ANALYSIS OF WORK ACCIDENTS IN COAL MINING WORKERS : LITERATURE REVIEW

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ABSTRACT

Through accident analysis, we can design effective measures to prevent accidents. Therefore, this study aims to analyze occupational accidents in coal mining workers. This study adopted a literature study approach, in which the data search process was carried out systematically referring to the PRISMA guidelines. Information retrieval encompasses not only the use of keywords but also Boolean operators in order to enhance the results of the search: “coal” AND “mining” AND “workers” AND “workplace accident”, Inclusion criteria of the articles were those published between the years 2019 to 2024. This study identified that the risk of accidents in coal mining is mainly caused by physical hazards such as roof collapse, fire, and gas explosion, as well as exposure to hazardous chemicals. In addition, human factors such as lack of safety awareness and weaknesses in management systems also contribute significantly to the high accident rate. The results show that the risk of accidents in coal mining is caused by physical hazards such as roof collapse, fire, gas explosion and chemical hazards such as toxic gases as well as human factors. These findings therefore underline the need for comprehensive measures that would improve occupational safety in coal mines. This will include improved safety management systems, more awareness of the workers themselves, and better regulation of physical hazards. These measures consequently offer protection not only to the employees but also present tokens of the organization towards being socially and ecologically responsible.

Keywords: Coal, Mining, Workers, Workplace Accidents.

INTRODUCTION

Mining is described as an activity of extraction deposits of minerals that have economic value and are of great value within the earth's crust (Rahma et al., 2022). Coal serves as an indispensable primary energy resource on a worldwide scale (Cheng et al., 2021). As the most prevalent fossil fuel on the planet, coal has emerged as a fundamental component of the energy sector, particularly in the context of electricity production and numerous applications within the chemical industry (Gagarin et al., 2020). Historically, coal has been acknowledged as the foremost energy source globally and a significant driver of sustainable economic advancement across the globe (Li et al., 2022).

Within the framework of energy transition, coal continues to

be essential for sustaining the stability of the energy system (Yinnan & Ruxiang, 2024). As one of the most essential sources of energy, coal plays a crucial part in the world energy structure. Coal mining has always turned into a hazardous and fatal activity that terribly compromises the safety of coal production and the lives of the workers. The causes of accidents in coal mines have been determined to result from human factors in excess of 90 percent (Yang et al., 2022).

The mining industry represents the backbone of many other key sectors, such as chemicals, construction, and information technologies. In other words, ample mineral supplies are a precondition for investment in technological development and innovation. However, mining activities are relatively dangerous, as workers may face many threats, from accidents at work to environmental consequences - therefore, the establishment of some strict occupational safety and health rules is quite relevant (ALTINDIS & BAYRAM, 2024).

According to statistics available from the International Labor Organization, ILO, in the year 2022, approximately 270 million workers worldwide experience work-related accidents, and an additional 160 million workers fall victim to work-related illnesses each year (ILO, 2022). In the context of the United States, OSHA has identified stress at work, poor supervision, and inadequacy of proper training in workplace safety as being prominent reasons for the high level of workplace-related accidents (Istisya et al., 2024). The International Labour Organization study was indeed comprehensive in illustrating that occupational accidents are a problem the world over. For instance, 2.9 million workers die every year due to occupational accidents, while about 402 million workers suffer injuries that are not life-threatening in nature (Tong et al., 2023).

Recent statistics reveal that work-related injuries are indeed prevalent in the coal mining industry. According to the ILO, although mining employs only about 1% of the workforce worldwide, it contributes as many as 8% to the total number of fatalities related to work worldwide (J. Tian & Wang, 2022). Mining is one of the most health hazardous activities, and accounts for 8% of all fatal injuries in this sector worldwide. Therefore, it is very important to identify the factors involved in these types of injuries in a timely manner (Cruz-Ausejo et al., 2024).

It is an important first step in the process of accident prevention. Only through deep analysis of the occurrences can a deeper understanding of the root causes of accidents be gained. This deeper understanding will, in turn, enable more effective prevention strategies to be developed; these include the setting up of relevant regulations, proactive risk management actions, and improvements in training for all personnel (Jia et al., 2024). Precise and structured information, which is beneficial for formulating strategies in preventing accidents, can be generated through a comprehensive analysis of vast accident data. This capability arises because the causes of accidents are relatively few; hence, identifying dominant patterns linked to the causes is possible (Kamil et al., 2023).

An extensive and methodical examination of the occupational health and safety conditions faced by miners has been performed utilizing risk analysis tools that have

received validation in epidemiological studies related to mining (J. Tian & Wang, 2022). Causal analysis of coal mine accidents is an important step in accident prevention efforts. By understanding the root causes of accidents, effective mitigation measures can be designed to reduce the frequency and impact of accidents (S. Tian et al., 2024).

According to the definition included in Article 33, a work accident can be described as a sudden, unexpected act triggered by external factors, being directly related to work-related duties, which consequently resulted in either bodily injury or death of the employee. (Konopka 2021) Konopka (2021) highlights four critical elements in this definition, namely the aspects of suddenness, externality, work-relatedness, and consequences in terms of injury or death (Wyganowska & Tobór-Osadnik, 2022). Accidents at work fall within the workplace and are the result of an external event that can cause physical and psychological trauma and even death in extreme occasions (J. Tian & Wang, 2022).

Occupational safety and health represents a multidisciplinary field dedicated to the prevention of workplace accidents and illnesses, while also enhancing the overall well-being of employees (Ali & Pal, 2022). The high exposure rate to chemical, physical, and ergonomic hazards in mining significantly increases the likelihood of accidents among workers in mines (J. Tian & Wang, 2022). This research paper aims to conduct an in-depth review of currently available literature and previous studies related to the analysis of occupational accidents that involve coal mining staff.

LITERATURE REVIEW

An occupational accident is defined as an unexpected event that occurs while performing work, is caused by external factors, and results in physical injury or death to the worker (Konopka, 2021). Important elements in this definition include surprise, external nature, relationship to work activity, and physical consequences or death.

Coal mining is a globally important energy sector and is one of the main sources of electricity and raw materials for the chemical industry, However, it is also recognized as one of the areas with the highest risk to occupational safety. Underground work activities, high geotechnical pressures, hazardous gases and intensive use of heavy equipment make coal mines a hazardous work environment.

Occupational health and safety (OHS) is a multi-disciplinary field that aims to prevent occupational accidents and occupational diseases, while improving the welfare of the workforce. In the context of mining, the Occupational Health and Safety (OHS) approach is not only a legal obligation, but also an ethical commitment of the organization to protect the lives of workers and maintain the company's reputation (Ali and Pal, 2022).

According to the ILO (2022), approximately 2.9 million workers die each year as a result of occupational accidents, and 402 million suffer non-fatal injuries. In the mining industry, despite employing only 1% of the world's total workforce, the sector accounts for up to 8% of total occupational fatalities globally. This data shows how important it is to take occupational safety seriously in this sector.

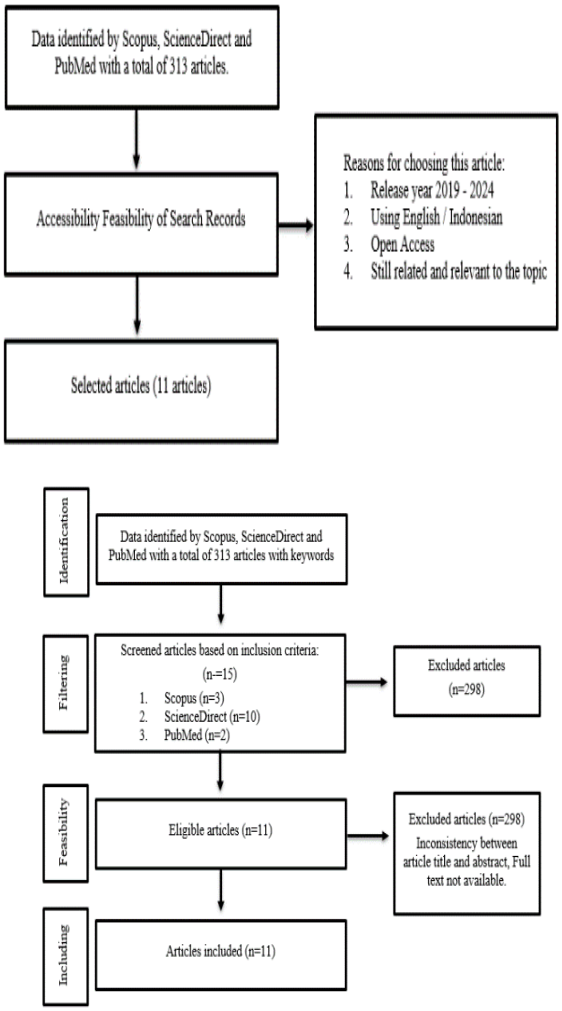
Strict Safety Management System: Create appropriate SOPs and implement them consistently.

Periodic Audit and Evaluation: Conduct regular Occupational Health and Safety audits and analyze accident data to develop corrective and preventive measures. (Tian and Wang, 2022).

RESEARCH METHODS

The literature review method in the present study followed a systematic data retrieval process according to the PRISMA guidelines. Information retrieval encompasses not only the use of keywords but also Boolean operators in order to enhance the results of the search: "work accident" AND 'worker' AND 'mining' AND 'coal'. Inclusion criteria of the articles were those published between the years 2019 to 2024 both in the English and Indonesian languages and found in open access journals. Full-text, qualitative, or quantitative research articles reporting should also be present.

For a comprehensive search, Scopus delivered a total of 39 articles, while ScienceDirect provided 261 articles and PubMed provided 13. Data extraction and filtering using inclusion criteria resulted in 11 relevant articles. The extracted data from the 11 articles were tabulated and subjected to a descriptive analysis.



Gambar 1. Diagram PRISMA

Table 1. Article Summary

No	Author	Tittle	Year	Result
1.	(Tian.,et al 2022)	Analysis of Mining-Related Injuries in Chinese Coal Mines and Related Risk Factors: A Statistical Research Study Based on Meta-Analysis	2022	The research findings indicate that roof collapse and fire are the two most threatening accidents to the life of the workers in Chinese coal mines. Eight other types of accidents were also identified as posing a high level of risk.
2.	(Wyganowska & Tobór-Osadnik, 2022)	Analysis of Mining Accident Levels against the Background of Changes in Productivity and Employment in the Hard Coal Mining Industry	2022	The findings obtained showed that work accidents reduced, yet the number of workers also reduced. Further analyses did not indicate a causal relationship between the number of accidents and productivity levels.
3.	(Zhao., et al 2024)	Analysis of coal mine safety accident features in China, 2017–2022	2024	According to research, excessive pressure, mine roof crack issues, poor conditions of the roof, weakness at supports, and leakage problems generally trigger mine roof falls. Poor ventilation results in common gas explosions, consequently bringing in methane gas build-up from inside the mine.
4.	(Yinnan., et al 2024)	Analysis of the spatial distribution and future trends of coal mine accidents: A case study of coal mine accidents in China from 2005–2022	2024	The study revealed The final results indicated that during the research period, gas explosion, permeability, bursts, asphyxiation, and roof collapses also significantly decreased. Nevertheless, coal mining accidents have shifted to the western part of the country, and most frequent accidents occur in Shanxi and Henan Provinces. Mining accident deaths in China also went through a steady trend, with an average five-year cycle.
5.	(Altyndis., et al 2024)	Data Mining Implementations for Determining Root Causes and Precautions of Occupational Accidents in	2024	These attributes contribute much to the formation of association rules: MP and MW. In this respect, implementation of planned production is always recommended to refer to principles related to occupational health and safety.

		Underground Hard Coal Mining		
6.	(Tian., et al 2024)	Analysis of the causes and safety countermeasures of coal mine accidents: A case study of coal mine accidents in China from 2018 to 2022	2024	All these findings have important implications for prevention, mitigation, and emergency response to coal mining accidents.
7.	(Jia., et al 2024)	Enhancing accident cause analysis through text classification and accident causation theory: A case study of coal mine gas explosion accidents	2024	The result showed that the algorithm of text classification, which was supported by the approach from the BERT model, had extremely better performance compared to the control model.
8.	(Miao., et al 2024)	Coal mine roof accident causation modeling and system reliability research based on directed weighted network	2024	This research provides a theoretical framework that could strengthen coal mine roof control safety in order to minimize the occurrence of accidents.
9.	(Ali., et al 2022)	Assessment of workers' safety behavior in the extractive industries: The case of underground coal mining in Pakistan.	2022	The findings of this study have again driven home the importance of age, experience, and safety behavior as risk factors for occupational accidents. Implications of the findings of this study will be very useful to take more specific measures to improve occupational safety in coal mines and enhance the protection of vulnerable workers.
10.	(Lia., et al 2022)	Identifying coal mine safety production risk factors by employing text mining and Bayesian network techniques	2022	In view of the above, it is rather impossible to fully control all major risk factors; thus, managing relevant factors that contribute to the occurrence of key risks will be a more effective approach in risk control so as to further improve the efficiency of accident prevention in coal mining.
11.	(Cheng., et al 2021)	Evolutionary model of coal mine safety system based on	2021	Occupational accidents depend on many different factors, including human, machine, and environmental ones. Complex

	multi-agent modeling	adaptive systems theory is able to model such complex interactions between these factors by using multi-agent modeling. This paper tries to provide an understanding of the evolution of safety systems in coal mining companies.

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DISCUSSIOIN

Coal is an extremely important primary source of energy in the world for both electrical energy needs and for various other types of industries that rely on it. Miners, when performing their duties within coal mines, are exposed to a wide array of hazards that can affect their occupational health and safety as well; occupational accidents in the coal mining industry are very high compared with the average occurrence rate of all industries. The research at present will look into the incidents of work-related accidents in the coal mining industry to draw a list of contributions that exist with determining and articulating the need for complete Occupational Health and Safety at work to ensure workers' health and safety.

Various studies report that the frequent types of accidents in coal mines include roof-related accidents, fires, protruding coal, toxic gases, gas explosions, and water problems in the mine. These accidents in mines either injure or kill people. To avoid this, we have to go through a detailed analysis of what types of frequent accidents may occur. The current study seeks to identify the types of risks commonly involved in accidents, and also discusses the measures for prevention (J. Tian and Wang, 2022). The conclusion of the current study supports past studies identifying gas explosions, roof collapses, and explosions as the three main classes of accidents in coal mining (Yinnan & Ruxiang, 2024).

Classifications of Coal Mining Accident

Incidents of gas explosions, mostly resulting from inadequate ventilation that allows the buildup of flammable gases, and coal and gas explosions caused by sudden discharge in rock material under high pressure, rank as the major causes of death for all mining-related incidents. It is also important to establish that these gas explosions are almost always accompanied by other incidents such as roof collapse or incidents of gas poisoning, leading to a higher number of casualties. From 2017 to 2022, gas explosions were noted as the leading cause of deaths among coal miners. Generally, gas explosions occur when there is sufficient accumulation of gas, there is an ignition source such as an open flame or a spark, and atmospheric conditions prevail with at least 9% oxygen. This research specifically examines the elements contributing to gas accumulation and ignition sources as essential components for comprehending the mechanisms underlying gas explosions. A significant number of gas explosion occurrences throughout the investigation period

transpired in mines typically regarded as having minimal gas concentrations. This suggests a lack of diligence in the enforcement of gas mitigation strategies by the managers of these mining operations (J. Tian & Wang, 2022). n general, gas-related incidents have brought huge casualties. So, it's very necessary for the accidents to avoid those accidents, including training of emergency response and all-around risk assessment accordingly (S. Tian et al., 2024).

The other class includes all those accidents that occur outside the production area of coal, such as through falling from high platforms, the falling of abandoned structures of mines, and death due to suffocation during entry into unauthorized areas of the mines and when some workers accidentally fall into the coal storage bunkers. As the human element is the main reason for these incidents, improvements in equipment and proper safety at work should be the key ways of preventing them.

Frequency distribution analysis concerning the number of deaths shows that most mining accidents result in 4-5 deaths. However, the coal dust explosion-related deaths increased considerably.

Correspondingly, fire accidents also reported the highest numbers of death even though coal dust explosions and fire are relatively rarer compared to other classes of accidents. The two classes of accidents should not be trivial since they have the most devastating outcomes as shown (J. Tian and Wang, 2022).

Data analysis for the past six years indicates that roof collapse accidents are leading in mines and have the highest fatality rate. Statistical analyses show that the impact of pressure is the primary triggering factor, and the root cause of a sudden release of elastic deformation energy accumulated in the rock mass. The random and dynamic nature of this event poses great challenges to prevention (Zhao et al., 2024). Additionally, the results indicate that the roof collapse is the main type of accident in coal mines (S. Tian et al., 2024).

Ambiguity in the management of corporate safety is a major risk factor that could be linked to the occurrence of serious accidents. Evidence of this can be seen in various ways, including how a poorly institutionalized mine leadership system can cause accidents resulting in fatalities within the workplace and a lack of developing the needed awareness of hidden hazards to make accidents continue escalating over time In addition, promoting occupational safety within coal mines requires special efforts toward providing workers with multiaspect safety training. This aims to build a strong safety culture among workers, as safety awareness is currently low (Tingjiang et al., 2023).

CONCLUSION

Data analysis in this study indicated that major contributors to accident in coal mining include physical hazards such as falling roofs, fires, and gas explosions, as well as chemical hazards from toxic gases. Additionally, human factors, including a lack of worker safety awareness and failures in company safety management, significantly impact the high accident rate. These findings highlight the need for comprehensive measures to enhance occupational safety in the coal mining industry. Traditionally, this industry has faced complex and inherent health and safety

challenges; however, creating a safer work environment is possible through a multi-dimensional approach. This includes improved safety management systems, greater worker awareness, and stricter regulation of physical hazards. Such measures not only protect employees but also demonstrate the organization's commitment to social and environmental responsibility.

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