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Achievements and Challenges in Occupational Safety and Health Management in Mineral Exploitation Activities in Vietnam

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ABSTRACT

The current international integration and technological development not only present opportunities for the growth of the mining industry but also highlight the urgent need for innovation and enhancement in Occupational Safety and Health Management (OSHM). Over recent years, OSHM in mineral exploitation in Vietnam has made significant strides, including the improvement of legal frameworks, increased awareness among employees and enterprises, then the gradual integration of science and technology into risk monitoring and control. However, this sector remains classified as high-risk. Challenges persist, such as the particularly high rate of occupational accidents (OAs) in small-scale and manual mining operations, limited specialized human resources, and the fragmented nature of supervision and inspection activities. Based on an analysis of both achievements and challenges, this paper proposes several key solutions, including the promotion of digital transformation in OSHM management, the enhancement of professional training quality, the improvement of oversight and inspection mechanisms, and the encouragement of active participation from enterprises. These proposals are intended to guide the improvement of the OSHM system in the mining sector in Vietnam in the coming years.

Keywords: Occupational Safety and Health, Occupational Accidents, Challenges, Mineral Exploitation.

1. Introduction

The mining industry plays a pivotal role in Vietnam's economy, providing essential raw materials for key sectors such as cement, metallurgy, chemicals, energy, and construction materials. As reported by the Ministry of Natural Resources and Environment, by 2023, over 4,000 mining licenses had been granted, with hundreds of enterprises operating across the country (Department of OSH, 2024).

While Vietnam's Occupational Safety and Health Management (OSHM) system, particularly in the mining sector, has made noteworthy strides, there remain significant challenges when compared to countries with advanced mining industries like China, Australia, and Canada. According to the International Labour Organization (ILO) report (2021), China has significantly reduced its occupational accident rates in the mining sector by implementing automated monitoring systems and advanced sensor technologies, resulting in a 25% reduction in accidents over the past five years (Xu Kuangdi, 2024). In Australia, WorkSafe Australia (2022) highlighted that strict safety standards and continuous worker training have led to a 30%

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decrease in occupational accidents in the mining sector compared to the previous decade (Tareq Ahram, et. al. 2020). In Canada, the Canadian Centre for Occupational Health and Safety (CCOHS, 2023) reported a decrease in serious accidents in mining to under five incidents per 1,000 workers annually, thanks to a comprehensive risk assessment system and active worker involvement (Canadian Centre for OHS, 2023). When compared to these countries, Vietnam still needs to further improve its legal framework, enhance professional training, and integrate new technological solutions to boost OSHM efficiency, ultimately reducing workplace accidents and occupational diseases in mining.

Despite the progress, the mining sector remains fraught with hazards such as fine dust, vibrations, noise, toxic gases, and extreme working conditions. These factors are direct causes of occupational accidents (OAs) and occupational diseases (ODs). According to the Department of Occupational Safety (Ministry of Labour, Invalids, and Social Affairs, 2024), from 2014 to 2024, the mining industry consistently recorded one of the highest occupational accident rates among all sectors, accounting for around 9-16% of the country's serious accidents each year (Ministry of Labour, Invalids and Social Affairs, 2024). Particularly, in 2000, 2020, and 2024, the sector witnessed the highest number of fatalities from OAs among high-risk industries as fig. 1. Incidents like collapses, gas poisoning, explosions, water breaches, and rock falls remain common, especially in underground mining and construction stone extraction. The persistent lack of adequate protective equipment, insufficient OSHM training, and the low safety awareness among certain workers continue to exacerbate risks and losses.



Figure 1: Occupational Accident Rate in the Mining Sector from 2014-2024

When Vietnam accelerates its industrialization, modernization, and international integration, ensuring OSHM within the mining sector is no longer merely a legal requirement but also a fundamental prerequisite for sustainable development and the protection of human resources. The unique working conditions in mining, characterized by frequent exposure to environmental and health hazards, make this sector one of the highest-risk areas among the 11 industries identified as high-risk for occupational accidents and diseases in Vietnam.

Over the past decade, efforts to enhance OSHM have been intensified, especially following the issuance of Directive No. 29-CT/TW by the Politburo and the National Assembly's adoption of the OSHM Law in 2015. Mining enterprises have increasingly prioritized organizing training programs, raising awareness, and building the capacity to implement OSHM measures effectively (Do Ngoc Hoan, et. al. 2024). Several solutions aimed at reducing pollution, protecting the environment, and preventing occupational accidents and diseases have been vigorously implemented. In addition, mining companies have stepped up efforts to inspect and monitor the implementation of policies related to workers, foster safety culture, improve working conditions, and integrate OSHM with environmental protection. Since 2016, the scope of occupational accident statistics has expanded to cover areas outside of formal labor relations, and with the growth in production scale, especially in sectors such as construction, electricity, mechanics, and mining, there has been an increase in both incidents and casualties (Mai Lam Son, 2024). While this trend reflects efforts to enhance transparency and improve the quality of occupational accident statistics, it also underscores the ongoing challenges in the sector.

Moreover, amid the rapid advancement of Industry 4.0, the Vietnamese mining sector faces increasing pressure to apply modern technologies in OSHM management and supervision. However, the adoption of Industry 4.0 technologies for monitoring working conditions, hazard detection, and safety training remains limited, particularly in non-state-owned enterprises.

As a consequence, this paper aims to summarize the significant achievements in OSHM management in Vietnam, identify the existing challenges, and propose solutions to enhance management effectiveness, ultimately contributing to the creation of a safe, healthy, and sustainable working environment.

2. Achievements in Occupational Safety and Health Management in the Mining Sector in Vietnam

2.1. Achievements

2.1.1. Positive Reforms in the Party and State's Policies on Occupational Safety and Health

Ensuring OSHM, improving working conditions, preventing occupational accidents (OAs) and occupational diseases (ODs), and safeguarding workers' health are essential socio-economic policies of the Party and the State, playing a critical role in the nation's development strategy. The Party has consistently emphasized that people are at the center of development, with the guiding principle "Safety for production, production must be safe." The Political Report at the 11th Party Congress underscored this, stating: "Protecting workers, improving working conditions, reducing OAs, strengthening inspections, strictly enforcing labor laws, and fostering stable, harmonious, and progressive labor relations." (Nguyen Anh Tho, 2021) The Party's continued leadership in OSHM in the evolving context is reaffirmed in Directive No. 31-CT/TW dated March 19, 2024.

State policies on OSHM focus on several core aspects: creating favorable conditions and incentivizing employers and employees to adopt OSHM measures; implementing advanced, environmentally friendly technologies that align with technical standards and modern management systems; investing in research and technological applications; supporting the prevention of OAs and ODs in high-risk industries; providing OSHM training for informal workers in hazardous environments; and promoting voluntary occupational accident insurance.

2.1.2. Continuous Improvement of the Legal Framework

In recent years, the Vietnamese government has introduced a series of policies and legal documents aimed at strengthening OSHM management, aligning with international trends and advanced labor standards. This is illustrated in Table 1.

Table 1: Legal Documents on OSHM in the Mining Sector

No.	Category of Legal Documents	Content
1	Relevant Laws and Codes	- The 2019 Labour Code includes provisions on occupational safety, professional health, and workers' rights.
		- The 2015 Occupational Safety and Health Law supplements regulations on OSHM, risk prevention, control measures, labor protection, and the responsibilities of stakeholders in ensuring workplace safety.
		- The 2025 Geology and Mineral Law: + Article 60 specifically addresses OSHM in mining operations. + Requirements for safety regulations, emergency response, and periodic reporting... (Effective from July 1, 2025).
2	Guidelines for Implementation	Decrees 44/2016/ND-CP, 39/2016/ND-CP, Circular 19/2016/TT-BYT, etc., provide a unified legal basis for OSHM activities.
3	National Technical Standards (QCVN)	Issued for specific industries, these standards support enterprises in implementing OSHM according to technical norms.
4	International Commitments and Standards	Vietnam has ratified ILO Convention 155 (2020) on OSHM and the working environment; it is gradually incorporating international standards into domestic law, aiming for a “Comprehensive Occupational Safety and Health.”
5	Corporate Applications	Vietnamese enterprises are adopting international standards (ISO 45001:2018, ISO 14001:2015) to ensure compliance with OSHM regulations.

2.1.3. Increasing Awareness of Occupational Safety and Health Among Mining Enterprises and Workers

This is reflected in the fact that mining companies are increasingly adhering to OSHM regulations, while workers themselves are more conscious about protecting both themselves

and their colleagues from the risks of OAs and ODs. Alongside focusing on investing in advanced and modern production lines to increase product value and enhance competitiveness, mining enterprises have placed significant emphasis on improving OSHM, firefighting measures, and working conditions for employees.

State management of OSHM training in the mining sector has also been reinforced, with particular attention given to training safety officers at mining sites and ensuring the quality of training organizations through checks and adjustments. During the OSHM Action Month, enterprises within Vietnam Coal and Mineral Industries Group (Vinacomin) launched a competition to generate ideas for improving working conditions, attracting nearly 34,000 participants and generating 16,000 initiatives, many of which came from the mining sector. These efforts have contributed to reducing OAs and ODs while enhancing working conditions at the sites. Thanks to these coordinated actions, the number of OAs in 2022 showed a clear reduction compared to the previous year, and no major accidents involving multiple fatalities occurred during the OSHM Action Month (Pham Huu Nguyen, 2023). Furthermore, TKV has implemented ISO 45001:2018 standards for OSHM management across most of its member units (Nguyen Anh Tho, 2021). Several companies engaged in stone mining for cement production have also begun applying ISO 45001:2018, ensuring environmental conditions and preventing lung diseases related to dust exposure. Moreover, state-owned mining enterprises routinely organize fire safety training, emergency evacuation drills, and incident response exercises.

The application of Industry 4.0 technologies and big data is gradually being established and integrated into practice. For example, units like Ha Lam and Mao Khe coal mines (Vinacomin) have begun using digital software for safety logs and AI-based monitoring of hazardous behaviors (Bui X. N., 2014). Research into IoT-based environmental monitoring systems for real-time data (such as dust, toxic gases, and temperature) has been initiated (Xu Kuangdi, 2024), with pilot applications at various Vinacomin units, including Deo Nai - Coc Sau, and Sin Quyen.

Safety inspections, especially for mining, transportation, and mineral processing equipment that require strict compliance, are also being tightly controlled. The inspection of imported goods, including group 2 items for mineral exploitation, and the management of inspection organizations are being carried out rigorously, ensuring that mining machinery and equipment meet safety standards.

Inspection and enforcement activities in the mining sector are concentrated in high-risk areas and enterprises, helping to detect and address violations promptly and raise awareness about OSHM legal compliance among both companies and workers in the sector.

Clear delineation of rights and responsibilities for both managers and workers in ensuring OSHM has been pioneered in state-owned mining enterprises. A wide-reaching network of safety officers has been established and operates effectively in enterprises managed by Vinacomin, resulting in high effectiveness and gradually building a culture of safety within these companies. Additionally, the medical network and worker healthcare services have also been prioritized, with 91,583 workers undergoing required health checks in 2024, achieving a compliance rate of 98.1% (Nguyen Duy Bao, 2012).

2.2. Limitations and Challenges

Although the legal framework for Occupational Safety and Health (OSH) in Vietnam has undergone significant improvements to adapt to the complex changes in production and the emergence of new risks associated with the Fourth Industrial Revolution (Industry 4.0), the implementation and effectiveness of these regulations in the mining sector, particularly in private mining operations, still face many limitations. These challenges arise from the specific characteristics of the working environment, delays in technology adoption, lack of coordination among stakeholders, and the insufficient awareness of both enterprises and employees regarding OSH.

2.2.1. High Occupational Accident Rate (OAs)

During the period from 2014 to 2024, the situation concerning occupational accidents in the mining sector has been complicated, particularly in non-state-owned enterprises. The number of accidents has fluctuated, with a noticeable increase in 2023 (1,193 incidents) and 2024 (1,171 incidents), marking the highest levels in the past decade. The number of fatalities has also shown complex fluctuations, ranging from 76 to 168, peaking at 168 deaths in 2000. The number of severe injuries remains consistently high, averaging around 1,500 cases per year. The mining sector consistently ranks among the top industries with the highest risks in terms of OSH violations fig. 2 (Ministry of Labour, Invalids, and Social Affairs, 2024).

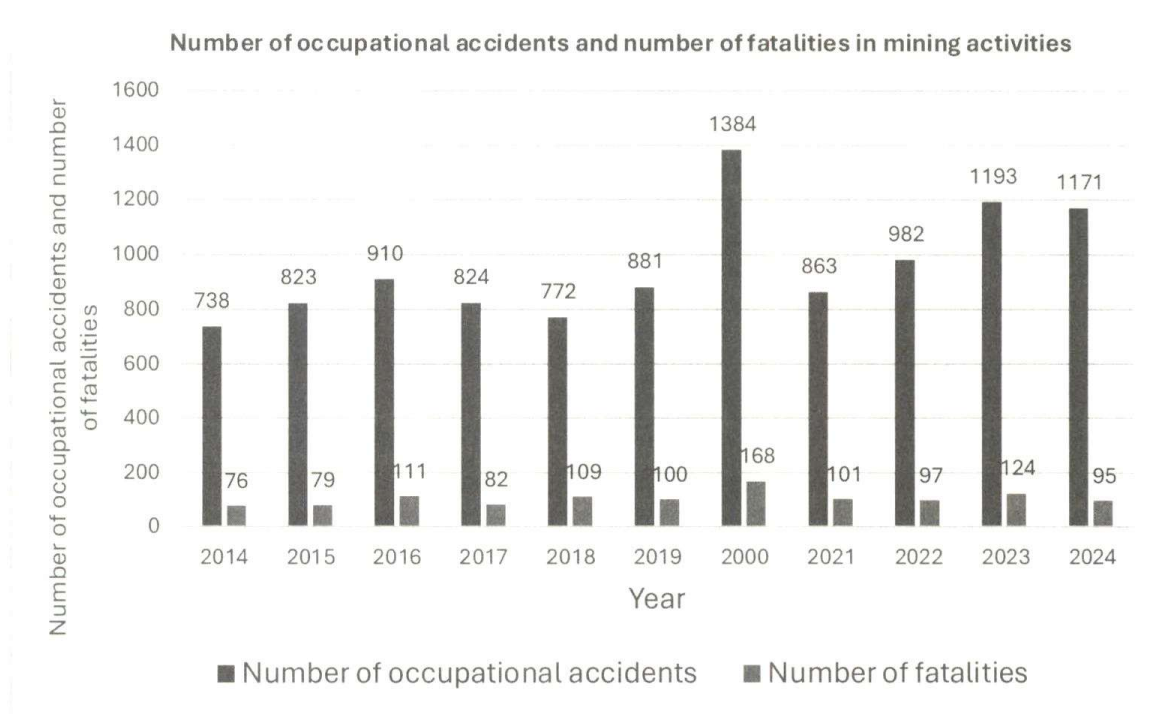


Figure 2: Number of Occupational Accidents (OAs) and Fatalities in the Mining Sector

In summary, the trend of OAs and ODs in the mining sector in Vietnam from 2014 to 2024 reflects the urgent need to raise awareness and enhance the responsibilities of both government management, employers, and workers. Enterprises must focus on improving working conditions, strengthening safety training, and implementing stricter monitoring.

2.2.2. Inconsistent Legal Compliance

In Vietnam's mining sector, the compliance with OSH laws varies significantly across different types of enterprises. According to a survey by the Institute of Occupational Safety and Health (2022), state-owned enterprises (SOEs) and foreign direct investment (FDI) companies typically have more structured OSH management systems, often adhering to international standards such as ISO 45001 or OHSAS 18001. In contrast, many private enterprises, especially small- and medium-sized ones, often fail to fully prioritize OSH due to limitations in financial resources, management expertise, or a focus on short-term profits. As a result, OAs are more prevalent in private enterprises. A report from the Ministry of Labor, Invalids, and Social Affairs indicates that between 2020 and 2023, more than 60% of serious OAs in the mining sector occurred in private companies.

Experts explain this disparity by noting that SOEs and FDI companies are subject to stricter regulatory oversight and must comply with internal audit requirements or international partner demands. Meanwhile, many domestic private companies still operate largely on experience, lacking formal OSH procedures, which often results in superficial or reactive compliance with OSH regulations. This not only increases the risk of accidents but also hampers the productivity and sustainable growth of the mining industry. Additionally, local management of mining activities remains weak, which contributes to insufficient enforcement of OSH compliance in private enterprises.

2.2.3. Hazardous and Risky Working Conditions

Mining is a unique industry classified as heavy, hazardous, and dangerous work. Most mines have complex geological structures, outdated extraction technologies, and rely largely on manual labor. Working conditions are harsh, with workers often laboring in deep, narrow, and confined spaces, facing exposure to various risks that lead to occupational diseases and related health issues, such as coal dust, stone dust, metals (cadmium, manganese), radiation, stagnant water, noise, vibrations, and toxic gases like CH₄, CO, CO₂, and others (Andreeva, S. N., 2005).

During the period from 2020 to 2024, certain sectors in mining were identified as hotspots for occupational accidents: mining and mineral extraction consistently recorded high accident rates, reflecting the inherently dangerous working environment, accounting for 12-17% of fatal accidents (Ministry of Labour, Invalids, and Social Affairs, 2024). Mine workers regularly face numerous hazards, including rock falls, tunnel collapses, water breaches, methane poisoning, and common occupational diseases such as silicosis, asbestosis, noise-induced hearing loss, high-frequency vibration syndrome, whole-body vibration disorders, chronic bronchitis, radiation illnesses, cadmium poisoning, manganese poisoning, carbon monoxide poisoning, TNT exposure, and skin diseases.

Mining activities involve many stages that generate significant dust, including drilling, blasting, hauling, crushing, and loading of rocks, coal, and ores. As a result, many work areas are heavily contaminated with dust, with total dust concentrations ranging from 30 to 100 mg/m³, exceeding permissible hygiene standards (TCVSCP) by 15 to 30 times. Respirable dust levels in some areas exceed TCVSCP by 9 to 11 times, and free silica content averages between 15% and 21%. The incidence of silicosis among coal miners ranges from 3-14%, with underground

mining accounting for 70% of cases, and chronic bronchitis affects about 19.3% of workers (Ministry of Labour, Invalids, and Social Affairs, 2024).

Hand-arm vibration syndrome is also prevalent among mine workers, especially those using hand drills or driving vehicles weighing over 20 tons. High-frequency vibration from hand drills leads to vascular disorders in the hands (approximately 4.3%), while joint damage in the wrists and elbows is found in 15% of workers. For drivers, the incidence of reduced flexibility in the lower spine is 42.3%, and low back pain syndrome affects 12.7% (Babenko, A. G., 2011).

Moreover, due to the damp working environment, the incidence of occupational skin diseases among coal miners is about 40.8%, with fungal infections being the most common (27.5%). It is also important to note that due to the nature of mining work, workers are exposed to multiple harmful factors simultaneously, which can lead to a combination of various occupational diseases. For example, drill workers may suffer from both noise-induced hearing loss and pneumoconiosis, or miners in metal ore extraction may experience both pneumoconiosis and poisoning from metals in the ores, along with chronic bronchitis.

2.2.4. Limitations in Preventive Measures

There is a lack of regular risk assessments, with many small private mining enterprises only conducting checks when incidents occur. This stems from a reactive mindset, insufficient understanding of the importance of accident prevention, and limited technical expertise and resources. The absence of regular risk assessments results in the overlooking of potential hazards in processes such as drilling, blasting, hauling, and crushing rocks, thereby compromising the safety of workers. Statistics indicate that most accidents at private quarries between 2020 and 2023 were related to unregulated risks, such as rock falls, water breaches, or the unsafe operation of equipment.

A significant issue in the mining sector is the inadequate quality of personal protective equipment (PPE), which is often not used correctly. Many enterprises, particularly small private mines, provide PPE that does not meet technical standards or is unsuitable for specific working conditions, such as dusty environments, toxic gases, high noise levels, or intense vibrations. Furthermore, workers are often not properly trained in the use, inspection, and maintenance of PPE, leading to incorrect usage or complete neglect, reducing its protective effectiveness. Research in OSH has shown that PPE is only effective when selected for specific risks and used according to established procedures. This highlights the urgent need to improve PPE quality and provide mandatory, regular training for workers in the mining sector.

2.2.5. Economic Pressures and Market Volatility

In the context of fluctuating mineral prices and pressure to maintain profits, many mining enterprises tend to increase production without proper control, especially when the market is scarce and prices rise. This causes fluctuations in mining scales, leading to the neglect or reduction of OSH management efforts. Many units prioritize speed and output, postponing equipment inspections, maintenance, and monitoring of working conditions, or delaying investments in improving the work environment. This increases the risk of occupational accidents and diseases. After the COVID-19 pandemic, many companies cut OSH costs to maintain production. As such, stricter oversight mechanisms are needed to ensure OSH management is not compromised by short-term economic pressures.

The impetus for digital transformation and automation in mining has brought significant benefits in productivity, precision, and the reduction of manual labor. However, this wave of new technologies also introduces new OSH risks. Automated control systems, smart machinery, and remote-controlled devices, if not operated according to proper technical procedures, can result in serious accidents due to loss of control. Additionally, workers have not been adequately trained to adapt to new technologies, leading to potential errors in operation, misinterpretation of control signals, or exclusion from risk control processes. Furthermore, increased use of digital devices and network connectivity introduces cybersecurity risks that could indirectly affect production system safety.

3. Enhancing the Effectiveness of Occupational Safety and Health Management in the Mining Sector in the Current Context

To improve the effectiveness of OSH management and ensure harmonious and stable labor relations within enterprises, several synchronized solutions must be implemented as fig. 3:

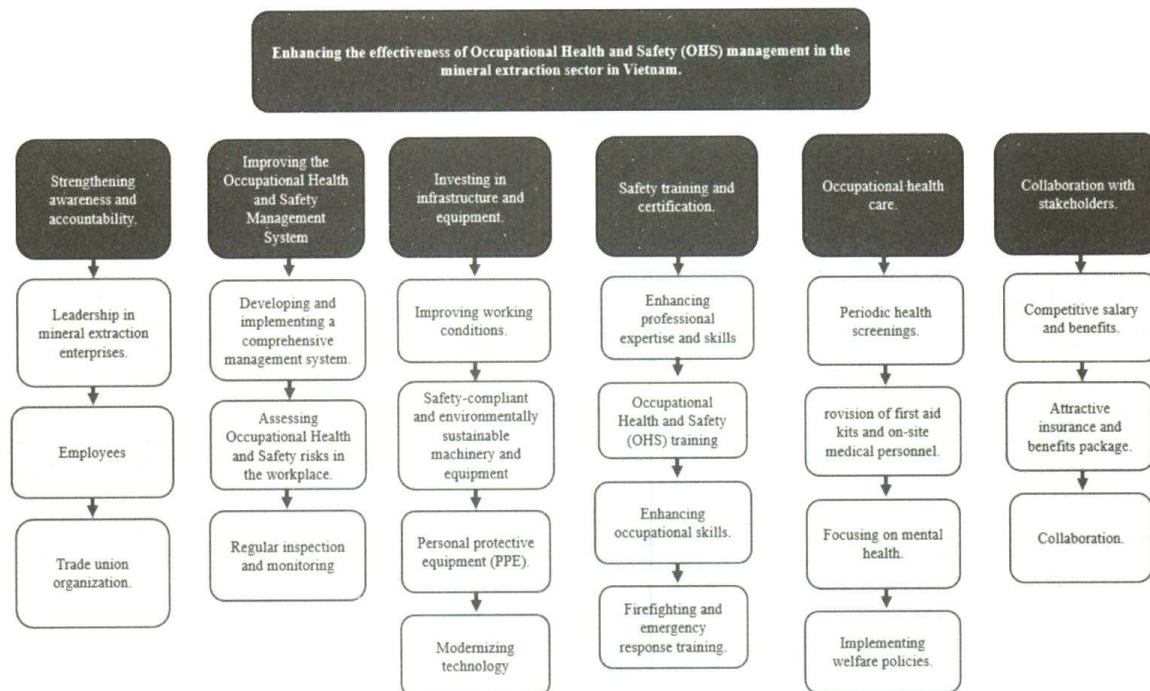


Figure 3. Enhancing the effectiveness of OHS management in the mineral extraction sector in Vietnam.

3.1. Strengthening Awareness and Responsibility

Mining Enterprise Leadership: Establish a strong safety culture, recognizing OSH as an essential component of the mining sector's development strategy. Commit to investing financial resources, human capital, and technology to ensure the effective implementation of OSH programs. Regularly update and share OSH information with all employees, fostering an environment where everyone feels responsible for their own safety and that of their colleagues.

Employees: Increase training to raise awareness about the importance of OSH, the rights and responsibilities of workers in protecting themselves and their colleagues. Encourage workers to actively participate in OSH activities, report safety hazards, and provide feedback to improve the working environment.

Unions: Serve as a key link between workers and enterprise management. Represent workers in the development, supervision, and proposal of measures to improve OSH. Organize OSH education and awareness activities for workers, ensuring their rights are protected.

3.2. Improving OSH Management Systems

Develop and implement a comprehensive OSH management system tailored to the size, industry, and specific characteristics of mining operations. International standards such as ISO 45001 may be applied, or a bespoke system based on OSH management principles can be created.

Regularly assess workplace risks, identify potential hazards, evaluate risk levels, and develop appropriate control measures, especially for private mining enterprises. The risk assessment process should involve leadership, workers, and OSH experts.

Conduct periodic checks and monitoring of working conditions, equipment, and production processes to identify and promptly address safety risks. Utilize modern OSH management tools, such as OSH management software, surveillance cameras, and environmental monitoring devices.

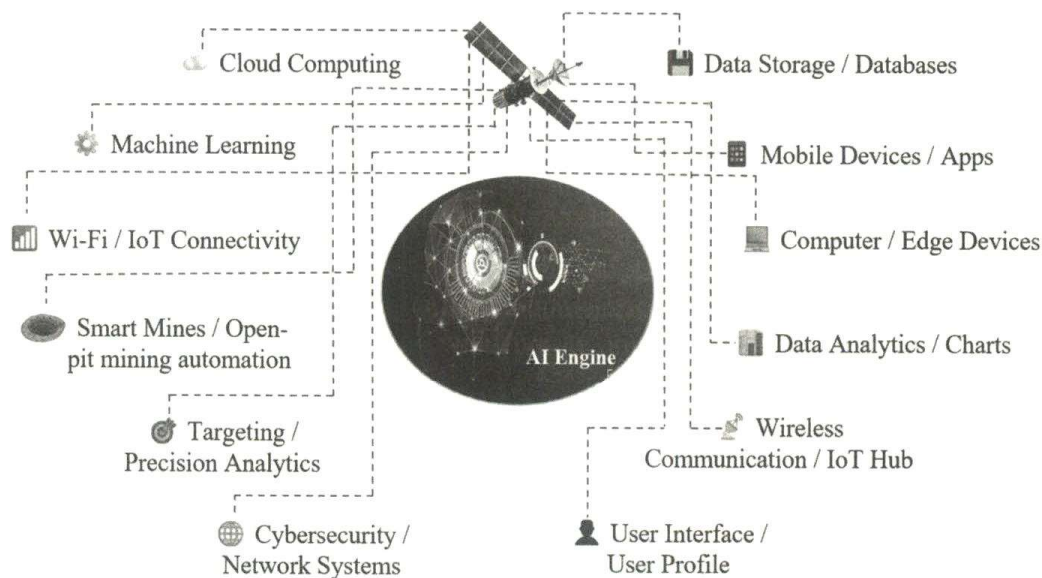


Figure 4. Adopt The AI Digital Platform to the effectiveness of OSH

3.3. Investment in Infrastructure and Equipment

Improve Working Conditions: Ensure workplaces are well-ventilated, adequately lit, and have controlled noise, temperature, and humidity levels appropriate for each task. Design workspaces to be ergonomic, comfortable, and reduce stress for workers.

Invest in Safe, Environmentally-Friendly Equipment: Invest in noise reduction, dust control machinery, mechanical lifting equipment to replace manual labor, and automated ventilation systems (fig 4).

Integrate Industry 4.0 Technologies into OSH: Use IoT sensors to monitor dust and toxic gases, AI cameras for hazardous behavior surveillance, OSH management software, and early warning devices for potential risks.

Provide PPE: Ensure workers are equipped with appropriate personal protective equipment (PPE), such as protective clothing, helmets, safety shoes, goggles, masks, earplugs, and gloves. Ensure PPE is of good quality, suitable for each task, and undergoes regular inspections and maintenance.

Modernize Technology: Invest in modern technology and automate mining processes to reduce heavy, hazardous, and dangerous work. Use safety-enhanced equipment that meets OSH standards.

3.4. Training and Education

Organize periodic OSH training for all workers, particularly newcomers, those changing jobs, and those working in hazardous environments. The training should cover basic OSH knowledge, legal regulations, and accident and disease prevention skills.

Hold practical training sessions on emergency response, first aid, PPE usage, and emergency evacuation procedures. Practical training helps workers gain hands-on experience, enabling them to respond quickly and accurately in case of incidents.

Provide opportunities for workers to improve their professional skills, become proficient in using machinery and equipment, and reduce accident risks. Organize specialized technical courses and update workers with new knowledge on technology and production processes.

Invest in Safe, Environmentally-Friendly Equipment: Invest in noise reduction, dust control machinery, mechanical lifting equipment to replace manual labor, and automated ventilation systems.

3.5. Encouraging Participation and Dialogue

Foster an open working environment where workers are encouraged to report safety hazards, accidents, and unsafe conditions without fear of retaliation. Create channels for easy reporting, such as suggestion boxes, hotlines, and mobile apps.

Regularly hold dialogues between management, trade unions, and workers to discuss and resolve OSH-related issues. Ensure that workers' voices are heard and respected.

3.6. Health Care for Workers

Organize periodic health checks for all workers, especially those working in hazardous environments exposed to dangerous substances. Health checks help detect work-related health issues early, allowing for timely intervention.

Equip workplaces with first-aid kits and establish onsite medical teams or contracts with healthcare providers to address occupational accidents and emergencies promptly. Ensure workers have access to high-quality healthcare when necessary.

Focus on workers' mental health by creating a supportive, stress-free working environment. Organize recreational, sports, cultural activities to help workers relax and recharge.

3.7. Welfare Policies

Competitive Wages and Bonuses: Ensure fair, competitive wages and bonuses based on workers' abilities, experience, and contributions. Build a transparent, publicly available compensation system to motivate employees and improve work efficiency.

Ensure compliance with social insurance, health insurance, and occupational accident and disease insurance according to the law. Protect workers' rights in case of risks.

Develop attractive welfare policies, such as housing support, transportation, education, entertainment, travel, and healthcare benefits for workers and their families.

3.8. Collaboration with Stakeholders

Comply with OSH laws and collaborate with relevant authorities to enhance the effectiveness of state OSH management. Participate in government-led OSH programs and projects.

Partner with social organizations and OSH experts to receive advice, technical support, training, risk assessments, and OSH management system development. Join OSH networks and forums to share experiences and learn from best practices.

4. Conclusion and Recommendations

4.1. Conclusions

The management of OSH in Vietnam's mining sector has made significant achievements, particularly in improving the legal framework, raising awareness among workers and employers, and increasing the use of technology in risk monitoring and control. Nevertheless, the field still faces several significant challenges, such as a high rate of occupational accidents, discrepancies in legal compliance among different types of enterprises, persistent risky working conditions, and an ineffective monitoring and inspection system, especially in small and non-state-owned mines.

As Vietnam enters a phase of industrialization, modernization, and digital transformation, continuing to improve the working environment, build a safety culture, and enhance OSH management in the mining sector is critical for protecting workers and ensuring the sustainable development of this key industry.

4.2. Recommendations

To improve OSH management in the mining sector, the paper recommends:

1. Government Authorities should continue to refine and effectively implement the legal framework, increase inspections, particularly in private enterprises and high-risk areas, and promote the digitalization of OSH data to facilitate transparent and efficient monitoring.

2. Mining Enterprises should establish OSH as a core value, invest more in safety technology, implement Industry 4.0 technologies (IoT, AI, risk management software), build

OSH management systems based on international standards, and maintain regular risk assessments.

3. Trade Unions and Social Organizations should strengthen their oversight roles, protect workers' rights, and actively collaborate in OSH promotion, training, and developing networks of safety officers, while encouraging workers to participate in OSH activities.

4. Training and Research Institutions should focus on deepening OSH training for the mining sector and collaborate on researching and transferring new technologies for forecasting and controlling safety risks in specific working conditions.

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Contributions of authors

Do Ngoc Hoan - conceptualization, main content writing (enhancing OSHM), writing (challenges and limitations), review & editing; Tran Quang Hieu - conceptualization; Tran Dinh Bao - writing (challenges and limitations); Lam Kieu Anh - literature search, translation, manuscript editing.

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