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Research Article

Assessment of Mine Ventilation Efficiency and Gas Control Practice in Underground Coal Mines

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Abstract

Underground coal mines are highly susceptible to methane accumulation, oxygen deficiency, and the presence of toxic gases, making efficient mine ventilation and gas control essential for ensuring operational safety and regulatory compliance. This study presents a comprehensive assessment of mine ventilation efficiency and gas control practices in underground coal mines by evaluating the performance of ventilation networks and the effectiveness of gas monitoring systems under varying mining conditions.

The primary objectives of this research are to evaluate the adequacy of airflow distribution, analyse ventilation parameters such as air quantity, air velocity, pressure differentials, and ventilation resistance, assess methane concentration and gas emission characteristics, and examine the effectiveness of existing gas control measures, including methane drainage, auxiliary ventilation, and continuous gas monitoring. The study also aims to identify factors affecting ventilation efficiency and propose measures to improve mine safety and operational performance.

The research methodology combines field measurements, ventilation surveys, gas monitoring, and analytical evaluation. Airflow parameters are measured using calibrated anemometers, while methane and other gas concentrations are monitored using portable and fixed gas detectors. Ventilation network performance is assessed through pressure measurements, leakage analysis, and fan performance evaluation. The collected data are analysed using statistical methods and compared with applicable national and international mining safety standards to determine the effectiveness of the ventilation system and gas control practices.

The expected outcomes include the identification of ventilation deficiencies, high-risk gas accumulation zones, and opportunities for improving airflow distribution and methane management. The study recommends optimizing ventilation network design, minimizing air leakage, implementing real-time gas monitoring systems, enhancing preventive maintenance, and adopting advanced ventilation modeling techniques. The findings are expected to contribute to improved mine safety, reduced explosion risk, enhanced worker health, and more efficient underground coal mine operations.

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1. INTRODUCTION

Underground coal mining plays a vital role in meeting the growing global demand for energy and industrial raw materials. However, mining operations in underground environments are associated with numerous occupational hazards, among which inadequate ventilation and the accumulation of harmful gases are particularly significant (McPherson, 1993; Hartman et al., 2002). Effective mine ventilation is essential for supplying fresh air to working areas, diluting and removing dust and gases, controlling temperature and humidity, and maintaining safe working conditions for miners (Misra, 1986; Hartman et al., 2002).

In underground coal mines, gases such as methane, carbon monoxide, carbon dioxide, and other noxious emissions may accumulate due to blasting, machinery operation, coal oxidation, and the natural release of gas from surrounding strata (Hartman et al., 2002; DGMS, 2019). If these gases are not adequately diluted and removed, they can pose serious risks, including explosions, asphyxiation, reduced visibility, and long-term health effects (Kissell, 2003; Tutak & Brodny, 2019). Consequently, ventilation efficiency and gas control practices are fundamental components of mine safety management (DGMS, 2017; CMPDI, 2020).

The efficiency of a mine ventilation system depends on several factors, including airway design, airflow distribution, leakage control, fan performance, and proper maintenance of ventilation structures (McPherson, 1993; Hartman et al., 2002). In addition, effective gas control requires continuous monitoring, timely detection of hazardous gas concentrations, and the implementation of appropriate preventive and corrective measures (DGMS, 2019; NIOSH, 2019). Despite advances in mining technology, ventilation-related incidents continue to occur in underground coal mines, highlighting the need for regular assessment and improvement of existing systems (Mishra et al., 2015; Tutak & Brodny, 2019).

Coal mining is one of the most significant sectors of the Indian economy and serves as the backbone of the country's energy infrastructure. India possesses one of the world's largest coal reserves and ranks among the leading coal-producing nations (Ministry of Coal, 2023). Public sector enterprises, particularly Coal India Limited and its subsidiaries, play a crucial role in meeting the nation's growing energy requirements (Ministry of Coal, 2023).

Coal Mining in India

Coal mining is one of the most significant sectors of the Indian economy and serves as the backbone of the country's energy infrastructure. India possesses one of the world's largest coal reserves and ranks among the leading coal-producing nations. Coal contributes the majority of fuel used for thermal power generation and also supports industries such as steel, cement, fertilizers, aluminium, and rail transportation.

The major coal-producing states include Jharkhand, West Bengal, Odisha, Chhattisgarh, Madhya Pradesh, Maharashtra, and Telangana. Public sector enterprises, particularly Coal India Limited and its subsidiaries, dominate coal production and play a crucial role in meeting the nation's growing energy requirements.

2. LITERATURE REVIEW

Mine ventilation is one of the most important engineering systems in underground coal mines because it supplies fresh air, removes methane (CH_4), carbon monoxide (CO), carbon dioxide (CO_2), dust, heat, and other hazardous gases, thereby ensuring a safe working environment (McPherson, 1993; Hartman et al., 2002; Misra, 1986).

According to McPherson (1993), an efficient ventilation system should supply adequate airflow to all working faces while minimizing air leakage and energy consumption. Hartman et al. (2002) also emphasized that proper ventilation is essential for maintaining acceptable oxygen levels, controlling gas concentrations, and reducing the risk of mine explosions. Methane is the primary hazardous gas in underground coal mines because it forms explosive mixtures with air at concentrations between 5% and 15% (Hartman et al., 2002; Tutak & Brodny, 2019). Karacan et al. reported that methane emissions increase with mining depth and coal seam gas content; therefore, ventilation alone is often insufficient in highly gassy mines, and methane drainage techniques are required (Qin et al., 2018; Yuan, 2016).

Several researchers have assessed mine ventilation efficiency using airflow measurements, air velocity, pressure drop, gas concentration monitoring, and ventilation network analysis (Mishra et al., 2015). Computational Fluid Dynamics (CFD) has become an effective tool for simulating airflow distribution and methane dispersion in underground workings, enabling engineers to optimize ventilation systems before field implementation (Mishra et al., 2015).

Continuous gas monitoring using fixed and portable methane detectors has significantly improved the early detection of hazardous gas accumulation (DGMS, 2019; NIOSH, 2019). Automatic alarm and power cut-off systems are widely used to prevent methane explosions when gas concentrations exceed permissible limits (DGMS, 2017; CMPDI, 2020).

Recent studies have highlighted the importance of integrating ventilation-on-demand systems, advanced monitoring technologies, and methane drainage methods to improve safety and reduce operational costs in deep underground coal mines (Kishore et al., 2021; Tutak & Brodny, 2019).

3. RESEARCH METHODOLOGY

Research Design

The study evaluates the efficiency of the mine ventilation system and the effectiveness of gas control practices using field measurements and mine records. Air quantity, air velocity, methane concentration, oxygen concentration, and carbon monoxide concentration were measured at selected underground locations using standard mine ventilation

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instruments (McPherson, 1993; DGMS, 2019). The measured values were compared with design values and statutory safety limits prescribed under the Coal Mines Regulations, 2017 (DGMS, 2017).

Instruments Used;

S.no	PARAMETER	INSTRUMENT	UNIT
1	Air velocity	Digital Anemometer	M/s
2	Air quantity	Anemometer + Cross-section	M^3/s
3	Methane	Multi-gas Detector	%
4	Oxygen	Multi-gas Detector	%
5	Carbon Monoxide	Co Detector	ppm
6	Air pressure	Digital Manometer	Pa

Sample field data

Location	Air quantity (m^3/s)	Air velocity (m/s)	CH_4 (%)	O_2 (%)	Co (ppm)
Main intake	120	3.2	0.10	20.9	2
Development face	72	2.4	0.60	20.6	5
Longwall face	65	2.1	0.80	20.4	7
Return airway	115	3.0	0.95	20.2	9
Panel end	58	1.8	1.20	20.0	11

Ventilation Efficiency

The ventilation efficiency is calculated as:

$$\text{Ventilation Efficiency (\%)} = \frac{Measured\ air\ Quantity}{Design\ air\ Quantity} \times 100$$

Example

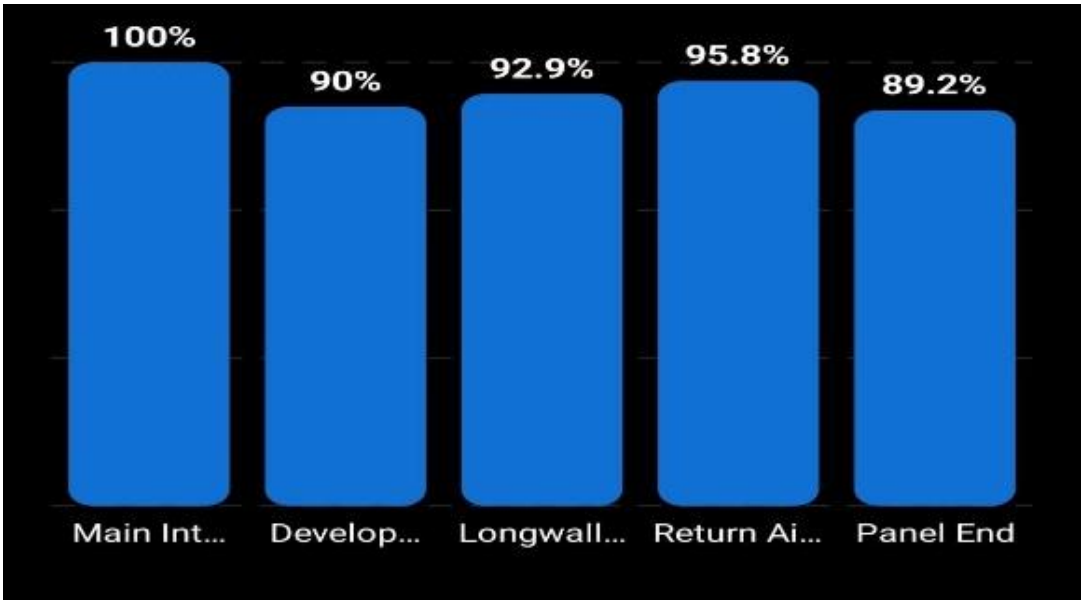
Design Air Quantity = 80 m^3/s

Measured air Quantity = 72 m^3/s

Ventilation Efficiency = $\frac{72}{80}$ x 100 = 90%

Location	Design Air Quantity (m^3/s)	Measured air quantity (m^3/s)	Efficiency (%)
Main intake	120	120	100
Development face	80	72	90
Longwall face	70	65	92.9
Return face	120	115	95.8
Panel End	65	58	89.2

Ventilation Efficiency by mine location



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4. CONCLUSION

The assessment of mine ventilation efficiency and gas control practices demonstrates that an effective ventilation system is essential for maintaining a safe and healthy working environment **(Hartman et al., 2002; McPherson, 1993)**. Regular ventilation surveys, continuous gas monitoring, timely maintenance of ventilation structures, and compliance with statutory safety standards significantly improve mine safety and operational efficiency **(DGMS, 2017; DGMS, 2019; CMPDI, 2020)**. The integration of advanced monitoring technologies and preventive maintenance strategies can further enhance the reliability of underground ventilation systems **(Kishore et al., 2021; Mishra et al., 2015)**. The assessment of mine ventilation efficiency and gas control practices in underground coal mines demonstrates that an effective ventilation system is essential for maintaining a safe and healthy working environment. Adequate airflow ensures the continuous supply of fresh air, dilutes and removes hazardous gases such as methane (CH_4) and carbon monoxide (CO), controls dust concentration, and regulates temperature and humidity within the mine. The study indicates that regular monitoring of ventilation parameters, timely maintenance of ventilation structures, and proper use of auxiliary ventilation systems significantly improve overall ventilation efficiency. Continuous gas monitoring using modern gas detection instruments enables the early identification of hazardous conditions, thereby reducing the risk of methane explosions, fires, and other mine accidents.

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