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Sustainable mining practices and mitigation strategic at Pachami Stone Field area: A Road Map for Future Development

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Abstract

Sustainable mining seeks to balance mineral extraction with environmental protection, social equity, and economic growth to meet present needs without compromising future generations. In India, stone and aggregate mining supports infrastructure but often causes land degradation, dust pollution, groundwater depletion, and biodiversity loss. Traditional practices of uncontrolled blasting, open dumping of overburden, and poor mine closure have intensified these impacts. These abstract highlights a paradigm shift toward "responsible extraction" guided by science, technology, and policy. Sustainable thinking begins with proper sitting and cluster-based mining to minimize scattered pits and land disturbance. Advanced practices include wet drilling, fog cannons, covered conveyors, and green belts to control particulate matter. Controlled blasting with electronic detonators reduces noise and vibration, while garland drains and siltation ponds prevent water pollution. Importantly, zero-waste models convert overburden and stone dust into M-sand, bricks, and construction fill, aligning mining with circular economy principles.

Keywords: *Sustainable mining, Environmental protection, Biodiversity, Green belts, Technology, Policy.*

1. Introduction

Sustainable mining is an approach to extracting minerals and resources that balances economic development with environmental protection and social responsibility. As the world increasingly recognizes the need for responsible resource management, sustainable mining has become a critical concept in the industry. The goal of sustainable mining is to minimize the negative impacts of mining on the environment, conserve natural resources, and benefit local communities. This involves adopting innovative technologies, reducing waste and pollution, and promoting transparency and accountability throughout the mining process.

What are the Sustainable Development Goals?

The Sustainable Development Goals (SDGs), also known as the Global Goals, were adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity.

The 17 SDGs are integrated—they recognize that action in one area will affect outcomes in others, and that development must balance social, economic and environmental sustainability.

Countries have committed to prioritize progress for those who're furthest behind. The SDGs are designed to end poverty, hunger, AIDS, and discrimination against women and girls.

The creativity, knowhow, technology and financial resources from all of society is necessary to achieve the SDGs in every context.

(Sources: https://commons.wikimedia.org/wiki/File:Sustainable_Development_Goals.png)

Definitions of Sustainable Mining: Sustainable mining is about finding a better balance – getting the minerals we need while protecting the environment, supporting local communities, and keeping the industry economically viable. It recognizes that mining plays a key role in developing technology and infrastructure, but also that the way we mine needs to evolve. The focus is shifting away from purely extraction-driven models toward ones that consider the health of ecosystems and communities throughout the entire mining process.

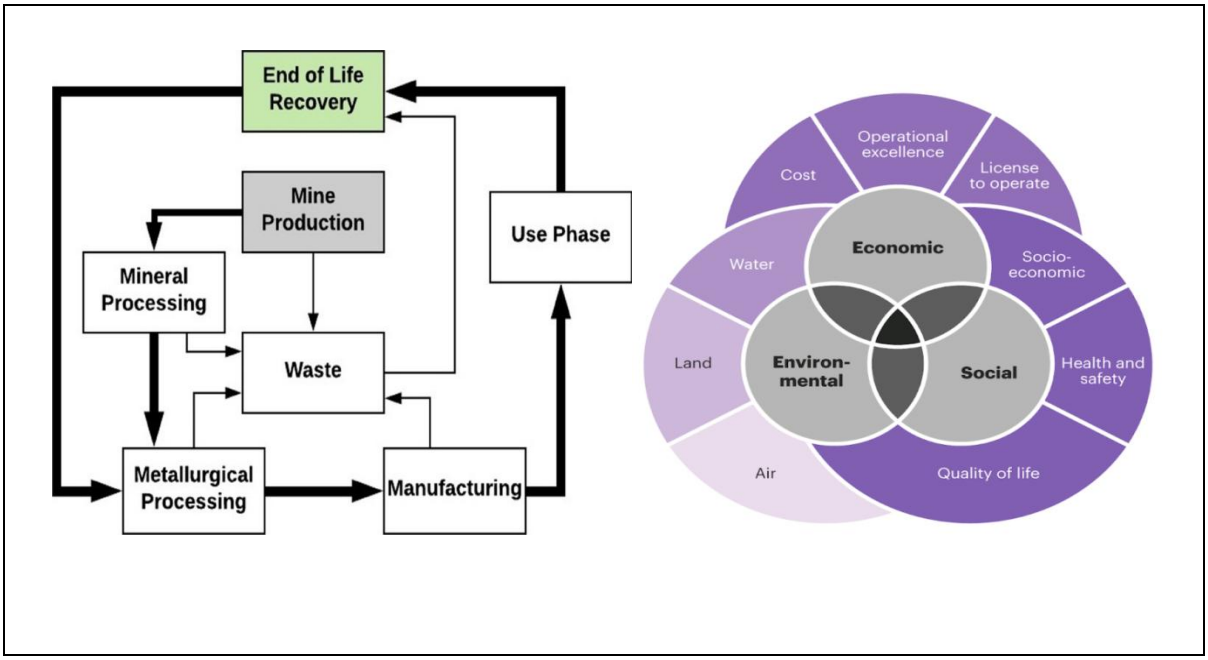

Fig 1: Mining cycle

Recent academic research, including a comprehensive 2025 review published in the Journal of Environmental Management, shows that sustainable mining is no longer a static concept. Instead, it has evolved through distinct phases, shaped by regulation, technological advancement, societal expectations, and the growing urgency of climate change. (Sources: December 15, 2025 / triple bottom line / By SLSV / Leave a Comment).

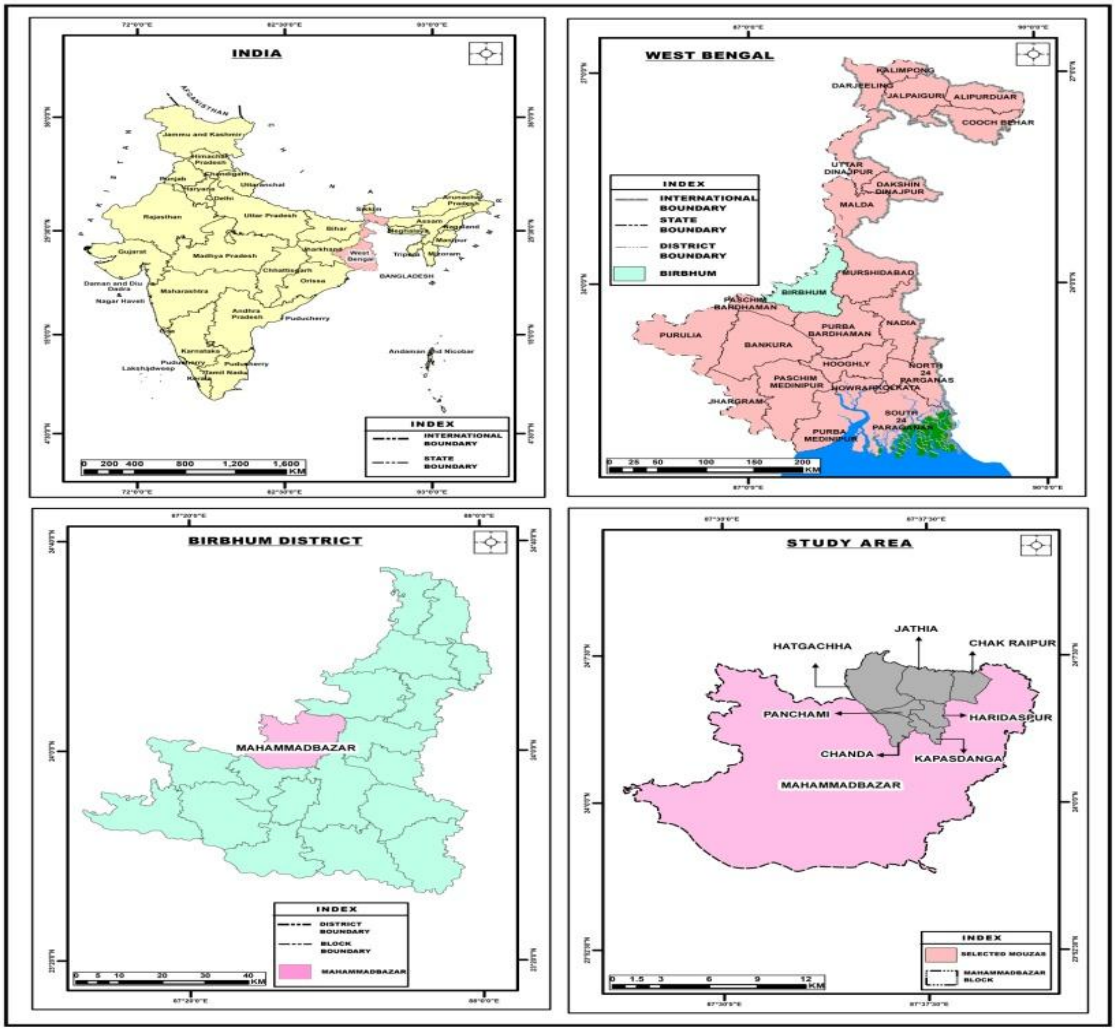

Figure – 2. Location map of the study area

2. Research objectives:

The object of the present research entitled "Sustainable mining practices and mitigation strategic at Pachami Stone Field area: A Road Map for Future Development. Md Bazar, Birbhuum." are the followings:

- To identify and assess socio-economic activities which are significantly influenced by mining activities.
- To examine local communities perceptions on how mining activities impact the environment.
- To suggest interventions that can assist in mitigating the negative impacts of mining.

3. Database & Methodology

The current research has employed both primary and secondary data. The main data were gathered using a structured questionnaire, a schedule, in-depth interviewing, case studies, and observation. Qualitative and quantitative data have been gathered using scheduled questionnaires and through interviews. Certain case studies have been gathered from participants, including an eye injury, housing issues, and a stone quarry worker. The purposive sampling technique has been utilized to select the subject of study. Photographic techniques were employed to gather information regarding the environmental conditions and to document their living patterns as well. In certain instances of data gathering, the telephonic approach has been utilized to obtain pertinent information related to this study from the participants. The secondary data were gathered from social media, journals, books, etc. All the data have been analyzed using Microsoft Office Excel.

4. Analysis & Discussion

Stone mining in India primarily utilizes open-cast methods, ranging from manual labor to semi-mechanized and mechanized techniques, particularly for dimensional stones like granite, marble, and sandstone. Key techniques include benching, drilling, and controlled blasting, or modern sawing with diamond wire saws to reduce wastage and increase productivity.

Figure 3. Opencast mining

Key Stone Mining Methods in India:

- **Opencast/Quarrying Method:** The dominant method for dimensional stones (marble, granite, Kota stone) and masonry stones, where the rock is exposed by removing overburden.
- **Controlled Blasting:** Used to loosen rock, particularly in hard stone mining (like granite or road metal) to minimize damages to the stone and surrounding environment.
- **Diamond Wire Sawing & Block Extraction**: Modern technique increasingly used for high-value dimension stone mining (granite, marble) to cut large blocks, improving yield and efficiency.
- **Drilling and Splitting**: A non-explosive method used for weaker or laminar rocks like slate and certain sandstones, using pneumatic tools, hammers, and chisels.
- **Riverbed Mining:** Collection of stones and gravel from riverbanks using excavators and manual tools.

Prevention of Environmental Degradation at Stone Mining in India

Stone mining is vital for construction and infrastructure in India, but it often leads to air pollution, land degradation, water depletion, and loss of biodiversity. Here's how it can be made more sustainable:

Key Environmental Impacts

1. **Dust & Air Pollution**: Crushing and blasting release PM2.5/PM10, causing respiratory issues.
2. **Land Degradation**: Open-pit mining creates barren pits and unstable slopes.
3. **Water Issues**: Depletes groundwater and pollutes surface water with silt.
4. **Noise & Vibration**: Blasting affects nearby villages and wildlife.
5. **Loss of Biodiversity**: Forest cover and habitats are cleared.

Fig 4 ; Heavy-Duty Trucks are major Pollution Sources.

6. Heavy-Duty Trucks: Heavy-duty vehicles (HDVs) are major pollution sources, accounting for over 40% of on-road nitrogen oxides (NOX) and 60% of particulate matter (PM2.5) emissions, despite comprising a small percentage of total vehicles. They cause severe cardiovascular and respiratory diseases, with older vehicles—particularly in India—acting as "super-emitters" creating up to 11 times more pollution.

Prevention & Mitigation Measures

Area	Measures
Air & Dust	Wet drilling, water sprinklers on haul roads, covered conveyor belts, green belt around mines
Land	Scientific mine closure plans, backfilling mined areas, bench plantation, terracing slopes
Water	Garland drains + siltation ponds, zero discharge policy, rainwater harvesting in pits
Noise	Controlled blasting with delay detonators, noise barriers, PPE for workers
Biodiversity	Wildlife corridors, compensatory afforesEtation, avoid mining in eco-sensitive zones
Waste	Use overburden for construction, stone dust for bricks/tiles, M-sand production

Regulatory Framework in India

1. MoEFCC Guidelines: EIA clearance mandatory for mining leases >5 hectares under EIA Notification 2006.
2. Sustainable Sand Mining Guidelines 2016 & 2020: Restrict mechanized mining, enforce replenishment studies.
3. DGMS Rules: Safety and dust control norms for workers.
4. District Survey Report: Must be prepared before granting leases to prevent illegal mining.

Sustainable Thinking for Future Stone Mining in Pachami Stone Field area

Stone mining is the backbone of India's infrastructure push—roads, railways, housing, and smart cities all depend on aggregates. But the traditional "dig-and-leave" model has left behind scarred landscapes, dust-filled villages, and depleted water tables. Future stone mining must shift from extraction to stewardship. That means thinking in three timeframes at once: present operations, closure, and post-mining land use.

The Pachami Stone Industrial Zone is one of West Bengal's premier stone-processing hubs. Established in the early 1960s, this industrial zone remains renowned for the quality of its products to this day; however, over time, it has failed to achieve commensurate progress, and various infrastructural deficiencies remain evident even now. A primary reason for this stagnation is a lack of government support. Currently, various private organizations are striving to develop an eco-friendly industrial zone by utilizing state-of-the-art machinery and technology, with the aim of fostering a sustainable and environmentally conscious industrial hub for the future.

Road Map for Future Development:

1. Planning Before the First Blast

Sustainability starts with siting. Future leases should avoid eco-sensitive zones, wildlife corridors, and groundwater recharge areas. District Survey Reports must use LiDAR and satellite data to map reserves accurately, preventing haphazard, scattered pits. Cluster-based mining, already promoted in Rajasthan and Karnataka, reduces footprint by concentrating operations and sharing infrastructure like roads, crushers, and green belts. Pre-mining baseline studies of air, water, soil, and biodiversity should be mandatory and publicly available.

2. Clean Technology on Site

Dust is the most visible impact. Future mines need wet drilling, fog cannons, covered conveyors, and wind-break plantations instead of open haul roads. Electric or LNG-powered excavators and trucks can cut diesel emissions and noise. Controlled blasting with electronic delay detonators reduces flyrock and vibration by 60-70%. Real-time IoT sensors for PM10, noise,

and vibration should feed data to SPCB dashboards, enabling instant penalties for violations. Water use must move to zero-discharge: garland drains with silt traps, pit water for dust suppression, and rainwater harvesting to recharge aquifers.

3. Circular Use of Waste

Overburden and stone dust are not waste—they're resources. Future policy should mandate 100% utilization: overburden for embankments, stone dust for M-sand, bricks, and ceramics, and even as a soil conditioner in agriculture. This aligns with India's circular economy goals and cuts illegal river sand mining. Mobile processing units can turn waste into value right at the quarry.

4. People and Livelihoods

Sustainable mining is also social. District Mineral Foundation funds must focus on health camps for silicosis screening, skilling local youth as drone operators or EHS technicians, and creating alternative livelihoods like agroforestry on reclaimed land. Transparent community monitoring committees build trust and reduce conflict.

5. Mine Closure as Land Creation

The biggest mindset shift: a mine is a temporary land use. Every mine plan should include a detailed closure blueprint—whether it becomes a water reservoir, biodiversity park, solar farm, or terraced farmland. Progressive reclamation, not end-of-life backfilling, should be the norm. Backfill benches with overburden, add topsoil, and plant native species while mining continues in other benches. This cuts costs and ensures land is usable from day one after closure.

6. Governance and Finance

Future sustainability needs teeth. Satellite surveillance and drone surveys every quarter can check for lease violations. Green bonds or ESG-linked credit can reward companies that exceed compliance. Star Rating of Mines by IBM should factor in water positivity and carbon reduction, not just production.

5. Conclusion

Future stone mining in India must be restorative, not extractive. If we mine with a closure mindset, treat waste as wealth, and put communities at the center, stone can literally become the foundation of a green economy. The goal is simple: when a mine ends, the land should be healthier, the water richer, and the community stronger than before it began.

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