Implementation of a risk-based OHS management system at IMC mining company

Igor Skripnik[1*], *Dmitry* Savelev[1], *Tatyana* Kaverzneva[2], and *Nina* Rumyantseva[2]

[1]Saint - Petersburg University of the State Fire Service of the Ministry of Emergency Situations of Russia Moskovsky Prospekt, 149, 196105, Saint Petersburg, Russian Federation
[2]Peter the Great St. Petersburg Polytechnic University 29, Politekhnicheskaya st, 195251, Saint Petersburg, Russian Federation

Abstract. IMC mining company produces gold and silver. In mining operations that are carried out every day in the workplace, there must be dangers and risks. All these hazards are more related to the transport systems and transport used in the mining process. International mining company (IMC) underground mines definitely have operations division jobs with a high level of risk against work accidents, for example, maintenance of transport installations and the systems. Therefore, it is important to identify hazards, risk assessments, and determine the type of risk control in the section where work accidents are found. Hazard Identification and Risk Assessment Determining Control is a prevention program against fatal incidents. Risk Management at IMC is based on the Hazard Identification and Risk Assessment Determining Control (HIRADC) methodology which focuses on managing mining safety risks. This article aims to find out what the potential hazards and risks are contained in the work of the engineering and transport of underground mining division as well as provide preventive measures to reduce these risks. **Keywords:** risk management, hazard identification, risk assessment determining control, underground, mining vehicles.

1 Introduction

Occupational safety and health in a company is one of the important aspects that need to be known, because the success of a company in achieving its goals is determined by the occupational safety and health of the workers in the company [1,2,3].

In industrial world there is the term Occupational Health and Safety, Occupational Health and Safety are all activities to guarantee and protect the health and safety of workers through efforts to prevent work accidents and occupational diseases [3-5]. Occupational Health and Safety aims to prevent accidents and work-related illnesses, provide protection to production sources so as to increase efficiency and productivity [6,7,8]. Occupational Health and Safety is an important element that must be owned by every company. Occupational health and safety is one aspect of protection for workers regulated in the Russian Law and OHAS. IMC is a company engaged in copper and gold mining. Company name changed for security

*Corresponding author: ig.skripnick2011@yandex.ru

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (http://creativecommons.org/licenses/by/4.0/).

reasons. IMC operates and conducts mining activities on the Eurasian part of the mainland [1,4,8]. Mining activities are carried out by open pit mining and underground mining. There are values that are reflected in SINCERE, namely - Safety, Integrity, Commitment, Respect and Excellence. The aim of SINCERE is to promote these values within the organization as basic pillars of corporate identity which are a core part of PTFI's operations. Vehicle accident information taken from the OHS division – PTFI, accidents with light to severe categories.

In IMC's underground mine transportation system, there are several companies that help in supplying underground mining transportation equipment. Those companies are ORICA, CATERPILLAR, SANDVIK. Australian mining equipment company ORICA supports the blasting process. CATERPILLAR is the world's leading American manufacturer of construction and mining equipment. CATTERPILAR at IMC underground mines, provides transportation services in the hauling process in underground mines. The vehicles used are TRUCK HAULING: AD30, AD55, AD 60, ADT 740, ADT 745. LOADER TRUCK: LHD 1600 & LHD 1700. SANDVIK is a mining transportation company from Sweden. SANDVIK provides ground support with JUMBO DRILL & SOLO DRILL transportation equipment. The transportation device is designed for fast and accurate drilling in tunneling and cave excavation. The types of light vehicles used around the IMC work area are the Toyota Hilux, Toyota Land Cruiser, Ford Ranger and Fort Everest which are operated in the High Land area, which has steep, narrow, winding, foggy, high rainfall and slippery road conditions on the road with the altitude 3700 – 4200 masl. Production of ore from the underground mine once reached 60,000 tons per day, making it one of the largest underground mining in the world. With the overall length of the underground mine reaching 500 KM, with a depth of 1.6 KM below ground and the area of 3.5 KM in diameter, it definitely requires a lot of vehicles to support mining activities at PTFI. It is possible for a vehicle accident to occur in an underground mine or IMC's work area.

This article will discuss about the application of mining safety management of the basic principles of “Hazard Identification, Risk Assessment, Determining Control (HIRADC)” as the implementation of a risk-based occupational health and safety management system in the workplace, IMC, to knowing the top risks that affect the mining process.

2 Materials & methods

HIRADC is also known as risk assessment or identification of hazards and OHS aspects. The organization shall establish, establish, implement and maintain procedures for carrying out hazard identification, risk assessment and determining the necessary hazard and risk controls [5,8-10].

There have been many incidents or accidents that have occurred as a result of not recognizing the hazards and risks related to work or activities in the workplace. This Hazard Identification, Risk Assessment, and Determining Control (HIRADC) program was implemented to overcome this problem [7,11-13]. This program is a prevention program against incidents. It is based on the concept of thinking that all accidents have a cause and those causes can be identified and the risk can be assessed. Therefore, the hazards of work need to be recognized; then the risk is assessed, the control device is determined, and carried out properly so that the hazard and risk do not cause an incident.

HIRADC or commonly called Hazard Identification Risk Assessment and Determine Control is the process of identifying hazards, measuring and evaluating the risks arises from a hazard that can occur in routine or non-routine activities in company, for further risk assessment of the hazard [13-15]. Result of the risk assessment is useful for making a hazard control program so that company can minimize the level of risk that may occur so that they can prevent work accidents. The purpose of this study is to prevent and reduce the risk work

accidents at IMC 's underground mining operations division using the HIRADC (Hazard, Identification, Risk Assessment, and Determine Control) method [5,8,10].

The context of HIRADC should consider the following internal and external factors:

2.1 Internal factors

Routine and non-routine activities/processes. Routine activities are defined as scheduled or frequent activities with the same process and work environment.

All changes to the organization's business processes caused by:

Changes in the organization, work environment, activities or materials that may lead to Modifications to the mining Safety management system, including temporary changes and impacts on operations, processes and other activities.

Normal and abnormal conditions of a process, potential incidents and emergency conditions during the process cycle.

Non-compliance with established recommendations, standards or existing mining safety procedures, or no follow-up to the recommendations given for incidents.

Worker's personal factors

Systems, maintenance and security of facilities, infrastructure, installation and mine tools.

Evaluation of the report on the technical review of the mine.

2.2 External Factors

Culture, politics, law, finance, technology, economy, nature and the environment competitive at local, national, regional and international levels.

The main motivators and development issues affecting the organization's goals.

Perceptions and values of external stakeholders.

Hazards identified from outside the worksite that could be hazardous safety and health of people in workplaces controlled by the company.

Legal obligations related to hazard identification and risk evaluation and necessary control.

Other things that can affect Mining safety.

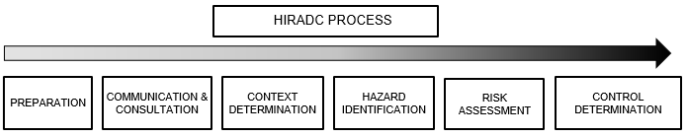

Fig. 1. HIRADC Process (compiled by authors).

HIRADC Process

1. Preparation (Pre-HIRADC)

The HIRADC methodology should consist of 5 (five) activities: communication and consultation, determining the context of a risk, identifying hazards and assessing risks, control risk, monitor and review.

2. Communication and consultation and must be carried out in every step of risk management in the form of:

a) Consultation with personnel or organizations with related expertise:

- Obtaining data or information from related parties such as data surveys, statistics, production reports, maintenance reports, manufacturing data, etc.
- Consult with experts such as government, teachers, parties makers, experienced employees, Mining Safety Practitioners, external advisor, etc.

b) Risk management communication:

- Internal parties such as employees, management, unions, parent company, etc.
- External parties such as Mining Service Companies, guests, Governments, shareholders, communities, external auditors, associations mining, etc.

3. Context Determination

- Determination of the risk context is related to determining the limits of the risk to be managed and determining the scope of the next HIRADC process. The context includes the determination of internal factors, external factors, the context in the HIRADC process, and the determination of risk criteria.

4. Hazard Identification is the process of recognizing the existence of a hazard. Identifying hazards is the most important part of the HIRADC process. Control measures against a hazard cannot be carried out if the hazard is not or has not been identified. Thorough hazard identification is very important so that no hazards are missed in this process.

5. Risk Assessment is a process of evaluating risk by observing the adequacy of the controls that have been implemented and determining whether a risk is acceptable or not. For the calculation of risk, it is necessary to combine consequences and possibilities using the HIRADC Matrix.

6. Determination of Risk Control is the process of determining effective mitigation measures based on the control hierarchy to reduce risk to a tolerable risk or to a tolerable level.

2.3 OHS Risk Assessment

IMC has FRM (Fatal Risk Management) program, which is FRM is a continuous program of HIRADC which is the implementation of a risk-based OHS management system in IMC 's workplace. FRM only focuses on the impact of accidents on workers. Then the risk assessment to risk identification using HIRADC. Injury, fatality and Risk Assessment from HIRADC become the main priority in determining the Top Risk [1,4,11].

The calculation of the risk value to determine the highest risk order uses a constant from the adjusted HIRADC Matrix 4x4 risk assessment (Table 1).

Table 1. PTFI's 4x4 Risk Assessment Matrix.

FCX 4x4 RISK ASSESSMENT MATRIX				**CONSEQUENCE**
4	8	12	16	Catastrophic (4)
3*	6*	9	12	Significant (3)
3	6			
2	4	6	8	Moderate (2)
1	2	3	4	Minor (1)
Unlikely (1)	Possible (2)	Likely (3)	Almost certain (4)	LIKELIHOOD OF OCCURRENCE
Highly unlikely to occur during the lifetime of an operation/project	Event that may occur during the lifetime of an operation/project	Event that may occur (<once per year)	Recurring event during the lifetime of the operation/project or >once per year.	

Rating Level	**Response required for risks identified on the SD Risk Assessment Form**
Actionable	Action Plan summary Form required. Identify key actions/milestones to be accomplished. Hierarchy of controls required to correct the risk (corrective and preventive actions

	needed). Determine if interim controls are needed to allow the activity to continue pending completion of action plan.
Monitor	Monitoring Plan Summary Form required
Medium	Monitoring required; proactive measures needed to prevent transition to Actionable. No Action or Monitoring Plan Summary Forms required.
Low	Monitor foe trends and patterns which may indicate increasing risk

*For H&S risks; risks with potentially fatal "significant" consequences and "unlikely" frequency, the Rating Level is "Medium" (yellow), requiring a monitoring effort consistent with IMC's Fatality Prevention Program. For H&S risks with "unlikely" likelihood and "catastrophic" consequences, or "possible" likelihood and "significant" consequence, the Rating Level is "Monitor" (orange), requiring a formal, documented monitoring plan specific to the risk.

Apart from using the risks and controls from HIRADC, the development of UG Mine Top Risk and Critical Control is also an extract from inputs by field supervisors and safety officers from both IMC and Contractors.

Calculate pure Risk by combining consequences and probabilities using HIRADC Matrix.

Consequences are the potential consequences, effects or outcomes of an event and/or activity related to injury, occupational disease, property damage and/or production loss. Pure Risk is all risk that can be calculated and identified that stands alone and has not been mitigated with all controls. Determining the consequences must consider aspects of safety Health, financial (Property Damage & Potential Operational Losses). Likelihood can be defined as the frequency of activities carried out related to Safety, Health and Operations. Likelihood is the frequency or probability that an event is likely to occur. It can also be described as the frequency with which activities are carried out. Calculate Risk by combining consequences and probabilities using HIRADC Matrix. Consequence is the potential consequence, effect or outcome of an event or activity related to injury, occupational disease, property damage or production loss.

a. Determining the consequences must consider the aspects, safety Health, financial (Property Damage & Potential Operational Losses).

b. Possibility (Likelihood) can be defined as the frequency of activities carried out related to Safety, Health and Operations. Possibility is the frequency or probability that an event may occur. It can also be described as the frequency with which activities are carried out.

2.4 Consequence Scores

Consequence scores are assigned with the assumption that the unintended event has occurred. The probability of the event is considered separately. For example, a haul truck collision is reasonably likely to result in a fatality. If controls are put in place to reduce the likelihood of a collision, the likelihood score would change. However, if a collision is still possible, the consequence is still a fatality. A single fatality is unacceptable. A Catastrophic consequence, with a rating of 4, is intended to cover outcomes with a large number of fatalities. These might include:

- a mass casualty event (slope failure with the potential to engulf multiple people, destruction of a personnel transport vehicle, underground fire, and similar)
- a gas release capable of engulfing multiple people (chlorine or H_2S release near an occupied building)
- a widespread exposure to a substance that could later cause a cluster of cases of cancer or other debilitating disease.

A significant consequence, with a rating of 3, is intended to cover incidents with the potential to cause one or more fatalities or permanently disabling injuries, or isolated cases

of fatal or debilitating disease. These incidents are unacceptable; the rating of 3 does not diminish this. Moderate consequences, rated as 2, are generally significant but reversible.

2.5 Likelihood Scores

The likelihood scores are assigned based on the probability of the unintended event. The scores are not assigned based on the frequency of the task. Probabilities are included to provide general guidance to clarify the terms unlikely, possible, etc. The intent is to highlight the differences between the various rankings, not to provide a defined probability of occurrence.

Probability should be considered based on the global industry as the basis, not just an individual site's experience. Consider the reliability and effectiveness of controls when assigning probabilities. Controls that are high in the hierarchy of controls are more reliable and effective. Risks that are rated as Unlikely, 1, would be mitigated with reliable and effective controls. Considering the industry's experience, it is highly unlikely to occur during the lifetime of the operation or project. Assigning scores related to exposure to toxic substances requires input from health and safety professionals with an understanding of industrial hygiene. Consider the level of exposure, the occupational exposure limit, the duration of exposure, and the possible health effects.

3 Results

There are 10 top risks of concern in IMC's underground mines. These top risks are determined based on the Risk assessment from HIRADC.

Apart from using the risks and controls from HIRADC, the development of UG Mine Top Risk and Critical Control is also an extract from inputs by field supervisors and safety officers from both Freeport and Contractors.

Based on data from the annual report on IMC's 2020 sustainability, data on fatal events that led to death were obtained. The following is the high-risk data that has occurred at mining company (IMC) for the last 4 years (see Fig. 2) [1,6,8,14].

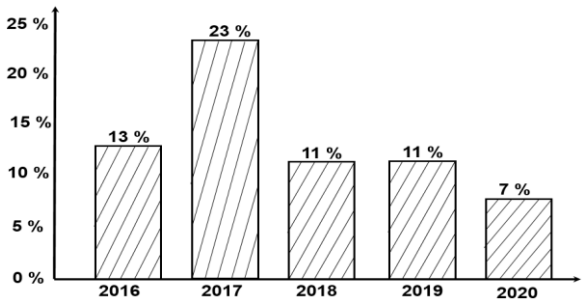

Fig. 2. Total recordable events (% high risk[1]). (Compiled by authors).

Our Sustainable Development Risk Matrix defines high-risk events as incidents that have the potential to result in a permanent disability or a fatality.

Table 2. Accident Risk Factor Summary (Injury) IMC 2020.

Risk factor	LT	RD	MT	FA
Hit by falling/flying rock/object	1		2	2
Falls	1	1		5
Pinched in between				1

Gases, smoke or chemical hazard	1			
Mobile equipment impact	1	1	4	6
Blast impact				1
Wet muck rush exposure				
Fire				
Exposed by electrical				
Dust exposure				1
Uncontrolled release of energy	1		2	6
Falling object				3

Risk Factor Formulation (Injury)
A constant value (Consequences), Base on HIRADC Matric with adjustment:

CFA : 1 (First Aids)	**CLT** : 3 (Lost Time)
CMT : 2 (Medical Treatment)	**CFatal** : 3.5 (Fatal)
CRD : 2.5 (Restricted Duty)	**CMF** : 4 (Multiple Fatal)

Risk Factor Value (RFV): RFV = (FA x CFA) + (MT x CMT) + (RD x CRD) + +(LT x CLT) + (Fatal x Cfatal) + (MF x CMF)

Table 3. Risk Factor Value.

Risk factor	LT	RD	MT	FA	RFV
Hit by falling/flying rock/object	3		2	2	7
Falls	3	2.5		5	11.5
Pinched in between				1	1
Gases, smoke or chemical hazard	3				3
Mobile equipment impact	3	2.5	8	6	19.5
Blast impact				1	1
Wet muck rush exposure					0
Fire					0
Exposed by electrical					0
Dust exposure				1	1
Uncontrolled release of energy	3		4	6	13
Falling object				3	

Based on the calculation of the risk factor value formula, the highest RFV value is Mobile equipment risk factor.

4 Discussion

The following thing that must be done after completion of HIRADC is Determination of Risk Control.

Determination of Risk Control is the process of establishing effective mitigation measures based on the control hierarchy to reduce risk to a tolerable risk or to a tolerable level. The principle of risk control in the application of OHS is to avoid and reduce risk. Avoiding risk is done by eliminating sources of danger or avoiding and stopping activities. Reduce risk is done by reducing the likelihood and reducing the level of risk the severity of the consequences of the activity. At this stage, supervisors play an important role in determining risk control.

The following are the steps that must be followed in determining the control (see Fig. 4).

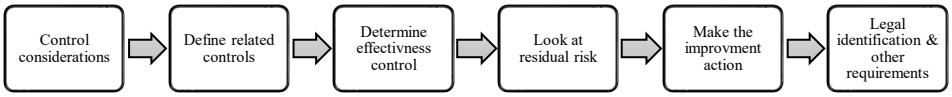

Fig. **4.** Risk control determination (compiled by authors).

A number of selected risks based on pure risk consequences, minimum can poses a single fatality or risk with a high and/or medium residual risk. Risk with minimum risk consequences is one fatality considered more important of residual risk with a higher value but not potentially fatal. Make a list of critical controls (critical controls or controls that by professionals through other methods are considered the most important/critical controls and contribute to fatality prevention) for each Top Risk. Based on the calculation data obtained from IMC's 10 Top Underground Risks, it is known that the highest RFV value is Mobile equipment risk factor. So, what needs special attention is in the mobile equipment section. These are the risk control for mobile equipment that need to be applied to reduce the risk of fatal accidents in the IMC's workplace:

- Conduct proper pre-operational checklist and prohibit to use damaged equipment;
- Lighted headlamp on hard hat at all times in the mine, except in fix facility with adequate illumination areas (exclude access) wear reflective clothes and ensure that the proximity detector on employees or equipment is functioning properly;
- Giving pedestrians priority, maintain eye contact and the equipment only moving when the pedestrian is clear from access;
- Practice a safe parking procedure and safe backing up: clear mirrors, backing up lights and rear camera, adequate maneuver space, and using spotter as needed;
- Seat belts are available, in good condition and properly fastened during equipment operation;
- reduce speed, drive to condition and sound horn at blind corners.

5 Conclusion

In conclusion, the implementation of a risk-based OHS management system in IMC's workplace is the application of the basic principles of hazard identification, risk assessment and control determination. This is inseparable from the accountability program established for supervisors in the implementation of the OHS management system at IMC 's workplace. The accountability program is Fatal Risk Management, which is a continuation program after HIRADC. The selection of the HIRADC method used by IMC with the aim of being able to identify any hazards that may occur at the risk of work accidents, as well as the risk of the work accident itself, if not addressed immediately, it will have an impact on reducing the effectiveness and efficiency of the company. According to the result, potential fatal risks that occur due to direct contact with the movement of mobile equipment against workers or other mobile equipment in the Underground Mine Operation area become the highest RFV, this information gives more attention to the company to increase the transportation management system at IMC to be even better to support safer production. In an effort to increase a sense of security and comfort in working in the company's work environment, it is very necessary to have a routine evaluation to always remind the importance of working in a healthy and safe condition such as carrying out a cycle of OHS handling activities on a daily, weekly, and monthly basis, starting from the group. - a small group of workers, and led directly by the head of the division, especially the OHS division in company.

References

1. N. Azadeh-Fard, A. Schuh, E. Rashedi, J.A. Camelio, Safety Science **76**, 160–167 (2015) DOI:https://doi.org/10.1016/j.ssci.2015.03.002
2. E.I. Kabanov, G.I. Korshunov, V.A. Rodionov, Gornyi Zhurnal **8**, 85–88 (2019) DOI:10.17580/gzh.2019.08.17
3. V.A. Rodionov, V.D. Tsygankov, S.Ya. Zhikharev, D.S. Kormshchikov, Mining Inf. Anal. Bull **(10)**, 69-79 (2021) DOI: 10.25018/0236_1493_2021_10_0_69
4. N. Holmes, H. Lingard, Z. Yesilyurt, Journal of Safety Research **30(4)**, 251-261 (1999)
5. *ISO 45001:2018. Occupational Health and Safety Management System – Requirements With Guidance for Use Of ISO 45001:2018*
6. N.R. Rahayu, S. Santoso, European Journal of Business and Management Research **6(4)**, 1-6 (2021) DOI: 10.24018/ejbmr.2021.6.4.913
7. Z.A. Abiev, V.A. Rodionov, G.P. Paramonov, V.I. Chernobay, Mining informational and analytical bulletin (MIAB) **5**, 26–34 (2018) DOI: 10.25018/0236-1493-2018-5-0-26-34
8. R.R. Vagapov, V.A. Rodionov, Neftyanoe khozyaystvo - Oil Industry **11**, 123–125 (2010)
9. M. Zhang, V. Kecojevic, International Journal of Injury Control and Safety Promotion **23(2)**, 1–14 (2015) DOI: https://doi.org/10.1080/17457300.215.1032982
10. B.P. Hughes, A. Anund, T. Falkmer, Accident Analysis & Prevention **90(1)**, 13–28 (2016) DOI: https://doi.org/10.1016/j/aap.2016.01.017
11. I.V. Klimova, Yu.G. Smirnov, V.A. Rodionov, Fuzzy Logic Occupational Safety in Industry **1**, 46–50 (2022) DOI: 10.24000/0409-2961-2022-1-46-50
12. G.I. Korshunov, E.I. Kabanov, M. Cehlár, Acta Montanistica Slovaca **25(3)**, 289-301 (2020) DOI: https://doi.org/10.46544/AMS.v25i3.3
13. C. Bao, J. Wan, D. Wu, J. Li, Journal of Risk Research, 1-17 (2019) DOI: http://dx.doi.org/10.1080/13669877.2019.1588912.
14. A.S. Semenov, M.N. Kruk, Journal of Industrial Pollution Control **33(1)**, 1024-1028 (2017) DOI: https://clck.ru/bmXQz
15. M.V. Tumanov, S.G. Gendler, E.I. Kabanov, V.A. Rodionov, E.A. Prokhorova, Mining Inf. Anal. Bull **6-1**, 230-247 (2022) DOI: 10.25018/0236_1493_2022_61_0_230