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Prioritizing the factors affecting the occupational health and safety of workers in the mining industry using the SWARA Technique

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Abstract

Despite providing employment opportunities for the semiskilled and economically marginalized people, the mining industries adversely impact the environment and the workers. The occurrence of occupational accidents and injuries is quite high in the mining industry than in other industries. The purpose of this study is to determine and assess the factors that impact workers' health and safety in Indian mining activities. The literature review and expert feedback resulted in the identification of fifteen key factors. These fifteen factors are evaluated in an actual mining field. In this research work, Step-wise Weight Assessment Ratio Analysis (SWARA) technique has been used to assess the worker's occupational health and safety (OHS) related problems. Musculoskeletal disorders, stress and fatigue, and dust inhalation or coal dust exposure are the top three critical factors causing problems to mine workers' health and safety according to the study's findings. Maximizing the automation in the working area, implementing Internet of Things (IoT) technologies, and incorporating predictive maintenance activities will provide in-depth knowledge to the managers in rectifying the health and safety problems identified. The findings of this research will benefit managers to establish more comprehensive and effective ways of responding to challenging situations. As the study is primarily focused on the Indian mining industries, a comparative study between two countries that have similar socio-economic conditions may help in generalizing the results.

***Keywords**: mining industry; occupational health and safety; SWARA technique; workers' safety in mining industry.*

1. Introduction

As stated by the International Labour Organization (ILO) (2015), the mining business is one of the most unsafe in the world, and mine workers consider it perilous and hazardous (Gyekye, 2006). Mine workers face a wide range of mechanical, chemical, biological, physical, and emotional hazards (Amponsah-Tawiah, Jain, Leka, Hollis, & Cox, 2013). Mining activities are helpful for the country's economic growth and also, while considering occupational health and safety (OHS) for employees, it is quite challenging (Amponsah, & Mensah, 2013). When compared to other key industries like construction, manufacturing, and rail, mining has the worst accident and illness record, giving it the label of the most dangerous industrial sector. In addition, mine surroundings are challenging since they destroy fast and vary as mining occurs. Rock breaking is creating huge dust and noise, to overcome this problem, proper light facilities and sufficient air ventilation facilities must be provided artificially in underground mines.

Mining and blasting both release toxic gases into the subsurface environment. Mining workers handle heavy machinery and perform strenuous work in the confined area making the industry an ergonomic hazardous one. Ergonomic hazards, often linked to poor engineering design, can contribute to higher safety concerns in some cases. Sustainable environments are progressively getting identified as a broad concept that affects the individual standard of living and has significant social consequences for public health. OHS is a multidisciplinary approach that focuses on improving the safety, health and welfare of people in the workstation (Amponsah-Tawiah, & Mensah, 2016). OHS refers to a worker's cognitive, psychological, and physical health as it relates to his or her job. Consequently, it is a critical area of attention that has a beneficial influence on attaining administrative goals (Bhagawati, 2015). Many small-scale mining industries find it difficult to access their larger competitors when it comes to identifying preeminent practices in health and safety and emerging proper risk management strategies. OHS management has become more prominent in the mining industry as a result of the increased requirement for ore minerals and the high threat variables that come by it. As a result, these mineral-rich developing countries' mining sectors are particularly vulnerable to occupational issues related to mortality and impairments. This has an impact on workers' approaches and purposes to their company. Occupational health programs are mainly focused on preventing illness due to working conditions, whereas the goal of safety programs is to avoid accidents and minimize destruction to people and possessions as a result of such incidents (Adeniyi, 2001).

A case study by Sánchez and Hartlieb (2020) in the Chinese mining industry stressed the need of incorporating the latest technologies for mitigating accidents and injuries to the workers. A similar study by Gedam, Raut, de Sousa Jabbour and Agrawal (2021) advised the mining industries to adopt CE practices to lower the adverse environmental impacts. Wang, Zhang, Deng, Su and Gao, (2022) used the DEMATEL technique to understand the causal interrelationship among the factors influencing the health of the mining workers.

From the above information, it was understood that the mining industry shows a crucial part in enhancing the economic progress of the country; however, it comes at the cost of adverse impacts on the environment and workers. Further, the workers in the mining industries are knowingly or unknowingly exposed to occupational musculoskeletal disorders. The main reason for the exposure to musculoskeletal disorders is the poor ergonomically designed workplace. Earlier studies advocated the environmental impacts of the mining industry and also suggested potential strategies for lowering the environmental impacts and improving the safety of mine workers. Some studies tried to understand the interrelationship between the various factors. However, none of the studies have considered and addressed the reasons for musculoskeletal disorders. Considering this fact, this work concentrates on the recognition and evaluation of the factors that impact the health and well-being of the mine workers.

1.1 Literature review

Attention must be given to the OHS of the workers in the industries as it has a direct impact on industrial performance. However, very little consideration is being given to the OHS of the workers by the developing nations and the developed nations. In this section, the detailed literature review is presented in three domains: (1) the importance of OHS, (2) the status of OHS in the mining industry, and (3) OHS and sustainable development goals. These three domains will help in better understanding the need and importance of this study.

1.1.1 Importance of OHS

The functioning of an organization largely depends on the health and safety of the workers. When the health and safety of the workers come under threat, there is a possibility of occurring a dip in the performance of workers. So, it is necessary to nurture the workers by ensuring their health and safety (Karuppiah, Sankaranarayanan, Ali, & Kabir, 2020). Employees, who were supposed to work in multiple work locations, are supposed to undergo unique demands and pressures and hence are vulnerable to hazards more than workers working in a single location (De Cieri, & Lazarova, 2021). People engaged in multiple work locations are exposed to the destruction of biorhythm, overwork, and task complexity. Min et al. (2019) state that taking the advantage of globalization, multinational companies are expanding production facilities in developing countries where the labours are subjected to work in the hazardous workplace without proper welfare. Here, multinational companies are not adhering to labour regulations. A recent survey carried out by the ILO underscores that nearly 317 million people are affected by work-related accidents of which 6,300 people are killed (Hou, Khokhar, Khan, Islam, & Haider., 2021). United Nations (UN) states that daily 6,500 people die due to workplace diseases while 1000 people die due to workplace incidences. These incidences also bring in economic losses. The occurrence of workplace accidents increases the frequency of absenteeism among workers. Workers' absenteeism results in a loss of working hours thereby halting industrial production activity (Asad et al., 2021). It has been found that small and medium enterprises (SMEs) comprise nearly 90% of the industrial activities in almost all countries. Notably, most OHS-related accidents are also occurring in SMEs. This is because most SMEs are functioning with limited space availability and are not adhering to the safety of the workers. The labourers of the SMEs are hired for minimal wages and are denied the fundamental health and safety norms. According to ILO, OHS-related accidents According to the International Labour Organization (ILO) (2015), OHS-related incidents cost the global economy 4% of its annual GDP. (Olcay, Temur, & Sakalli, 2021; Ma et al., 2022).

1.1.2. Status of OHS in the mining industry

The mining industry is a crucial one in the economic progress of several emerging nations. The mining industry shows a crucial part in the economic progress of the following nations: India, Russia, China, Canada, Australia, the UK, the USA and South Africa (Fijorek, Jurkowska, & Jonek-Kowalska, 2021). Here, the mining industry helps around 0.5% of the global GDP (Upadhyay, Laing, Kumar, & Dora, 2021). As a highly required labour industry, the mining industry acts as a job provider for a huge population that is semiskilled and deprived of proper education. Although the mining industry provides employment opportunities, it pays very little attention to the healthiness and wellbeing of the workers. As a result, 8% of workplace fatalities are related to the mining industry and continues to reoccur in many parts of the world due to negligence of the mining industrial management (Tetzlaff et al., 2021). Donoghue (2004) reviewed the chemical, physical, ergonomic, biological, and psychosocial risks to workers' health associated with mining and connected metallurgical operations and insisted that proper attention is required to ensure exposure to coal dust and control of crystalline silica. Scott and Grayson (1990) analyzed the health-related issues that occurred to mining workers due to diesel particulate matter, coal dust, asbestos, noise, welding fumes, silica dust, skin disorders and lead, and suggested a few new rules and regulations for the workers like separation of hazardous chemicals used, train the miners about HazCom Programs to improve the safety in the workplace.

Amponsah-Tawiah and Mensahet (2016) examined the correlation and influence of OHS on workers work involvement in Ghana's mining industry. The findings demonstrated that OHS had a considerable impact on psychological, ethical, and long-term commitment. Tetzlaff et al. (2021) analyzed the OHS studies on mining to check how risk management has been portrayed in the past regarding accident causation in the mining industry. The findings revealed two separate frames for interpreting the data: the individual's involvement in safety culture and the organization's role in safety culture. Ismail, Ramli and Aziz (2021) reviewed the contributing variables on workplace safety in the mining industry using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) and Systematic Literature Review (SLR) review methods. The behavioral aspect has the largest prompting variable in creating a good well-being environment (47%), followed by the conditional variable (29%) and emotional variable (24%). Musah and Ayarkwa (2021) examined how well the mining industry adhered to health and well-being regulations. The results exposed a modest degree of compliance and suggested conducting periodic evaluations to examine OHS requirements and raise awareness of the frequent use of safety products. The transition of risk-based thinking from quality management systems to OSH management systems was studied by (Rudakov, Gridina, & Kretschmann, 2021). They demonstrated how a company doing open-pit mining processes may use this strategy. Their research shows that risk-based thinking, when integrated into an OSH management system, can be a reliable and effective tool for OSH development and execution.

Weeks (1991) analysed the implementation of OHS management rules and regulations and found stakeholder pressure, organizational culture, act, and regulation integrated OHS management and investment are the influencing factors. Ramaganesh and Bathrinath (2020) analysed the environmental and health problems in the mining industry using Interpretive Structural Modelling (ISM) and found that gas emissions, particulate matter formation, noise and vibration, and pollution in the drinking water are the primary causes of the worker's health issues in the mining industry. Leontidou and Boustras (2022) studied the historical overview of OHS problems in Cyprus and addressed the issues that have arisen, as well as the nation's engineering, governmental, and authorized schemes' gradual modernization over the implementation of innovative procedures and guidelines to safeguard workers. Tubis, Werbińska-Wojciechowska, Sliwinski, & Zimroz, (2022) proposed a fuzzy risk-based maintenance policy by considering safety aspects for mining industry machinery maintenance works. They suggested five levels of analysis like hazard analysis, risk evaluation, and determining Risk Based Maintenance (RBM) recommendations for safety, maintenance and resource allocation. Alrawad, Lutfi, Alyatama, Elshaer, & Almaiah, (2022) used psychometric paradigm to investigate workers' views of work-related and ecological risks and threats. The model's high explanatory power, which explained roughly 73 percent of the difference in mineworkers' threat view, makes it appropriate for assessing workers' threat views of work-related and ecological problems and threats.

Mohsin, Zhu, Naseem, Sarfraz and Ivascu, (2021) used an solicitation of the Semi-Quantitative Mathematical method in the mining industry to determine the effect on social interaction, public health, economic growth, and environmental sustainability. They suggested that the quality of life for residents can be improved by creating new employment opportunities and raising environmental awareness. Management in the mining business should adhere to local and worldwide sustainable environmental policies to protect environmental and workers' social and health problems. Mancini and Sala (2018) assessed the social impact of the mining sector using different indicators sets and compared the results with other indicator frameworks used in different contexts like Sustainable Development Goals (SDGs), Global Reporting Initiative (GRI), European Union (EU) policy and Social Life Cycle Assessment (LCA). Gul and Ak (2018) proposed a comparative outline in OHS risk assessment in the underground copper and zinc mining industry. They used Pythagorean fuzzy analytic hierarchy process (PFAHP) for weighting risk factors of 5 × 5 matrix and fuzzy technique for order preference by similarity to the ideal solution (FTOPSIS) for prioritizing the hazards identified.

1.1.3 OHS and SDGs

SDGs proposed by the UN is not only concerned with the environmental performance of the industrial community; it also insists on the well-being of the industrial workers. SDG 8 (Decent work and Economic growth) and SDG 9 (Industry, Innovation, and Infrastructure) are completely devoted to the technological up-gradation of the industrial community and also to ensuring the well-being of the industrial workers (Karuppiah et al., 2020). A policy 'Vision Zero' was envisaged by the ILO to achieve zero accidents in the industries. By eliminating accidents in the industrial environment it is possible to minimize occupational deaths and diseases. According to a report by the ILO, majority of the industrial accidents are occurring in developing countries than in developed countries. Further, it was highlighted that the proportion of industrial accidents in some developing countries in the Asian and Gulf regions is four times higher than in developed countries (Ali, Liaqat, Azhar, & Ali, 2021). It has been identified that nearly 80% of global industrial accidents are occurring in lower-middle-income countries. Occupational accidents incur 10 trillion dollars in loss to emerging and developing countries (Rai, Brown, & Ruwanpura, 2019). Such kind of huge economic loss decelerates the growth of emerging nations in the accomplishment of ecological improvement. A work by Chaigneau et al., (2022) advocates that sustainable industrial practice is not limited to environmental conservation alone; it also includes the well-being of the workers. Such an argument seems to be acceptable as the countries on the top of the sustainability index account for the minimum number of industrial accidents. Labor laws and reforms are not strictly enforced by the industrial community of developing countries. Such negligence leads to an increased number of industrial accidents. Further, the working environment in developing countries is not ergonomically designed (Koppiahraj, Bathrinath, & Saravanasankar, 2021). Prolonged work in a congested and non-ergonomically designed industrial environment increases the occurrence of occupational injuries. Countries that are accounting for more industrial accidents are ranked low in the sustainability index. From this information, it could be perceived that there occurs a strong correlation among work-related fitness and the sustainability progress of a nation. So, industrial management needs to pay adequate attention to ensuring the well-being of the workers.

2. Objective

Considering the analysis of the earlier literature, it has been agreed that there exists a direct relationship between the worker's well-being and the country's progress toward sustainability. The mining industry is one of the area where there is an immense need of ensuring workers' health. Workers in mining industries in India are often deprived of proper safety and well-being in the workplace. As a result, most workers are supposed to health hazards and are exposed to premature death. Therefore, it is necessary to find various important safety issues to be considered by the Indian mining industry. Taking into consideration this, this work has the following objectives.

- To identify key factors of health and safety issues in the mining industry.
- To determine the most influencing key factors of health and safety issues using the SWARA technique.
- To suggest alternative solutions to solve the most influenced key issues.

The methodology used in this study is explained in the next section.

3. Methodology

Figure 1 shows the methodology used to find the most influencing factor in mine workers' health and safety factors identified. One of the novel multi-criteria decision-making (MCDM) approaches were used for decision-making in this study. The Step-wise Weight Assessment Ratio Analysis (SWARA) approach is used for a variety of reasons. The new SWARA technique was suggested by (Keršuliene, Zavadskas, & Turskis, 2010). SWARA's perspective differs from those of other related methodologies such as the analytic hierarchy process (AHP), analytic network process (ANP), and factor relationship (FARE). SWARA permits policymakers and decision-makers to prioritize problems according to the current level of the economy and location. And also, in this strategy, the function of the specialists is critical. Experts play a critical part in the decision-making process for major projects. Finally, SWARA has the advantage of calculating weights and the comparative significance of criteria in a more logical manner. The SWARA approach has certain similarities to the AHP method, but it also has its unique characteristics. Specialists show a crucial part in evaluating and computing weights in this procedure. In addition, each expert has assigned a value to each criterion. Then, from the first to the last, all specialists assess all of the criteria. Expert builds on their implicit knowledge, facts, and experiences to solve problems. Using this procedure, the best important criterion is ranked first, while the least important criterion is ranked last. The complete position of the team of specialists are computed based on the mean score of ranks (Keršulienė, & Turskis, 2011). This approach is useful for coordinating and getting information from specialists. Furthermore, the SWARA approach is simple, and specialists can collaborate effortlessly. The key benefit of this decision-making process is that significance are established according to company or country strategies in some cases, and there is no need for ranking criteria to be evaluated.

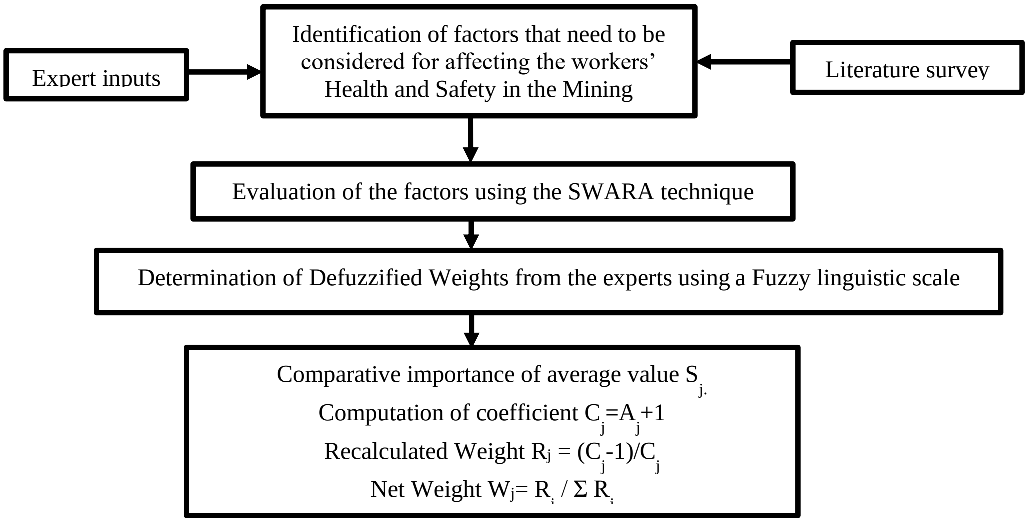

Figure 1 shows the methodology used to find the most influencing factor in mine workers' health and safety factors identified.

3.1 Step-by-step procedure of the SWARA method

The procedure for finding the relative weights of criteria using the SWARA method is given below (Thakkar, 2021).

Step 1: Determination of defuzzified weights

First, 15 key factors related to the health and safety of mineworkers were finalized with the discussion of experts and a literature survey. Next, experts are asked to assess the significance of the factors identified. To assess the significance, the fuzzy triangular linguistic scale is given in Table 1.

Table 1 Fuzzy linguistic scale

Linguistic terms	**Fuzzy scale**
Extremely insignificant	(0.0, 0.0, 0.1)
Not very significant	(0.0, 0.1, 0.3)
Not significant	(0.1, 0.3, 0.5)
Fair	(0.3, 0.5, 0.7)
Significant	(0.5, 0.7, 0.9)
Very significant	(0.7, 0.9, 1)
Extremely significant	(0.9, 1, 1)

The outcomes were collected from all the expert's opinions about the significance level of the factors identified. Next defuzzified weights are determined by taking the average value of the collected results. The significance of each factor is indicated by its weight. The additional benefit of the SWARA method is that it allows researchers to eliminate ineffective criteria and indicators as specialists must relate criteria. If the reserve among criteria converts excessively great, they can claim that one of the criteria has no significant impact on the research technique (Zolfani, & Saparauskas, 2013).

Step 2: The factors are arranged in reverse order according to their projected significance.

Step 3: Comparative importance of average value (Aj).

For each factor, starting with the second, the answer specifies the comparative implication of criterion j with respect to the prior (j-1) criterion. According to Keršuliene et al. (2010), this ratio is the Comparative importance of average value (Aj).

Step 4: Determine the coefficient Cj as follows:

$$C_j=\begin{cases} 1 & j=1 \\ A_j+1 & j>1 \end{cases} \quad (1)$$

$$K_j=\begin{cases} 1 & j=1 \\ S_j+1 & j>1 \end{cases} \quad (1)$$

Step 5: Determine the recalculated weight R_j as follows:

$$R_j=\begin{cases} 1 & j=1 \\ \frac{c_j-1}{c_j} & j>1 \end{cases} \quad (2)$$

$$q_j = \begin{cases} 1 & j=1 \\ \frac{k_{j-1}}{k_j} & j>1 \end{cases} \quad (2)$$

Step 6: The relative weights of the evaluation factor are computed as follows

$$W_j = \frac{r_j}{\sum_{k=1}^{n} r_k} \quad (3)$$

$$W_j = \frac{q_j}{\sum_{k=1}^{n} q_k} \quad (3)$$

Where W_j denotes the relative weight of criterion j.

4. Application of SWARA in evaluating the factors to be considered in the mining industry

According to Figure 1, the work begins by identifying the factors affecting the health and safety of workers in the mining industry. Initially, the factors affecting the health and safety of the mining industry workers are identified through the narrative literature review. Generally, the narrative literature review is preferred when the study intends to answer focused research questions (Jahan, Naveed, Zeshan, & Tahir, 2016). Here also, the narrative literature review is used to get responses to the examination queries given in the introduction section. For identifying the factors affecting the health and safety of the mining workers, the narrative literature review was acted upon in scientific repositories such as Science Direct, Google Scholar, EBSCO, Scopus, and Wiley. To collect relevant literature related to the research work, several keywords combined using the Boolean operators are used. The following keywords are used for collecting relevant literature: ‘Mining industry’ AND ‘Occupational safety’, ‘Mining industry’ AND ‘Health issues’, ‘Developing countries’ AND ‘Occupational safety’, and ‘Developed countries’ AND ‘Occupational safety’. Research articles published only in the English language are preferred. Also, articles published after 2016 are considered for review. The initial search resulted in 123 research articles. Then, these 123 articles were analyzed in a stepwise manner. First, the title of the 123 articles is checked. Next, the abstract and keywords are looked at. Finally, the core problem addressed in the selected articles is analyzed. Based on the analysis, only 43 articles devotedly addressed the OHS problem concerned with the mining industry. The remaining articles contained only the word mining industry in the title and keywords. The finalized 43 articles are considered for narrative literature review. After reviewing the finalized 43 articles, 15 key factors impacting the health and safety of the mining workers were collected.

Since the collected factors are related to the real-time workers, a focus group interview was carried out to measure the worthiness of the factors collected. Focus group interviews are conducted with a group of participants to collect and verify the information. The number of participants in the focus group interview is usually limited to ten participants. Here, a small group of participants is preferred over a large group to avoid dominance and concept diversification (Heikkilä, & Katainen, 2021). In this study, ten participants working in the mining industry are approached for the focus group interview. The participants include the mine manager (3), superintendent (2), geologist (3), and process manager (2). The participants had 16 years' worth of experience working on average. At the beginning of the interview, the participants were asked to list the difficulties faced by them while working in the mining industry. Then, a list of identified 15 key factors impacting the health and safety of the mining workers were given to the participants. The factors were rated by them using a 5-point Likert scale. Factors receiving 50% of acceptance from the participants were further evaluated. Here, all the 15 factors identified from the literature received more than 50% acceptance from the participants, and hence, all 15 factors are considered for further evaluation. It is essential to ensure the reliability of the factors under consideration in any study (Toke, & Kalpande, 2018; Toke, & Kalpande, 2019). Hence, the reliability of the identified factors was examined using SPSS software. Here, Cronbach's alpha value of the identified factors is estimated (Kalpande, & Toke, 2022). The Cronbach's alpha value obtained in this study is 0.789 which is acceptable. The finalized 15 factors impacting the health and safety of mining workers are given in Table 2.

Table 2 List of health and safety factors identified

S. No	Health and Safety Factors	Description
1.	Dust inhalation or coal dust exposure (P1)	The emission of dust particles into the air from mining processes harms workers' health.
2.	Excessive Noise in the working Area (P2)	Extreme noise is produced in the working area by cutting, materials handling, crushing, conveying, drilling, blasting, ventilation, and ore processing.
3.	Whole body vibration (P3)	Workers who operate large-capacity haul trucks, front loaders, bulldozers, wheel dozers, etc., are facing whole-body vibration due to a continuous work schedule.
4.	Risk of over Exposure to UV (ultraviolet) radiation (P4)	Outdoor workers suffer health damage like skin aging, and eye damage due to exposure to UV radiation.
5.	Musculoskeletal disorders (P5)	Mining workers faced problems with lower back strain, muscle strains, pain in shoulders and neck due to repetitive strain, vibration, working in an awkward posture, and lifting heavy objects.
6.	Thermal or Heat stress (P6)	Exposure to extreme heat causes occupational illness and injuries to the mineworkers.
7.	Chemical hazards (P7)	Exposures of chemicals used in the mining process cause fire accidents, and explosions.
8.	Stress and Fatigue (P8)	Extreme tiredness both physically and mentally due to a tight work schedule.
9.	Fire Accidents (P9)	Fire accidents happened from the toxic gases used, flame-cutting, and welding processes which caused severe injuries to the workers.
10.	Cave-ins and Rock Falls (P10)	Due to the removal of earth and rock from their natural position, cave-ins and rockfall have occurred underground.
11.	Poor Ventilation (P11)	Inside subsurface mines, poor ventilation exposes workers to toxic gases, heat, and dust, leading to disease, injury, and death.
12.	Use of Explosive (P12)	Explosives used for constructive purposes cause hazardous injuries to mine workers and damage to property.
13.	Biological hazards such as malaria and dengue (P13)	In some distant mining areas, tropical diseases such as malaria and dengue fever pose a significant threat.
14.	Psychosocial hazards such as abusing Drug and alcohol (P14)	Consumption of drugs and alcohol by mining workers causes severe health problems.
15.	Work in high altitude (P15)	Work in high altitude areas causes unexpected falling and leads to severe injuries till death.

The factors were then rated by the participants using the fuzzy scale provided in Table 1. After receiving the ratings from the participants, Eq. (1) – (3) is used to determine the weights of the factors. The calculated defuzzified weights were given in Table 3. Cave-ins and Rock Falls (P10) and Biological hazards such as malaria and dengue (P13) have a low defuzzied weight of less than 0.5 in the results, which were not going to significantly impact the further SWARA calculation method. Hence these two factors were rejected for further processing. The remaining 13 factors were only carried forward for calculating the net weights. The results are given in Table 4.

Table 3 Results of defuzzified weights

Health and Safety Factors	Defuzzified weights	Select/reject	Symbol
Dust inhalation or coal dust exposure	0.624	Select	P1
Excessive Noise in the working Area	0.756	Select	P2
Whole body vibration	0.659	Select	P3
Risk of Over Exposure to UV (ultraviolet) radiation	0.657	Select	P4
Musculoskeletal disorders	0.669	Select	P5
Thermal or Heat stress	0.897	Select	P6
Chemical hazards	0.785	Select	P7

Health and Safety Factors	Defuzzified weights	Select/reject	Symbol
Stress and Fatigue	0.786	Select	P8
Fire Accidents	0.856	Select	P9
Cave-ins and Rock Falls	0.465	Reject	P10
Poor Ventilation	0.659	Select	P11
Use of Explosive	0.836	Select	P12
Biological hazards such as malaria and dengue	0.486	Reject	P13
Psychosocial hazards such as abusing Drug and alcohol	0.623	Select	P14
Work in high altitude	0.789	Select	P15

Table 4 Result of SWARA Approach

Factors	Sj	Kj	Wj	Qj	Rank
P5	-	1	1	0.34	1
P8	.866	1.866	.535	0.182	2
P1	.133	1.133	.472	0.160	3
P3	.365	1.365	.346	0.117	4
P2	.486	1.486	.233	0.079	5
P6	.556	1.556	.149	0.050	6
P7	.885	1.885	.079	0.026	7
P4	.587	1.587	.050	0.017	8
P9	.654	1.654	.030	0.010	9
P14	.559	1.559	.019	.006	10
P15	.567	1.567	.012	.004	11
P12	.657	1.657	.007	.0021	12
P11	.158	1.158	.006	.0020	13

5. Results and discussions

From the findings, it was noted that Musculoskeletal disorders (P5), Stress and Fatigue (P8), and Dust inhalation or coal dust exposure (P1) are identified as the top three critical factors causing problems to mine workers' health and safety. Musculoskeletal disorders (P5) are the top-ranked factor that occurred to the mining workers because of facing problems in lower back strain, muscle strains, pain in shoulders and neck due to repetitive strain, vibration, working in an awkward posture, and lifting heavy objects. A work by Smith, Balogun and Dillman (2022) advocated that workers in the mining industry are required to work in a constrained position for a prolonged time. Working in a constrained and awkward position for a long time exposes the workers to pain in the shoulders and neck and this results in musculoskeletal disorders. Besides, working in a congested workplace has exposed workers to respiratory problems. Though several improved techniques have been introduced for the automation of industrial activities, such kind of automation has failed to find its place in the mining industry (Rogers et al., 2019).

Next to the musculoskeletal disorders problem, stress and fatigue (P8) were identified as the second top-ranked factor. Stress and fatigue are due to the extreme tiredness both physical and mental of mineworkers (Inayah, & Widyawati, 2021). Psychological and physiological, cognitive and behaviour changes can be identified in the workers. Psychological represents the stress-induced actions of workers, weariness, and lack of motivation. Physiological changes like loss of strength and stamina and energy consumption loss occurred to the workers. Cognitive behavioral changes like slowed reaction time and forgetfulness are observed. Behavioral changes like eyelid closure or head nodding, slower speech, and decreased productivity. As the workers in the mining industry are forced to perform repetitive work under a constrained space, the exposure level of workers to stress and fatigue is high among the mining workers (Nunfam et al., 2021).

The third-ranked most important key factor is Dust inhalation or coal dust exposure (P1).

The release of dust particles in the air causes breathing problems for the workers. Inhaling coal dust, sand dust, and other minute-grained minerals may harm the lungs and cause severe breathing problems. Dust particles can irritate the eyes, and skin and breathing problems, and extended revelation can also cause a variety of severe lung infections. Implementation of safety precautions and adequate earlier checking will minimize the serious problems and enhance the safety level in the working environment (Bhalaji, Bathrinath, Samantra, & Saravanasankar, 2020). Marimuthu, Sankaranarayanan, Ali, and Karuppiah, (2021) recommended that the implementation of new technologies and innovative ideas will help to transition from fossil fuels to renewable fuels and to minimize the emissions level in the mining industry. Here, only the top three factors affecting the health and safety of the mining workers are discussed. However, the remaining factors considered in this study also need to be addressed by the mining industry in ensuring its safety and health of the mining industry. In a study, Fargnoli, Lombardi, Haber and Guadagno (2018) used the quality function deployment technique to analysis the hazards in the construction industry.

6. Managerial implications

According to the results, this work suggests some implications that could help the mining industry management in addressing the factors. First, musculoskeletal disorders are the most critical factor in this study as they completely collapse the mining industry's work. Since the mining industry demands more physical work, the workers are forced to work in a constrained environment. Thus, to lessen the burden on the workers, shift-based work allocation has to be followed by the mining industry. A study by Seifi, Schulze and Zimmermann (2021) on improving the health of mining workers suggested shift-based work allocation for the workers. Further, with the advancement of technologies, industrial activities have been mostly becoming automated in many industrial environments. Such kind of automation has to be used in the mining industry also (Paredes, & Fleming-Muñoz, 2021). Here, automation can be used in the transportation of raw materials. By maximizing automation wherever possible in the working areas, it is possible to reduce the repetitive strain on the workers. And also, involving robotics and other automation systems will be a favored decision in the extraction, transportation, loading and unloading of ores. Implementation of user-centric jobs also will reduce musculoskeletal disorder risks. Along with this, as mentioned by Fargnoli, De Minicis and Di Gravio (2011), the integration of knowledge management is very crucial in preventing and minimizing the occurrence of industrial accidents. Next, stress and fatigue are the second important factors to be addressed. Conducting periodic medical check-ups and counseling the workers helps to relieve their stress levels. Encouraging workplace wellness and involving in social activities helps to rectify psychological and behavioural changes. Improving work planning and scheduling, such as reassessing shift schedules and arranging different work apart from their regular repetitive work, could help reduce stress and fatigue. Asare-Doku, James, Rich, Amponsah-Tawiah, & Kelly, (2022) suggested recreational activities and motivational programs as the best interventions for enhancing the mental health of the workers. Dust inhalation or coal dust exposure is another important factor to consider. Removing hazardous gases by substituting a safer alternative will help to reduce breathing problems. Finally, implementing the Internet of things (IoT) and conducting predictive maintenance activities will help increase the productivity and safety aspects of the mineworkers. Effective eco-innovation methods will help to emphasize health and safety as well as environmental awareness (Marimuthu, Sankaranarayanan, Ali, de Sousa Jabbour, & Karuppiah, 2021).

7. Conclusion

This work aims to recognize, assess and reveal the OHS issues occurring the mining industry workers. Initially, a systematic literature review was conducted for factor identification, and fifteen factors were identified. Then, the identified factors were finalized by getting ten experts' opinions who have profound awareness and knowledge in the mining industry. Then, the SWARA technique was used to calculate the defuzzified weights of the factors. Out of fifteen factors, two factors were rejected because of low defuzzified weight values. The remaining thirteen factors were considered next to compute the net weights. The study's findings indicate that Musculoskeletal disorders, stress and fatigue, and dust inhalation or coal dust exposure are the top three ranking factors to address first to rectify the health and safety problems of mineworkers. Among these three factors, musculoskeletal disorder occupied the top position, primarily affecting mineworkers' health and safety problems. Severe back pain, shoulder pain, stress and fatigue problems, and other psychological problems are occurred due to repetitive strain and working in awkward postures, and lifting heavy objects. Companies should implement an alternate working process by maximizing automation and introducing IoT technology. IoT-enabled real-time updates will help to manage the operations as well as to improve business decision-making. Optimized operations and knowledge management will enhance the business logistics and equipment and improve quality control. And also, the company should implement predictive maintenance activity to avoid accidents in the working area. Sensors embedded in the equipment could help the machines' performance and help predict failure before it occurs. In this study, only ten participants from the mining industry were considered. In future work, the same study can be carried out by increasing the number of participants and may give different results.

8. References

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