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Research paper

Analysis and evaluation of risks in underground mining using the decision matrix risk-assessment (DMRA) technique, in Guanajuato, Mexico

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ABSTRACT

In this article special emphasis is placed on the importance of underground mining worldwide, in the Country of Mexico and in the State of Guanajuato, thereby generating the hiring of operational personnel to perform the main activities of this sector such as blasting, use of machinery and equipment, exploitation, fortification and amacize. Occupational accidents and diseases occur as a result of the aforementioned activities since the conditions in which workers work are not the most appropriate. To help improve working conditions, the decision matrix risk-assessment (DMRA) technique was applied, in which accidents are classified according to their severity and probability, in order to perform an assessment of the risks and identify the activities that should continue in the same manner, those that require control measures and, as a last resort, those activities that must stop. At the end of the study, corrective actions are proposed that can help to avoid the occurrence of the accidents presented, through the application of occupational safety and health regulations issued by the Secretaría del Trabajo y Previsión Social, which is a government entity that is responsible for both the issuing of and compliance with those regulations. Also establishes the obligations that must be documented according to rules that are applicable to mining activities.

1. Introduction

Globally, the most dangerous occupational sectors are: construction, agriculture and mining (ILO, 2018). In all industrial sectors, every company must take precautions related to accidents and occupational diseases. The activities or production processes that are carried out endanger life and human health (Chu & Muradian, 2016; Sanmiquel, Rossell, & Vintró, 2015).

Mining represents an important source of income worldwide (Mancini & Sala, 2018; Nguyen, Boruff, & Tonts, 2017). The production of metals is essential for modern life since they are used for manufacturing processes, energy, housing, technology and for the innovation of new alloys that aid the lives of human beings (Camacho et al., 2016; Huerta-Diaz, Muñoz-Barbosa, Otero, Valdivieso-Ojeda, & Amaro-Franco, 2014; Li & Zhan, 2018).

Mining investments create economic development through the direct and indirect generation of employment, social development through campaigns, significant improvements to the community in general and therefore contributes to reducing poverty (Foo, Bloch, & Salim, 2018). The constant increase in the extractive industry has led to an increase in labor and therefore to an increase in accidents at work (Comberti, Demichela, & Baldissone, 2018; Pietilä, Räsänen, Reiman, Ratilainen, & Helander, 2018).

In Mexico, for 2016, the mining sector contributed 4% of the national Gross Domestic Product and Mexico was the biggest silver producer globally, with 25% (SE, 2018).

In Mexico a report presented on the incidence rate of accidents for the period 2010–2015 of an underground mine in Mexico. In which the disabling accidents are calculated per 100 workers; in 2010 this was 3.2 and in 2015 2.7. The average incidence rate of underground accidents at the national level is 2.03, in 2015 the incidence rate in underground mining exceeded the national average, reaching 2.73. Exceeding the national average is caused by an increase in accidents that can range from small injuries to fatal accidents. Fatal accidents in 2015 decreased from 73 in 2012 to 35. Of the 35% of fatal accidents which occurred in 2015, 46% occurred in mining companies affiliated with the Cámara Mexicana de Minería. The highest incidence rate occurs in unaffiliated companies. 46% of the fatal accident rate equals a total of 19 accidents

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in 2015, these are divided into different types, such as falling stone (10 accidents), blasting (1 accident), run over (1 accident), other factors (2 accidents), electrocuted (2 accidents) and trapped by machinery (3 accidents). The age ranges of the victims of fatal accidents were as follows: 30 to 39 five accidents, 40 to 49 three accidents, 20 to 29 three accidents, 50 to 60 two accidents, 16 to 19 one accident and in 5 of the accidents the age of the victim unknown. 63% of these accidents occurred in contractor companies (CAMIMEX, 2015).

The mining district of the State of Guanajuato has been one of the main producers of silver nationally through the years and as it is a state with a large number of air and land transport routes it has become an investment center for mining companies. Underground mining is one of the main economic activities of the state and it has led to the development of the state, figures given by Servicio Geológico Mexicano and Secretaría de Economía between 2015 and 2016 show Guanajuato had a production of 2367.30 kg of gold 169,310 kg of silver, due to the operation of three mining plants of: Endeavor Silver Corp and Great Panther Silver LTD (SE, 2018). The continuous increase of investment in the state in the mining industry generates more production and therefore the hiring of more personnel. This has led to the increased need to apply safety and hygiene programs that contribute to controlling accidents and occupational diseases within the sector (Azadeh-Fard, Schuh, Rashedi, & Camelio, 2015).

Underground mining focuses on extracting minerals by excavating the land to obtain them (Ben-Awuah, Richter, Elkington, & Pourrahimian, 2016). However; the conditions to which workers are exposed during working hours are not optimal and as a consequence of this work accidents and illnesses that affect the workers' quality of life arise (Sanmiquel et al., 2015).

The constant increase in the underground mining industry has led to the use and implementation of new technologies and the use of different substances for the processing and extraction of minerals, which increases the risks in the activities that develop in the mine (Gonzalez-Delgado et al., 2015). The increase in activity increases labor directly or indirectly and is proportional to the increase in risks, injuries and even deaths (Brown, 2017).

The risk of accidents in mining depends on the nature of the mine, in underground mining the workers performs their activities in confined spaces, therefore they are exposed to a high number of elements that can affect their health, cause illness or death (Amirshenava & Osanloo, 2018; Duzgun & Einstein, 2004; Mishra et al., 2017). Accidents are traumatic and costly for the workers and their families. They can be also a burden on mining companies because, in addition to the costs of personal injuries, they may incur far greater costs from damage to property or equipment and production losses (Sari, Selcuk, Karpuz, & Duzgun, 2009).

Some of the most common causes of occupational diseases and accidents in underground mining are: environmental risks, risks of physical and mental overload and risks derived from specific sources (Ryan & De Souza, 2017).

Environmental risks are factors that are present in the working environment and that impede the proper performance of work, these risks can include physical, chemical and biological contaminants (Krzemień, Sánchez, Fernández, Zimmermann, & Coto, 2016; Pashkevich, 2017).

Physical contaminants are environmental conditions from different point sources, such as noise, temperature, lighting, vibrations, etc. Being exposed to them can directly or indirectly affect the human body (Dudek, Dudek, & Przystupa, 1998; Feng & Wang, 2011).

Chemical contaminants are those that are constituted by inert matter in the form of solids, gases, vapors, dust, fumes, etc., which when in contact with a worker, can cause moderate to severe damage (Chaulya & Prasad, 2016; Dong, 2012; Widiatmojo et al., 2015). Biological contaminants are agents generated by microorganisms that can cause some type of infection, allergy and intoxication, some of these contaminants are bacteria, viruses, fungi, parasites, etc.

When the human body is subjected to some strain to perform certain activities, the individual may be exposed to risks of physical and mental overload. Ergonomic and psychosocial risks also fall under this category (Amponsah-Tawiah, Jain, Leka, Hollis, & Cox, 2013).

Ergonomic risks relate to tasks performed by the worker which can lead to them suffering damage to sensitive parts of the musculoskeletal system. This can be caused by, for example: over exertion when lifting a load, repetitive movements that can cause injuries and inadequate postures (Mayton, Porter, Xu, Weston, & Rubenstein, 2018; STPS, 2017; Winn Jr, Biersner, & Morrissey, 1996).

Psychosocial risks consist of anxiety and stress disorders which constitute inadequate work conditions, caused by, for example: traumatic events and workplace violence (Amponsah-Tawiah, Leka, Jain, Hollis, & Cox, 2014; Roghanchi & Kocsis, 2018).

Another category of factors that affect workers in the work environment are mechanical and electrical risks. Mechanical risks are caused by the use of machines that can cause entrapment, dismemberment, particle projection, falls, blows, etc. Electrical risks are caused by electrical installations or equipment, which can cause electric shocks, fires or explosions due to overloads or short circuits in conductors (Mahdevari, Shahriar, & Esfahanipour, 2014).

Finally, it is important to consider the fact that:

> "natural hazards are indeed geophysical events, such as earthquakes, landsliding, volcanic activity and flooding. They have the characteristic of posing danger to the different social entities of our planet, nevertheless, this danger is not only the result of the process per se (natural vulnerability), it is the result of the human systems and their associated vulnerabilities towards them (human vulnerability)" (Alcantara-Ayala, 2002, p.108).

> "The hazard relates to the source of harm, while risk is the probability of the harm being experienced. The risk may be defined as a combination of hazard and probability of hazard occurrence, where hazard is defined as the degree of harm to human beings, property, society or environment. In this context risk analysis can be defined as an exercise, which includes both qualitative and quantitative determination of risk and its multidimensional impacts" (Khan & Abbasi, 1998, p. 262).

> "The risk is measurable uncertainty, uncertainty is an immeasurable risk. This implies that, when it is measurable, an uncertainty must be considered a risk, therefore the risk is quantifiable and lends itself to the evaluation" (KarimiAzari, Mousavi, Mousavi, & Hosseini, 2011, p. 9106).

In risk analysis and assessment methodologies, the techniques are classified into three main categories:

Qualitative: qualitative techniques are based both on analytical estimation processes, and on the safety managers engineers ability. For example: checklists, What-If Analysis, safety audits, task analysis, the STEP technique and HAZOP.

Quantitative: risk can be considered as a quantity, which can be estimated and expressed by a mathematical relation, using data of real accidents recorded on a work site. For example: the proportional risk-assessment (PRAT), the decision matrix risk-assessment (DMRA), risk measures of societal risk (SRE), Quantitative Risk-Assessment (QRA), Quantitative Assessment of Domino Scenarios (QADS), Clinical Risk and Error Analysis (CREA), Predictive, Epistemic Approach (PEA) and Weighted Risk Analysis (WRA).

Hybrid techniques: qualitative and quantitative, semi-quantitative. Hybrid techniques can be of great complexity. For example: Human Error Analysis Techniques (HEAT) or Human Factor Event Analysis (HFEA), FTA Fault-tree analysis, ETA (Event Tree Analysis) and Risk-based Maintenance (RBM).

In this article the decision matrix risk-assessment (DMRA) will be applied which has the following advantages:

- Easy application of the technique
- Safe results, based on the recorded data of undesirable events or accidents
- It combines risk analysis with risk evaluation
- It can help the safety managers/engineers to predict hazards, unsafe conditions and undesirable events/situations, and also to prevent fatal accidents.
- It can be applied to any company/corporation or productive procedure
- It is a quantitative and also a graphical method which can create liability issues and help the risk managers to prioritize and manage key risks.

The disadvantage is that the results depend on the opinion of expert safety managers or production engineers (Marhavilas, Koulouriotis, & Gemeni, 2011).

2. Material and methods

The Secretaría del Trabajo y Previsión Social is responsible for monitoring compliance with regulations on occupational safety and health. This establishes mandatory risk analysis for the identification of hazards and risk control of the work centers (STPS, 2012).

As previously mentioned, this article focuses on a company in the mining sector in the State of Guanajuato Mexico. The study applies "the decision matrix risk-assessment (DMRA) technique, it is a systematic approach for estimating risks, which is consisting of measuring and categorizing risks on an informed judgment basis as to both probability and consequence and as to relative importance" (Marhavilas et al., 2011, p. 480).

Below the series of steps necessary to carry out the identification and evaluation of the risks is presented:

1. Subjective mapping of the risks derived from carrying out the main activities of underground mining is performed according to Table 1.

In the context of the risk matrix the value of risk is a discrete value, corresponding to the categories of consequence and likelihood: "If frequency is "f"' category AND severity of consequences is "c" category THEN risk is "r" category". The likelihood categories can be respectively identified by nominal, textual descriptions, such as "negligible", "serious", "catastrophic", and "almost impossible", "probable", "often". It is logical that the categories should be placed in order along the sides (ordinates) of the risk matrix, that is to say consequence categories should be ranked from least to most severe, and likelihood categories should be ranked from lowest to highest. (Duijm, 2015, p. 22) (See Table 2).

2. Classify accidents according to their impact on the environment, human life or the economic position of the company, that is to say the severity of the year caused.

The likelihood is expressed as frequency (number of expected occurrences per unit time), and these frequencies may vary by many orders of magnitude. Thus, likelihood is represented on a logarithmic scale. Consequence categories can also be expressed on scales of a logarithmic nature, in many safety-related risk matrices different "metrics" are used in subsequent categories in such a manner that it obscures the nature of the scaling, for instance: minor injuries, loss-time injuries, severe injuries, and fatalities. (Duijm, 2015, p. 24) (See Table 3).

3. Development of the risk matrix for each work activity according to the aforementioned statistics, considering likelihood classes and consequence classes (See Tables 4–8).

Table 1
Subjective mapping of the risks derived from executing underground mining activities.

Activity	Risk							
	Environmental risks			Risks of physical and mental overload		Risks from specific sources		Natural risks
	Physical	Chemicals	Biological	Ergonomic	Psychosocial	Mechanics	Electrical	
Blasting: action and result of the use of explosives to break rocks or minerals	Dust, noise, vibrations, high and low temperatures and lighting	Irritability due to dust contact			Stress due to high concentration for the time needed to perform the activity			Landslides, floods and earthquakes
Use of mining machinery and equipment:	Noise, vapors, gases, and vibrations	Contact with hydraulic oils		Inadequate and repetitive postures		Entrapment, shock, and particle projection	Electrocution when machinery or mobile equipment is driven by electrical energy	Landslides, floods and earthquakes
Exploitations: the works destined to the preparation and development of the area that contains the mineral deposit, as well as those works which aimed to knock down and extract the materials in a mine	Temperature, dust, lighting, gases, noise and vibrations			Inadequate and repetitive postures	Monotonous activities			Landslides, floods and earthquakes
Fortification: the reinforcement of the roof, floor and walls of a mining project through any structural support system	Temperature, dust, lighting, gases, noise and vibrations	Poisoning		Inadequate and repetitive postures	Stress for high concentration necessary to perform the activity			Landslides, floods and earthquakes
Amacizar: the action of testing the walls, ceiling and front of an area of work or gallery by means of an iron bar, to knock down badly adhered rocks that may represent a risk to the personnel	Temperature, dust, lighting, gases, noise and vibrations			Inadequate and repetitive postures				Landslides, floods and earthquakes

Table 2
Example of risk matrix to use risk matrix.

		Consequence classes			
		C1 (1) Insignificant Consequences	C2 (2) Significant Consequences	C3 (3) Serious Accident	C4 (4) Major Accident
Likelihood classes	F4 (4) Frequent	R4	R8	R12	R16
	F3 (3) Probable	R3 No personal Harm	R6 Recoverable Injuries	R9	R12
	F2 (2) Improbable	R2	R4	R 6 Single Fatality and several Injuries	R8 Several Fatalities and many Injured
	F1 (1) Very Improbable	R1	R2	R3	R4

Table 3
Accidents that occurred in the year of 2016 classified by severity.

Activity	C1: Insignificant consequences	C2: Significant consequences	C3: Serious accident	C4: Major accident
Blasting	0	0	0	0
Use of mining machinery and equipment	3	1	1	0
Exploitation	4	4	0	0
Fortification	2	2	0	0
Amacizar	20	12	0	0
Total	29	19	1	0

Table 4
Risk matrix of the blasting activity.

	Consequence classes			
Likelihood classes	4	8	12	16
	3	6	9	12
	2	4	6	8
	1	2	3	4

Table 5
Risk matrix of the use of machinery and equipment.

	Consequence classes			
Likelihood classes	4	8	12	16
	3	6	9	12
	2	4	6	8
	1	2	3	4

3. Results

According to the activities evaluated in the decision matrix risk-assessment (DMRA) technique, it proceed to present tables of results with the corresponding analysis.

Table 6
Risk matrix of the exploitation activity.

	Consequence classes			
Likelihood classes	4	8	12	16
	3	6	9	12
	2	4	6	8
	1	2	3	4

Table 7
Risk matrix of the fortification activity.

	Consequence classes			
Likelihood classes	4	8	12	16
	3	6	9	12
	2	4	6	8
	1	2	3	4

Table 8
Risk matrix of amacizar activity.

	Consequence classes			
Likelihood classes	4	8	12	16
	3	6	9	12
	2	4	6	8
	1	2	3	4

For the blasting activity, according to the statistics presented in which there are no accidents, it has been determined that they can be presented no personal harm and single fatality and several injuries. However, for a better analysis of the results, the NOM-023-STPS-2012: Trabajos en minas subterráneas y a cielo abierto is used, which classifies the magnitude of the risk as serious, high, medium, low and minimal. For the blasting activity the level of risk is minimal, low and high, therefore, the following actions should be taken: minimal risk requires attention, low risk requires attention and correction if necessary, for high risk immediate attention and review of security conditions is required (See Table 9).

The use of mining machinery and equipment, according to the statistics, led to 4 accidents of which 1 was fatal, which is located at the intersection of categories F2: Unlikely and severity and C3: Serious Accident. It is determined that they can be presented no personal harm and single fatality and several injuries. However, special attention should be paid to corrective actions to avoid the occurrence of a new fatality that occurred unexpectedly and without warning. However, for a better analysis of the results, the NOM-023-STPS-2012: Trabajos en minas subterráneas y a cielo abierto is used, which classifies the magnitude of the risk as serious, high, medium, low and minimal. For the

Table 9
Likelihood classes and consequence classes of the blasting activity.

Blasting	C1: Insignificant consequences	C2: Significant consequences	C3: Serious accident	C4: Major accident
Accidents	0	0	0	0
Probability to happen with its consequence.	F1: very improbable	F2: Improbable	F3: Probable	F4: Frequent
R	R1	R2	R3	R4
	No personal harm		Single fatality and several injuries	

Table 10
Likelihood classes and consequence classes of the use of mining machinery and equipment activity.

Use of mining machinery and equipment	C1: Insignificant consequences	C2: Significant consequences	C3: Serious accident	C4: Major accident
Accidents	3	1	1	0
Probability to happen with its consequence.	F2: Improbable	F1: Very improbable	F2: Improbable	F1: Very improbable
R	R2	R4	R6	R4
	No personal harm		Single fatality and several injuries	

use of mining machinery and equipment the level of risk is minimal, low and high, therefore the following actions should be taken: minimal risk requires attention, low risk requires attention and correction if necessary, for high risk immediate attention and review of security conditions is required as a fatal event occurred due to this activity (See Table 10).

There were 8 exploitation accidents, which were classified as having Insignificant Consequences and Significant Consequences. It is determined that they can be presented no personal harm and single fatality and several injuries.

However, for a better analysis of the results, the NOM-023-STPS-2012: Trabajos en minas subterráneas y a cielo abierto is used, which classifies the magnitude of the risk as serious, high, medium, low and minimal. For the activity of exploitation the level of risk is minimal, low and high, therefore the following actions should be taken: minimal risk requires attention, low risk requires attention and correction if necessary, for high risk immediate attention and review of security conditions is required (See Table 11).

For the activity of fortification, there were 4 accidents, which were classified as having Insignificant Consequences and Significant Consequences. It is determined that no personal harm and single fatality and several injuries may be presented.

However, for a better analysis of the results, the NOM-023-STPS-2012: Trabajos en minas subterráneas y a cielo abierto is used, which classifies the magnitude of the risk as serious, high, medium, low and minimal. For the activity of fortification the level of risk is minimal, low and high, therefore the following actions should be taken: minimal risk requires attention, low risk requires attention and correction where appropriate, for high riskis immediate attention and review of security conditions is required (See Table 12).

For the activity of amacizar 32 accidents occurred, which were classified as having Insignificant Consequences and Significant Consequences. It is determined that recoverable injuries and single fatality and several injuries may be presented.

However, for a better analysis of the results, the NOM-023-STPS-2012: Trabajos en minas subterráneas y a cielo abierto is used, which classifies the magnitude of the risk as serious, high, medium, low and minimal. For the activity of amacize the level of risk is medium and high, therefore the following actions should be taken: for medium risk correction is required and for high risk immediate attention and revision of the security conditions is required (See Table 13).

4. Discussion

Independently of applying the decision matrix risk-assessment (DMRA) technique and as a result of the evaluation of the activities of blasting, use of machinery and equipment, exploitation, fortification and amacizar where these are located within the matrix as: no personal harm, recoverable injuries and single fatality and several injuries, except several fatalities and many injured by the preventive actions that are applied within the mining industry. However, it is important to note that during the use of machinery and equipment a fatal event occurred, which was an unexpected event on the part of the security team. before this it is important to apply immediate corrective actions to prevent accidents from occurring. Elevate and move it one step up within the risk assessment matrix and it should be considered as several fatalities and many injured.

The use of NOM-023-STPS-2012: Trabajos en minas subterráneas y a cielo abierto, was required for the analysis of the magnitude of risk in which the actions that should be taken are mentioned according to the

Table 11
Likelihood classes and consequence classes of the exploitation activity.

Exploitation	C1: Insignificant consequences	C2: Significant consequences	C3: Serious accident	C4: Major accident
Accidents	4	4	0	0
Probability to happen with its consequence.	F2: Improbable	F2: Improbable	F1: Very improbable	F1: Very improbable
R	R2	R4	R3	R4
	No personal harm	Single fatality and several injuries		

level of risk that classified each work activity.

5. Conclusions

The risk assessment matrix allows organizations to categorize work accidents in terms of severity and their probability of occurrence, thereby establishing evaluation criteria to classify the work activity as green (no personal harm), yellow (recoverable injuries, a single fatality and several injuries) and red (several fatalities and many injured). With the identification of colors, it is possible to inform risk assessors that they should take control measures to prevent the repetition of occupational accidents within this industry.

In addition to the aforementioned analysis, we propose corrective measures that should be applied to avoid an increase in accidents and occupational diseases in this company:

For the blasting activities the risks are as follows: Physical, chemical, psychosocial and natural. For this activity the following preventive activities are applied: Separation of explosive material, transport of explosive separated from high explosive with artifices, non-use of metallic elements, Specialized transport vehicles, training on the use and handling of explosives and the use of protective equipment for specific staff. The following standards should be applied: NOM-023-STPS-2012, Minas subterráneas y minas a cielo abierto – Conditions of health and safety at work, NOM-026-STPS-2008 Colores y señales de seguridad, NOM-017-STPS-2008 Equipo de protección personal, SEDENA 02-039, Ley federal de Armas de Fuego y Explosivos; training is required in: Security procedures for the reception, storage, internal transport, handling and use of explosives to produce blasting, use, handling, disinfection and final destination of Personal Protective Equipment, safety signs to identify stored products, the associated risks and security conditions.

The activity of Use and Management of Machinery and Equipment carries the following risks, identifies Physical, chemical, ergonomic, mechanical, electrical and natural. The current control measures are: Emergency stops, the ANSUL suppression system, Training in the use and management of machinery and equipment, an Internal Control License and Mandatory use of personal protective equipment. The regulations that must be applied will be: NOM-004-STPS-1999 Sistemas y dispositivos de seguridad en maquinaria, NOM-002-STPS-2010 Prevención y protección contra incendios, NOM-023-STPS-2012 Trabajos en minas subterráneas y a cielo abierto, NOM-017-STPS-2008 Equipo de protección personal, NOM-018-STPS-2000 Identificación de peligros y riesgos por sustancias químicas, Norma Oficial Mexicana PROY-NOM-036-1-STPS-2017, Factores de riesgo ergonómico en el trabajo-Identificación, análisis, prevención y control. Parte 1-Manejo manual de cargas. Training should be provided on: machinery and equipment in underground mines. Work procedures must be in place that contain the applicable safety measures and prohibitions, according to the corresponding risk analysis. Training in: the use, and handling of personal protective equipment, use and handling of fire-fighting equipment, blocking and tapping, repetitive postures and activities, handling hazardous chemical substances, safe operation of machinery and equipment, as well as the tools they use to develop their activity and safety procedures and safe work practices on load manuals. Finally, it is necessary to create awareness, training and apply serious policies in the workers to apply safe work procedures.

Table 12
Likelihood classes and consequence classes of the fortification activity.

Fortification	C1: Insignificant consequences	C2: Significant consequences	C3: Serious accident	C4: Major accident
Accidents	2	2	0	0
Probability to happen with its consequence.	F2: Improbable	F2: Improbable	F1: Very improbable	F1: Very improbable
R	R2	R4	**R3**	**R4**
	No personal harm	Single fatality and several injuries		

Table 13
Likelihood classes and consequence classes of the amacizar activity.

Amacizar	C1: Insignificant consequences	C2: Significant consequences	C3: Serious accident	C4: Major accident
Accidents	20	12	0	0
Probability to happen with its consequence.	F4: Frequent	F4: Frequent	F1: Very improbable	F1: Very improbable
R	R4	R8	R3	R4
	Recoverable injuries		Single fatality and several injuries	

Exploitation activity leads to identifies Physical, ergonomic, psychosocial and natural risks. The controls that are currently applied are: Delimitation of the area, ventilation systems and mandatory use of personal protective equipment. The following normative framework must be fulfilled: NOM-023-STPS-2012 Trabajos en minas subterráneas y a cielo abierto, NOM-017-STPS-2008 Equipo de protección personal, NOM-006-STPS-2014 Manejo y almacenamiento de materiales y Norma Oficial Mexicana PROY-NOM-036-1-STPS-2017, Factores de riesgo ergonómico en el trabajo-Identificación, análisis, prevención y control. Parte 1-Manejo manual de cargas. Training should be provided on safety procedures for conducting exploration and exploitation activities, use, and handling of personal protective equipment, use and handling of explosive material, safe work procedure, handling and storage of materials, safety procedures and safe work practices on manual loads. It is necessary to create awareness, provide training and serious policies on workers to apply work procedures.

For the activity associated with fortification, physical, chemical, ergonomic, Psychosocial and natural risk are identified. The preventive activities that are current applied are: Delimitation of the area, ventilation systems, mandatory use of personal protective equipment and training. The following regulatory framework must be fulfilled: NOM-023-STPS-2012 Trabajos en minas subterráneas y a cielo abierto, NOM-017-STPS-2008 Equipo de protección personal, NOM-006-STPS-2014 Manejo y almacenamiento de materiales y Norma Oficial Mexicana PROY-NOM-036-1-STPS-2017, Factores de riesgo ergonómico en el trabajo-Identificación, análisis, prevención y control. Parte 1-Manejo manual de cargas. Training must be specific on: Use, handling, disinfection and final destination of the Personal Protective Equipment, Safe work procedure for fortification activity, the Handling and storage of materials and safety procedures and safe work practices on load manuals.

Finally, for the activity associated with the amacizar, physical, ergonomic and natural risk are identified. The preliminary activities that are currently applied are: Ventilation systems and, Mandatory use of personal protective equipment. The regulatory framework that must be met is: NOM-023-STPS-2012 Trabajos en minas subterráneas y a cielo abierto, NOM-017-STPS-2008 Equipo de protección personal y Norma Oficial Mexicana PROY-NOM-036-1-STPS-2017, Factores de riesgo ergonómico en el trabajo-Identificación, análisis, prevención y control. Parte 1-Manejo manual de cargas. Training must be based on: The Use, handling, disinfection and the final destination of Personal Protective Equipment, Safety procedures for conducting amacizar activities and Safety procedures and safe work practices on manual loads.

Conflicts of interest

None declared.

Ethical statement

Authors state that the research was conducted according to ethical standards.

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Appendix A. Supplementary data

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None.

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