IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

DUST AND NOISE POLLUTION IN OPENCAST COAL MINING: A SYSTEMATIC REVIEW OF CONTROL TECHNOLOGIES, ENVIRONMENTAL IMPACTS, AND RECLAMATION STRATEGIES IN INDIA

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Abstract: Opencast coal mining plays a crucial role in meeting India's growing energy demand, contributing more than 70% of domestic coal production. Despite its economic importance, opencast mining generates substantial environmental challenges, particularly dust and noise pollution, which adversely affect ecosystems, mine workers, and nearby communities. Dust emissions originate from drilling, blasting, excavation, haul road transportation, crushing, and coal handling operations, while noise pollution arises from heavy machinery, blasting activities, transportation systems, and processing plants. The cumulative effects of these pollutants include respiratory diseases, hearing impairment, ecological degradation, reduced agricultural productivity, and deterioration of community well-being. This systematic review critically examines the current state of knowledge regarding dust and noise pollution in Indian opencast coal mines, evaluates existing control technologies, and assesses reclamation strategies aimed at environmental restoration. Literature published between 2010 and 2026 was systematically reviewed using major scientific databases and government reports following PRISMA guidelines. The review identifies water spraying systems, chemical dust suppressants, green belts, enclosure technologies, acoustic barriers, equipment maintenance, and controlled blasting as the most widely implemented mitigation approaches. However, their effectiveness varies considerably under Indian climatic and operational conditions. The study further highlights successful reclamation initiatives undertaken by Coal India Limited (CIL) and Singareni Collieries Company Limited (SCCL), emphasizing afforestation, mine spoil stabilization, and ecosystem restoration. Regulatory frameworks established by the Ministry of Environment, Forest and Climate Change (MoEFCC), Directorate General of Mines Safety (DGMS), and Central Pollution Control Board (CPCB) have improved environmental management but face implementation challenges. The review concludes by identifying technological gaps, recommending AI-enabled monitoring systems, and advocating integrated environmental management approaches for sustainable mining practices in India.

***Keywords* -** Opencast coal mining, dust pollution, noise pollution, environmental impacts, mine reclamation, sustainable mining, Coal India Limited, environmental management

I. INTRODUCTION

India's reliance on coal to meet over 55% of its energy demand continues to drive the rapid expansion of opencast mining operations, the resulting degradation of local air and acoustic environments has emerged as a critical sustainability challenge (Kaushik, Jade and Patel, 2026; Yadav and Chaurasia, 2025; Yadav and Chaurasia, 2025a). These mining activities, characterized by intensive drilling, blasting, and mechanical transportation, significantly elevate the concentration of suspended particulate matter and respirable dust beyond permissible national limits (Ghose and Majee, 2001; Yadav et al., 2025; Tiwari et al., 2025; Tiwari et al., 2025a; Giri and Chaurasia, 2025). Such elevated concentrations of coal fines and benzene-soluble matter not only pose severe respiratory risks to mine personnel but also degrade the ecological integrity of surrounding habitats (Ghose, 2002; Yadav and Jamal, 2016; Mansoori and Chaurasia, 2025). Furthermore, the pervasive nature of particulate matter, where PM10 often constitutes up to half of the total generated dust, necessitates a rigorous examination of the correlation between mining-induced air pollution and chronic cardiovascular or respiratory pathologies among nearby communities (Dominici et al., 2015). Beyond these health implications, the environmental footprint is compounded by noise pollution from heavy machinery and explosive operations, which disrupts local biodiversity and challenges the socio-economic well-being of peripheral rural and tribal settlements (Mishra and Das, 2017; Mansoori and Chaurasia, 2025; Singh, Chaurasia and Beg, 2025). Consequently, the cumulative impact of these disturbances often leads to the degradation of agricultural productivity, displacement of indigenous populations, and the permanent alteration of local landscapes (Mukherjee and Pahari, 2019; Yadav and Chaurasia, 2025a).

To address these environmental externalities, various operational sources such as dragline maneuvers, haulage transport, and coal processing activities must be systematically mitigated through advanced suppression technologies (Chabukdhara and Singh, 2016; Raidas and Chaurasia, 2025; Giri and Chaurasia, 2025). While traditional manual water sprinkling remains the standard intervention, its efficacy is frequently compromised by operational inefficiencies and excessive water consumption (Panicker et al., 2023). Recent developments advocate for a transition toward integrated dust management strategies, which incorporate advanced dust extraction systems, chemical suppressants, and automated wet drilling technologies to enhance operational sustainability (Kumar, 2020; Tiwari, 2026; Singh et al., 2024). Moreover, current research underscores the necessity of implementing digital modeling and soft computing frameworks to optimize blast designs, thereby reducing excessive air overpressure and fly rock alongside particulate emissions (Patel et al., 2026; Singh et al., 2024; Sahu and Chaurasia, 2025; Tiwari et al., 2025; Tiwari and Chaurasia, 2026).

Coal remains the backbone of India's energy sector, accounting for nearly 55–60% of electricity generation. India is the world's second-largest coal producer, with production exceeding one billion tonnes annually. Major coal-producing regions include Jharkhand, Odisha, Chhattisgarh, Madhya Pradesh, Telangana, and West Bengal. In addition to conventional coal utilization, Indian coalfields possess significant potential for coalbed methane (CBM), hydrocarbon generation, and other forms of coal-derived energy. For example, investigations of the Raniganj Coalfield have demonstrated its potential for CBM exploitation and hydrocarbon generation, highlighting the complex resource characteristics of Indian coal-bearing basins (Panwar et al., 2017; Panwar et al., 2020; Panwar et al., 2021; Panwar et al., 2021; Panwar et al., 2022). Geochemical investigations have further demonstrated that coal properties, thermal maturity, maceral composition, and depositional conditions play an important role in determining hydrocarbon-generation potential (Panwar et al., 2021; Nath et al., 2023a, 2023b). These studies demonstrate that Indian coalfields represent complex energy-resource systems in which extraction, utilization, environmental management, and resource conservation must be considered together. Approximately 90% of India's coal is extracted through opencast mining due to its economic advantages and higher recovery rates (Yadav and Chaurasia, 2025). However, opencast mining operations significantly alter natural landscapes and generate substantial environmental pollution. Among the various environmental concerns, dust and noise pollution are the most pervasive and persistent challenges affecting workers, local communities, and ecosystems (Mansoori and Chaurasia, 2025; Singh, Chaurasia and Beg, 2025). Particulate matter generated during mining activities contributes to air quality deterioration, while continuous exposure to elevated noise levels impacts human health and wildlife. Several studies conducted in Indian coalfields such as Jharia, Raniganj, Talcher, Korba, and Singrauli have reported particulate concentrations and noise levels exceeding prescribed regulatory limits. India's commitment to sustainable development and environmental protection necessitates effective pollution management strategies. Consequently, understanding the effectiveness of existing mitigation technologies and reclamation practices has become increasingly important (Bisen et al., 2025; Bisen and Chaurasia, 2026).

The review focuses primarily on Indian opencast coal mines while incorporating relevant international studies for comparative analysis. Emphasis is placed on environmental impacts, mitigation technologies, regulatory frameworks, and reclamation practices implemented between 2010 and 2026 (Singh et al., 2024; Bisen et al., 2025; Bisen and Chaurasia, 2026; Chourasiya and Chaurasia, 2026; Chourasiya and Chaurasia, 2026a; Daharwal and Chaurasia, 2026; Ravi Singh and Chaurasia, 2025; Ravi Singh and Chaurasia, 2025a; Patel and Chaurasia, 2025; Patel and Chaurasia, 2025a; Tripathi and Chaurasia, 2025; Tripathi and Chaurasia, 2025a).

2. Methodology

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure transparency, reproducibility, and methodological rigor. The PRISMA framework provides a standardized approach for identifying, screening, and synthesizing evidence, which is particularly valuable for environmental science and mining impact studies where data sources are diverse and often interdisciplinary. A comprehensive search strategy was developed to capture relevant literature on dust and noise pollution, control technologies, environmental impacts, and reclamation strategies in Indian opencast coal mining. Electronic databases searched included Scopus, Web of Science (Core Collection), Google Scholar, ScienceDirect, and PubMed. Additionally, grey literature and official repositories were explored, such as the Ministry of Environment, Forest and Climate Change (MoEFCC), Directorate General of Mines Safety (DGMS), Coal India Limited (CIL) annual reports and sustainability documents, Singareni Collieries Company Limited (SCCL) publications, and Central Mine Planning & Design Institute (CMPDI) technical reports. These sources were chosen for their comprehensive coverage of peer-reviewed research and India-specific policy and operational data.

The search was performed between January and June 2026 using Boolean operators and a combination of keywords and phrases: (“opencast coal mining” OR “open cast mining” OR “surface coal mining”) AND (India OR Indian coalfields) AND (“dust pollution” OR “particulate matter” OR PM10 OR PM2.5 OR “fugitive dust”) AND/OR (“noise pollution” OR “noise levels” OR “occupational noise”) AND (“control technologies” OR “mitigation measures” OR “suppression” OR “reclamation” OR “restoration” OR “mine closure”). Variations such as “Jharia,” “Raniganj,” “Korba,” “Talcher,” “HEMM,” “overburden,” and specific technologies (e.g., “fog cannon,” “wet drilling,” “biological reclamation”) were also included to broaden retrieval.
The screening process followed a multi-stage approach. Initial database searches yielded approximately 850 records. After removing duplicates (using EndNote and manual verification), 620 unique records remained. Title and abstract screening eliminated clearly irrelevant items, reducing the pool to around 280 records. Full-text assessment was conducted on 180 articles/reports, resulting in 112 studies finally

included for qualitative synthesis. A PRISMA flow diagram (typically presented as Figure 1 in published versions) would illustrate: Identification (n ≈ 850), Screening (n ≈ 620 after duplicates), Eligibility (n ≈ 180 full-text reviewed), and Included (n = 112). Reasons for exclusion at the full-text stage included insufficient India-specific data, lack of focus on dust/noise, or poor methodological quality.

Data extraction was performed using a standardized form capturing study characteristics (author, year, location, design), key findings on pollutant levels, technology effectiveness, impacts, reclamation outcomes, and limitations. Quality appraisal was conducted using adapted tools such as the Joanna Briggs Institute (JBI) checklists for observational and review studies and the MMAT (Mixed Methods Appraisal Tool) where applicable, evaluating aspects like sampling, measurement validity, and bias risk. Synthesis was primarily narrative and thematic, organized by the major sections of the review, with quantitative summaries (e.g., ranges of PM concentrations, noise levels, dust reduction percentages) presented where data permitted. Tabular summaries were used for comparing control technologies and reclamation case studies.

3. Dust Pollution in Opencast Coal Mining

Sources and Generation Mechanisms Opencast coal mining generates substantial fugitive dust due to large exposed surfaces and intensive mechanical operations. Primary sources include drilling, blasting, excavation by heavy earth moving machinery (HEMM) such as excavators and dozers, haul road traffic, coal crushing and screening, loading/unloading activities, and wind erosion from overburden dumps and stockpiles. Vehicular movement on unpaved haul roads can contribute up to 80% of total dust emissions in some operations. Unlike underground mining, opencast methods expose vast areas, making dust generation significantly higher, especially in dry seasons prevalent in Indian coalfields.

Environmental and Health Impacts (Especially in India) In major Indian coalfields like Jharia (Jharkhand), Talcher (Odisha), and Korba (Chhattisgarh), dust levels frequently exceed national standards. Concentrations of suspended particulate matter (SPM), PM_{10}, and $PM_{2.5}$ often range from 294–965 μg/m³, 100–498 μg/m³, and 85–296 μg/m³ respectively in active mining zones. Dust deposition on vegetation reduces photosynthetic efficiency by impairing stomatal function and blocking light, leading to 10–20% lower CO_2 absorption. This affects forest health, crop yields, and biodiversity in surrounding areas.
Health impacts are severe. Workers face risks of coal workers' pneumoconiosis (black lung disease), silicosis, and respiratory illnesses. Communities experience higher incidences of cardiovascular diseases, asthma, and eye irritation. Dust also contaminates soil and water bodies, affecting agriculture and local livelihoods in densely populated mining regions.

Current Control Technologies and Their Effectiveness India has implemented various dust suppression measures, led by Coal India Limited (CIL) and its subsidiaries. Wet suppression systems, including fixed and mobile water sprinklers and fog cannons (mist cannons), are widely used and can achieve 50–95% dust reduction when properly maintained. Fog cannons project fine mist up to 40–100 meters, effectively capturing airborne particles with minimal water use. Other technologies include wet drilling, surface miners (which reduce dust at source), chemical dust suppressants, wind barriers, and tarpaulin-covered trucks on black-topped haul roads. Effectiveness varies with climate, maintenance, and integration. Monsoon rains provide natural suppression, but dry periods demand intensive efforts. Progressive afforestation and green belts around mines also help trap dust. Despite progress, challenges like high water consumption in water-stressed areas and inconsistent enforcement limit overall impact.

Figure 1: Major Sources of Dust Generation and Primary Control Technologies in Opencast Coal Mines

4. Noise Pollution in Opencast Coal Mining

Sources and Characteristics Opencast coal mining is inherently noisy due to the extensive use of heavy earth moving machinery (HEMM) and blasting operations. Major sources include dozers, dumpers, excavators, drills, crushers, conveyors, and coal handling plants. Noise levels frequently range from 90–115 dB(A) or higher near operating equipment, with low-frequency components from diesel engines and machinery vibrations dominating the spectrum. Blasting produces impulsive noise peaks exceeding 120 dB(A). In Indian mines, haul road traffic and continuous operations amplify exposure, especially during peak production hours. Unlike steady industrial noise, mining noise is intermittent yet persistent, making it particularly intrusive.

Environmental and Health Impacts (with Indian Case Studies) Prolonged exposure to high noise causes Noise-Induced Hearing Loss (NIHL), tinnitus, hypertension, cardiovascular issues, stress, and sleep disturbances. Workers face elevated risks of occupational deafness, while nearby communities suffer communication interference, irritability, and reduced quality of life. In Talcher coalfield (Odisha), studies show blasting as the primary source, with 91% of households reporting severe noise-related problems including hearing impairment, mental disturbance, and structural damage to houses. In Jharia and Raniganj coalfields, persistent exposure affects both miners and residents, contributing to higher incidences of stress-related disorders and wildlife displacement. Fauna in surrounding forests experience behavioral changes, reduced breeding success, and habitat avoidance due to chronic noise.

Control Measures and Best Available Technologies India’s Directorate General of Mines Safety (DGMS) sets the permissible exposure limit at 90 dB(A) for an 8-hour shift, with a danger threshold of 115 dB(A) requiring mandatory hearing protection. Control strategies follow a hierarchy: engineering controls (acoustic enclosures, mufflers, vibration dampeners, and quieter equipment), administrative measures (job rotation, scheduling high-noise activities during less sensitive periods), and personal protective equipment (ear plugs and muffs). Wet drilling reduces both dust and noise. Advanced approaches include real-time noise mapping, predictive modeling, and community buffer zones. Controlled blasting techniques and maintenance of HEMM also help lower emissions. However, adoption of comprehensive noise mapping remains limited in many Indian mines despite DGMS mandates.

Figure 2: Typical Noise Levels from Key Equipment and Control Hierarchy in Opencast Coal Mines.

5. Reclamation Strategies and Mitigation Approaches in India

Reclamation of opencast coal mines in India is a critical component of sustainable mining practices, aimed at restoring ecological balance, land productivity, and community well-being after mining operations. It integrates technical, biological, and chemical approaches, supported by progressive reclamation during active mining phases.

Biological, Physical, and Chemical Reclamation Methods Technical (physical) reclamation forms the foundation and involves backfilling of mine voids with overburden material, contouring to stable slopes, and proper drainage design to prevent erosion. Topsoil management is crucial — stripping, stockpiling, and respreading fertile topsoil (typically 15–30 cm thick) enhances microbial activity and plant growth. Biological reclamation follows with afforestation using native and stress-tolerant species such as *Azadirachta indica*, *Dalbergia sissoo*, *Acacia nilotica*, and grasses like *Vetiveria zizanioides*. These species improve soil structure, control erosion, and enhance biodiversity. Chemical methods, though less common due to cost, include application of lime, gypsum, or organic amendments to neutralize acidic overburden and improve nutrient availability in degraded soils. Integrated approaches combining these methods yield better long-term success.

Successful Indian Case Studies Coal India Limited (CIL) and Singareni Collieries Company Limited (SCCL) have reclaimed thousands of hectares. CIL reported reclaiming over 12,000 hectares by 2025 through progressive and concurrent reclamation. Notable examples include the development of eco-parks and biodiversity zones. The Kothagudem opencast mine (SCCL, Telangana) transformed mined-out areas into lush green landscapes with recreational facilities, demonstrating successful community-oriented end-use. In Korba and Talcher coalfields, reclaimed lands now support plantations, water bodies, and agriculture, improving local livelihoods. Progressive reclamation — reclaiming mined-out areas while operations continue elsewhere — has become standard practice, reducing the backlog of unreclaimed land.

Policy and Regulatory Framework The regulatory backbone is provided by the Ministry of Environment, Forest and Climate Change (MoEFCC) through Environmental Impact Assessment (EIA) notifications (2006, amended) and the Environment Protection Act. Mine closure guidelines updated in 2020 emphasize sustainable end-uses such as forestry, agriculture, or water reservoirs. The Directorate General of Mines Safety (DGMS) mandates Environmental Management Plans (EMPs), regular monitoring, and financial assurance for reclamation. Coal companies must submit detailed mine closure plans with progressive and final reclamation schedules. Despite robust policies, challenges remain in implementation, monitoring, and community participation.

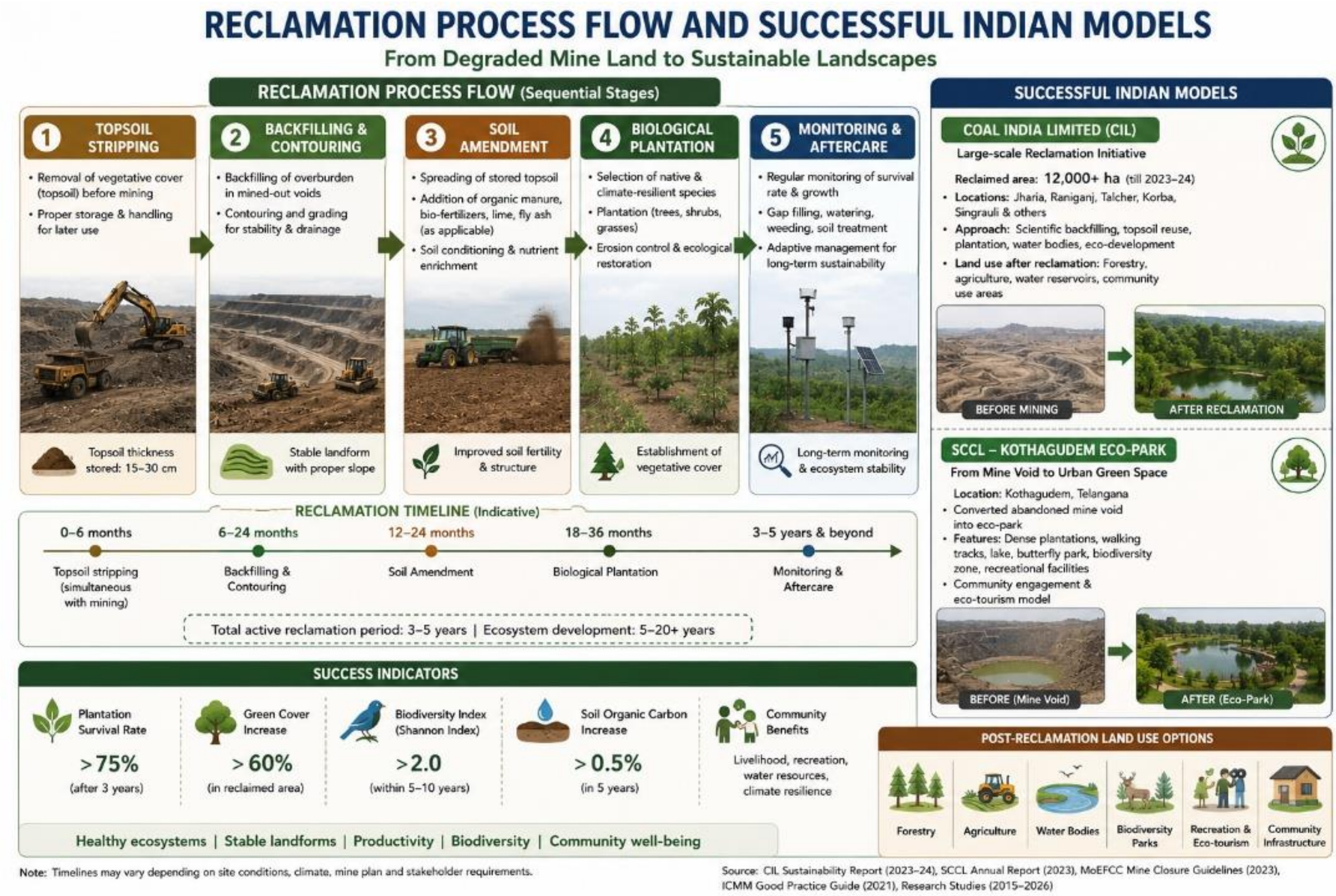

Figure 3: Reclamation Process Flow and Successful Indian Models.

6. Discussion

Despite notable progress in dust and noise management and reclamation practices, significant gaps persist in India's opencast coal mining sector. One major limitation is the limited large-scale adoption of advanced control technologies. While water sprinklers and fog cannons are widely deployed by Coal India Limited (CIL) and Singareni Collieries Company Limited (SCCL), many mines still rely on conventional methods that prove inadequate during peak dry seasons. Real-time monitoring systems using IoT sensors and AI-driven predictive analytics — common in Australian and US mines remain underutilized in India due to high initial costs and technical skill gaps. Site-specific challenges exacerbate these issues. The monsoon climate in eastern and central Indian coalfields (Jharia, Raniganj, Talcher, Korba) creates a dual problem: excessive water during rains leads to runoff and erosion of reclaimed areas, while prolonged dry periods intensify dust generation and strain water resources for suppression systems. Rugged terrain and high overburden ratios further complicate haul road maintenance and progressive reclamation. Enforcement inconsistencies between regulatory bodies (MoEFCC and DGMS) and operational priorities also hinder effective implementation. Many Environmental Management Plans (EMPs) remain on paper, with weak third-party audits and limited community oversight. Indian practices lag behind global best practices in integration and innovation. Australia employs automated dust suppression fleets and continuous noise mapping integrated with production planning, achieving consistent compliance below 85 dB(A). China has successfully scaled chemical suppressants and drone-based monitoring in large surface mines. In contrast, Indian efforts excel in cost-effective local adaptations, such as using native plant species for dust-trapping green belts and community-led nursery development for reclamation. However, synergistic impacts of dust and noise on public health and biodiversity are insufficiently studied. Combined exposure amplifies respiratory diseases and ecosystem degradation, yet longitudinal studies tracking these effects in Indian contexts are scarce. Balancing escalating production targets (India aims for 1.5 billion tonnes of coal annually) with environmental mitigation remains a core challenge amid resource constraints. Socio-economic pressures in mining-dependent regions often prioritize jobs over strict compliance. Publication bias toward successful case studies further masks ground realities. Future research should focus on low-water technologies, climate-resilient reclamation models, and socio-technical integration frameworks tailored to Indian conditions. Comparative studies with leading coal-producing nations could facilitate technology transfer while respecting local economic realities. Overall, while regulatory frameworks are robust, the translation into measurable on-ground outcomes requires stronger political will, capacity building, and multi-stakeholder collaboration.

7. Conclusion and Recommendations

Opencast coal mining remains vital for India's energy security but continues to generate substantial dust and noise pollution with far-reaching environmental and health consequences. This systematic review highlights that while source-level controls (wet suppression, surface miners) and progressive reclamation strategies have demonstrated effectiveness, implementation gaps, climatic challenges, and enforcement inconsistencies limit their overall impact. Successful Indian models by CIL and SCCL prove that integrated technical-biological approaches can restore land productivity and support biodiversity when executed with commitment.

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