarship programmes have opened pathways to better opportunities for rural children and youth. RO plants, sanitation facilities, and watershed interventions have enhanced water security and hygiene. Road networks and community assets have strengthened local connectivity and public services. Afforestation, zoo adoption, and wildlife-safety initiatives have contributed to biodiversity conservation and environmental awareness.

The mine's performance is validated by its sustained 5-Star Rating, IMS certifications, and recognition from district authorities and communities. As India advances towards *Viksit

Bharat by 2047* and SDG targets, such integrated models of CSR in mining offer an important blueprint for aligning resource extraction with inclusive development, environmental resilience, and long-term social license to operate.

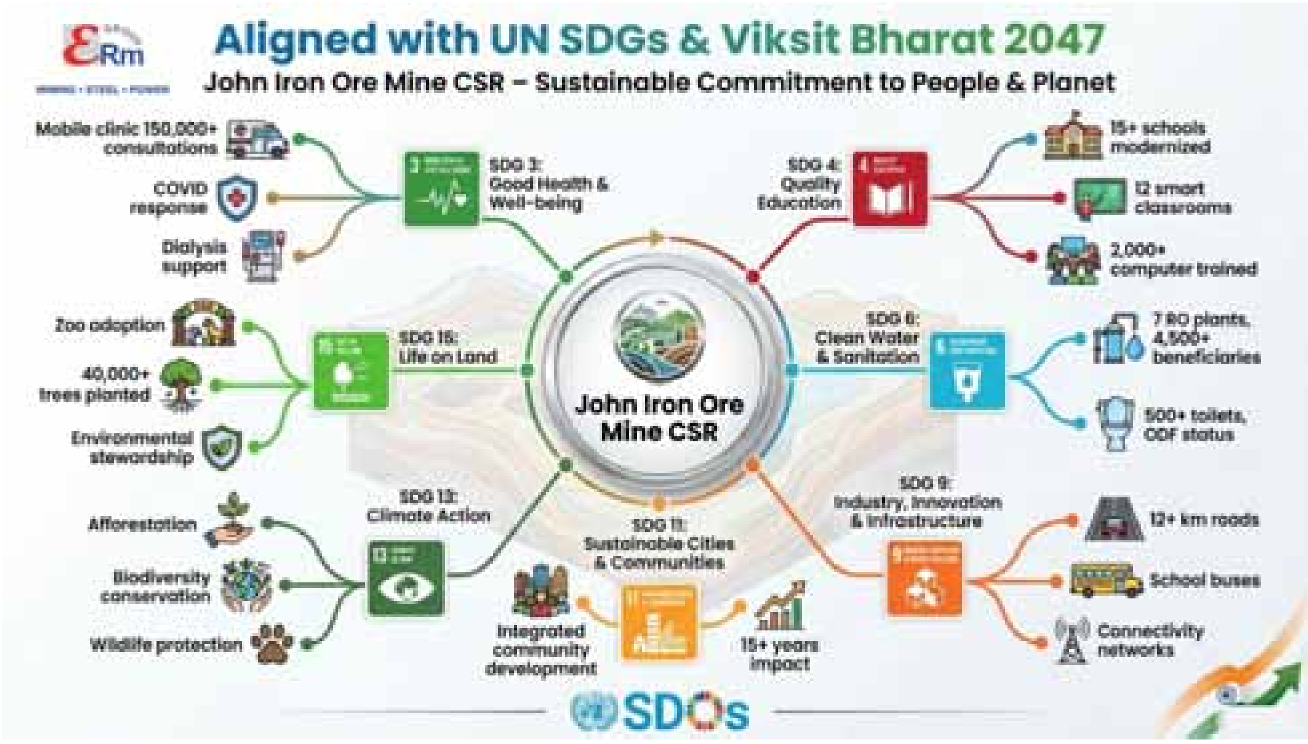

Figure 7: *John Iron Ore Mine CSR initiatives aligned with UN SDGs.*

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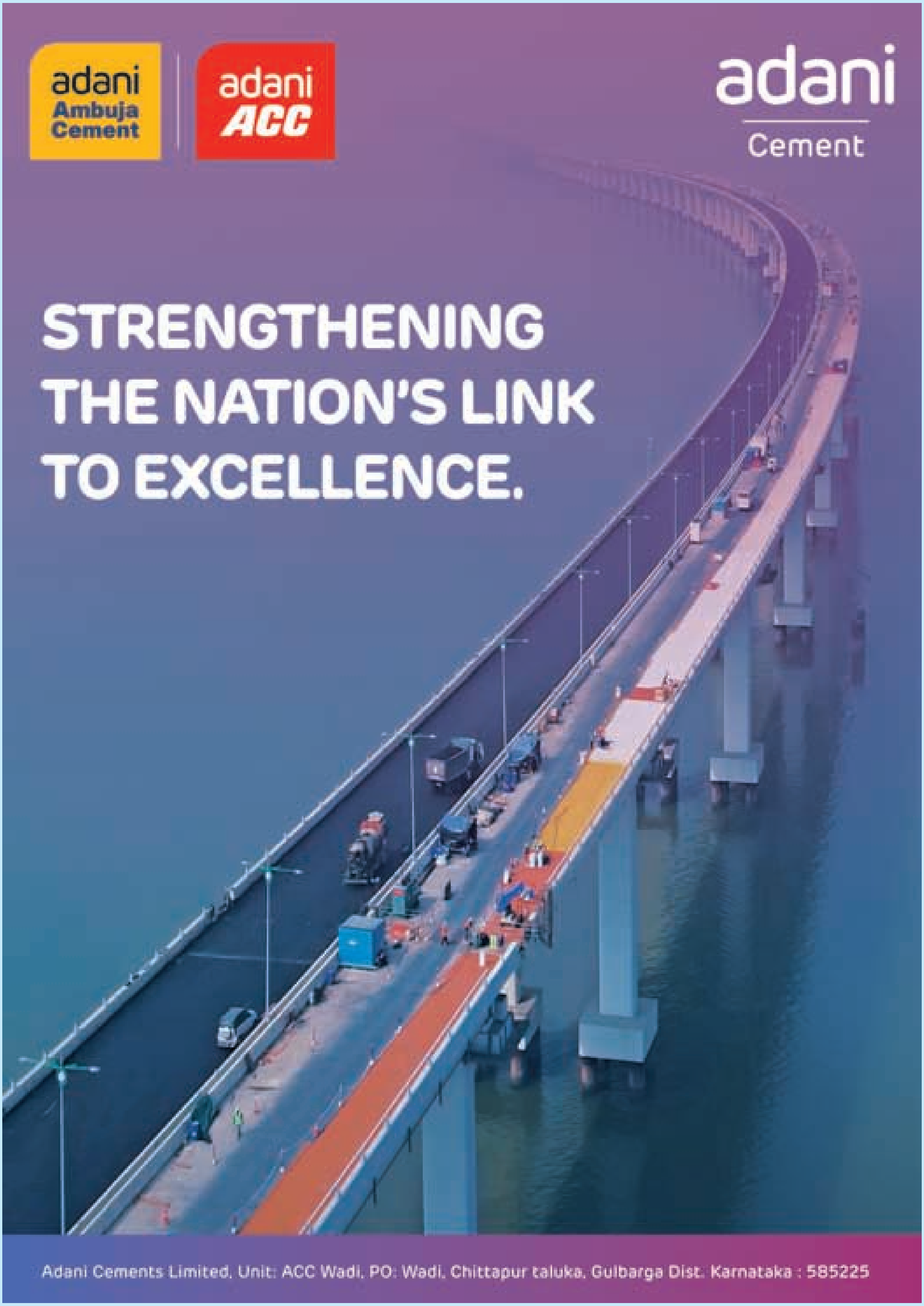
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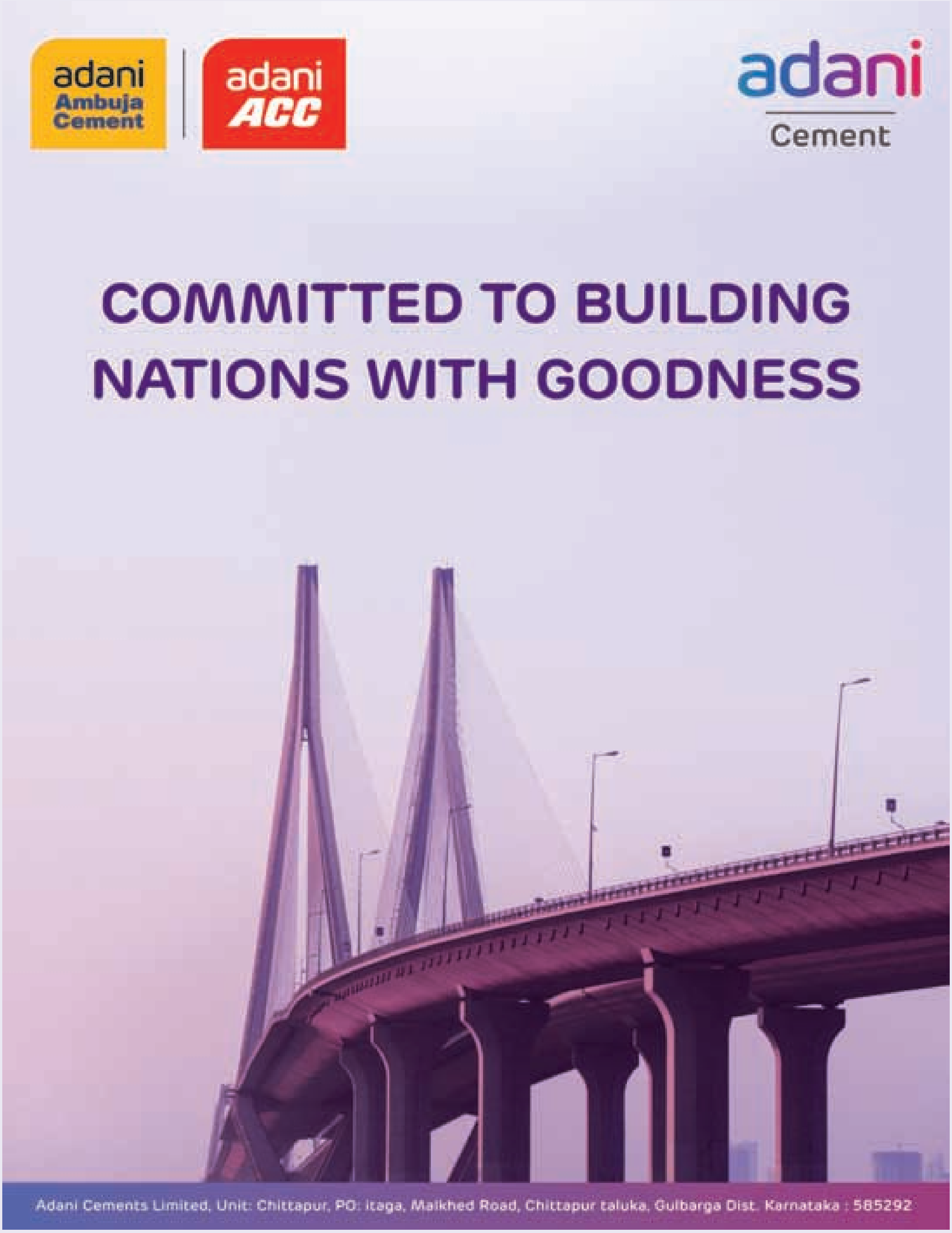
Kallur Limestone Mine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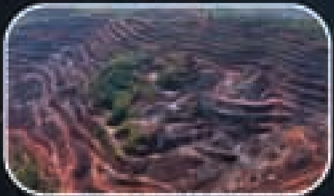
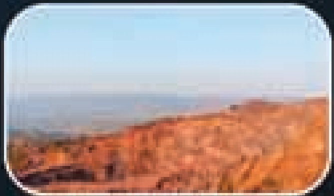
Iron Ore · Magnesite · Dunite · Chlorite · Limestone · China Clay · Titaniferous Magnetite · Quartz · Feldspar · Dolomite · Soap Stone · Bauxite

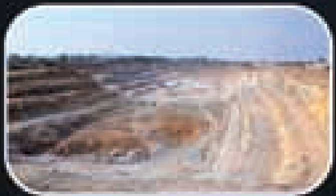


Subbarayanahalli Iron ore Mine, Sandur



Thimmappanagudi Iron ore Mine, Sandur

Karya Magnesite Mine, Mysore



Neerlakere Dolomite Mine, Bagalkot

Nandhihalli Clay Mine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