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Risk Assessment & Safety Management Plan for Mines: Case study of large Mechanized Iron Ore Mine

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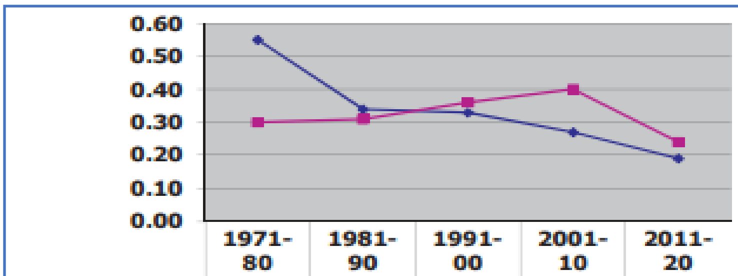
ABSTRACT:

Unlike major industries, mining has high potential risk of accidents. The present-day environment demands to have a fresh look at safety management as a structured process composed of well-defined systems that emphasizes continuous improvement in work quality, health, welfare and productivity of workforce engaged in mining industry through setting up of improved safety standards and their effective implementation and administration. Because the statutory provisions can never be fully comprehensive, appropriate and site specific and because the process of legislation making is often slow, these trail behind the technological innovations. It is now widely accepted that the concept of "risk management" through "risk assessment" contributes greatly toward achieving these objectives. This paper deals with methodology to conduct risk assessment studies and implement safety management plan to control accidents in Indian Surface Mines

Key words: risk assessment, hazard, risk, SMP

1.0 INTRODUCTION:

Mining is renowned for being one of the most hazardous sectors in the world due to its complex work environment. Workers in mines are exposed to several risky conditions during their work activities which may cause loss of life or serious injury which has a direct and indirect cost for employees and employers. Accidents in mines can often have serious catastrophic consequences. Over the years, the Directorate General of Mines Safety (DGMS), mining companies, research institutes and academics have made constant efforts to prevent accidents in Indian mines by proposing solutions, such as additional regulations, improved training, advanced technology and reliable equipment. The trend of accident frequency rates in coal mines show a steady decline over the years, however, the same is not exactly true about the non-coal mines. The accident trends in terms of fatal accidents and fatality rates per thousand persons employed at 10 yearly average since 1971-80 to 2011-20 (up to October, 2020) are indicated below in **Fig-1**.



	1971-80	1981-90	1991-00	2001-10	2011-20
Coal	0.55	0.34	0.33	0.27	0.19
Non-Coal	0.30	0.31	0.36	0.40	0.24

To regulate the hazards in mines, risk management has been proposed, implemented and mandated by Australian, New Zealand, Canadian, British, American and South African mining industries over the last few decades. It is now widely accepted world over that the concept of "Risk management" through "Risk assessment" contributes greatly towards achieving the objective of 'Zero harm ' in mines through continual improvement.. Considering the accident scenario in Indian Mining Industry, it has now become essential that risk assessment be undertaken of all hazardous operations, equipment and machinery, taking account of the procedures used, maintenance, supervision and management. The DGMS has made it mandatory to conduct risk assessment and management in all Indian coal mines after the revision of Coal Mines Regulations in November 2017 (CMR, 2017).

Risk management is a systematic approach taken to eliminate or mitigate risk, by identifying hazards and implementing controls at the workplace. In simple terms, risk management is a thorough analysis of what could cause harm in mining activities, so that one can review the current precautions taken and increase them if required, to prevent harm. Risk assessment and risk treatment are the two major processes in the risk management system. The output of the risk assessment will be the input for the decision-making process of the industry, so an effective risk assessment is essential for the successful control or elimination of risks in the workplace.

The hazard identification phase is the most crucial step of the risk assessment process, as the leading causes are identified in this step and unless the cause is identified, it cannot be actively managed. In India, Mining is carried out by both opencast and underground mining methods. Board-and-pillar and longwall methods are the most commonly employed techniques for coal production in underground coal mines while excavation by a system of deep hole blasting & use of HEMM is mostly used for mechanised / highly mechanised opencast mining of coal/ ore. The types of machinery commonly used in underground / open cast mines are load-haul dumpers, side-discharge-loaders, universal drill machines, excavators / shovels, Dozers, pay loaders, cranes, handheld drill machines, rope haulage, conveyors, ventilation fans, dewatering pumps, shuttle cars , locomotives etc.

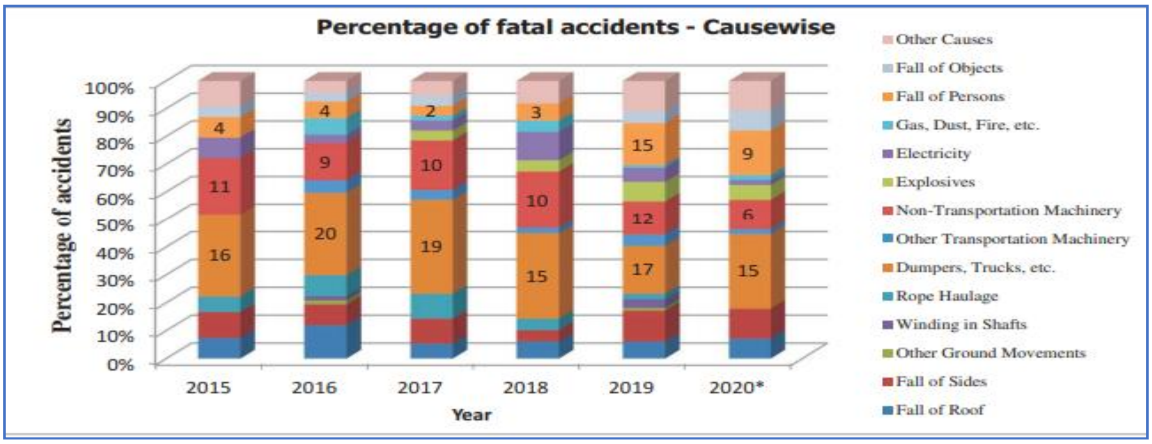


Figure 2 shows the percentage of fatal accidents cause-wise in mines during 2015- 2020.It can be observed that the major reason for fatal accident is Dumpers, Truck etc. followed by Fall of Persons.

2.0 SAFETY MANAGEMENT PLAN (SMP):

Firstly, this concept was adopted in coal mines of Queensland, Australia in 1990. They introduced risk-based mining legislation in 1990s in Australia. In India, concept of safety management plan was conceived in National Safety Conferences starting from 9th National Safety Conference which recommended Risk Management System/Plan as a tool for development of appropriate Health and Safety Management System in Indian Mines. Subsequently Safety Management Plan became part of Statue in 2017 in CMR 2017.

The safety management plan is tool to manage safety. It is a Self-Regulation of mine, specific to mine conditions beyond the rules and regulations. It is a scientific tool for ensuring safe operation of the mine and it is an all-time working document. It brings together a number of procedures and policies to enable the mine operator to follow a systematic monitoring approach to achieve an effective level of health and safety.

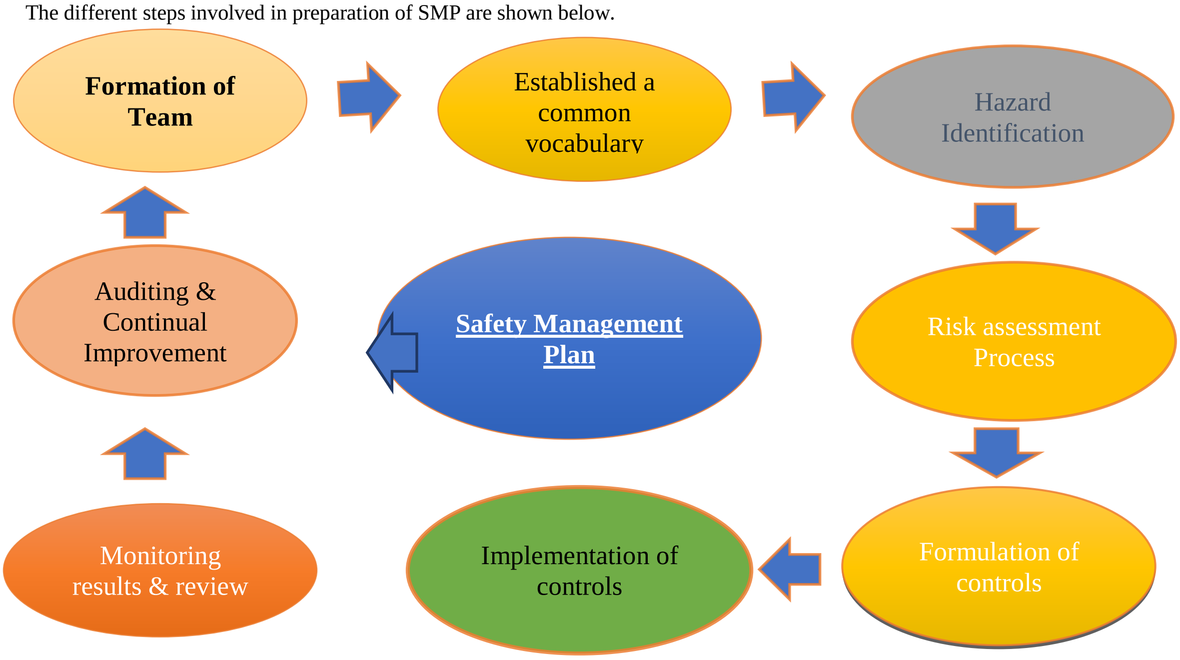
The Directorate General of Mines Safety had issued following Technical Circular to implement SMS.

a) DGMS Tech. Cir.13 of 2002 - Safety Management System -A guideline for Implementation.

b) DGMS Tech. Cir.8 of 2009 - System Study and Safety Audit for the purpose of eliminating the Risk of Accidents & Dangerous Occurrences

c) DGMS (Tech) (S&T) Circular 2 of 2011 -Provision for Audit and Review of SMS.

The different steps involved in preparation of SMP are shown below.



3.0 CASE STUDY OF LARGE MECHANISED IRON ORE MINE

The mine under study is a captive mine of a steel company having a capacity to handle 5.0 MTPA ROM with 4.25 MTPA of finished products (lump & fines).

Geologically the deposit is associated with typical metamorphosed iron bearing sedimentary rocks of Proterozoic (upper pre-Cambrian) age. The deposit is bounded by BHJ on the northern, western and southern sides, while extensive laterite occurs towards the eastern side. Soft laminated ore outcrops are rare while the blue dust does not appear on the surface at all. Float ore, through confined slopes, is negligible in quantity.

The mineable block of the Mine has strike length of 960 m with average width of 450 m. Particulars of Fe, SiO2 & AL2O3 in lumps is 62.95%, 2.8% & 2.36% and in fines, is 62.45%, 3.6 %, % 2.80% respectively. The benches are 10-12 m high. Generally, the width of the benches is kept as 35m. Both ore and wastes are worked by forming benches. Wherever the ore is friable and soft in nature, it is excavated directly by hydraulic excavator. Drilling and blasting operations are undertaken only where hard laminated, BHQ/BHJ and any thick laminated portion of ore body at the contacts including area of hard laminated ore, are encountered. Drilling is done by 150mm diameter blast hole drills in staggered pattern with 4.5- 5.0m burden & 5.5-6.0m spacing. Blasted material is loaded into 50/100 te dumpers by hydraulic shovels having bucket capacity of 4.5/9.5 m^3. Permission under Reg. 106(2) (b) of the Metalliferous Mines Regulations 1961 has been obtained from DGMS to work with deep hole blasting and deployment of HEMMs for excavation, digging and removal of Overburden & Ore at the Mine. The mined ore is dumped into hopper at crushing & screening plant where after sizing & washing , as required, it is stacked in stock pile through a system of conveyors. Ore is reclaimed from the stockpile through a system of reclaimer & wagon loader for loading on to the wagons for transporting to various internal consumers. Power is received from JSEB to Main Sub Station, 33KV/11KV/3.3KV, 5.7MVA substation inside mine lease hold. All the installations in the mines are supplied 3.3KV/220V substations at different pit.

3.1 MATERIAL & METHOD :

In line with DGMS guidelines, following methodology has been adopted while preparing the SMP.

Health & safety hazards to which the persons employed at the Mine may be exposed, have been identified through safety audit findings, report of accidents/ near miss cases, inspection report of safety officers & workmen inspectors, minutes of pit safety committee meetings, violation pointed out by statutory authorities and action taken thereon, compliance of recommendations of the various bipartite & tripartite safety conferences in mines etc. Following team was constituted for conducting Hazard identification & Risk Assessment .

- ✓ Mine Manager/Operations-in charge as team leader
- ✓ Safety officer
- ✓ Engineer (Mines)
- ✓ Workmen's Inspector(s)
- ✓ In-charge, mine production
- ✓ In-charge, mechanical maintenance
- ✓ In-charge, electrical maintenance
- ✓ In-charge, occupational health & hygiene
- ✓ In -charge, mine surveying
- ✓ Supervisor's and/or workmen as required

- Associated Risks have been identified, ranked & prioritised.
- Measures have been determined after consultation with the Agent, Manager, Safety Officer and other departmental heads, to eliminate, control, minimise as well as provide PPEs and monitor the risks that remain even after all these steps.

The following Scales of Consequences, Probability & Exposure as per DGMS Tech. Cir.13 of 2002 - Safety Management System - A guideline for Implementation, has been utilised for calculation of risk scores of the hazards.

Consequences	Scale	Probability	Scale	Exposure	Scale
Several Dead	5	May well be expected	10	Continuous	10
One dead	1	Quite possible	7	Frequent (daily)	5
Significant chances of fatality	0.3	Unusual but possible	3	Seldom (weekly)	3
One permanent disability / less chance of fatality	0.1	Only remotely possible	2	Unusual (monthly)	2.5
Many lost time injuries	0.01	Conceivable but unlikely	1	Occasional (yearly)	2
One lost time injury	0.001	Practically impossible	0.5	Once in 5 years	1.5
Small injury	0.0001	Virtually impossible	0.1	Once in 10 years	0.5
				Once in 100 years	0.02
RISK SCORE(RS) = COSEQUENCE X LIKLIHOOD = CONSEQUENCE (C) X PROBABILITY (P) X EXPOSURE (E)					

Following risk assessment matrix has been used to categorise risks:

RISK CALCULATOR

RISK ASSESSMENT MATRIX

Step 3 Calculate the Risk		Consequence				
		1	2	3	4	5
Probability		Catastrophic Death/Massive financial loss	Major Hospitalisation/Large Financial loss	Moderate Medical Treatment/High Financial loss	Minor First Aid Treatment/Medium Financial loss	Negligible No injuries/Minimal Financial loss
A	Almost certain Often Occurs / Once a week	Extreme Risk	Extreme Risk	Extreme Risk	High Risk	High Risk
B	Likely Could easily happen/Once a month	Extreme Risk	Extreme Risk	High Risk	High Risk	Moderate Risk
C	Possible Could happen or known it to	Extreme Risk	Extreme Risk	High Risk	Moderate Risk	Low Risk
D	Unlikely Hasn't happened yet but could/once every 10 years	Extreme Risk	High Risk	Moderate Risk	Low Risk	Low Risk
E	Rare Conceivable but only in extreme circumstances/Once every 100 years	High Risk	High Risk	Moderate Risk	Low Risk	Low Risk

ZERO HARM

STEP-1: A sample worksheet for calculation of risk score on identified hazards is attached as **Annexure-1**

STEP-2: Initial hazard identification & Risk assessment

Sl. No	Hazard description	C	P	E	RS
1.	Machinery	5	7	5	175
2.	Ore processing Plant	5	7	5	175
3.	Pit slope failure	5	3	10	150
4.	Explosive & blasting	5	7	3	105
5.	Mechanical loading of wagons & siding	5	2	10	100
6.	Shortage of skilled persons / deployment of unskilled persons	5	3	5	75
7.	Dumping of waste rock	5	2	5	50
8.	Unauthorised entry	0.3	7	5	10.5
9.	Poor supervision	0.3	7	5	10.5
10.	Fire in HEMM (Heavy earth moving machinery)	0.3	7	5	10.5
11.	Improper surveying	0.3	7	5	10.5
12.	Environmental issues	0.3	3	10	9.0
13.	Training facilities	0.3	1	10	3.0
14.	Occupational health	0.3	1	10	3.0
15.	Inundation	0.3	0.1	2	0.06

STEP-3: Prioritization of risks: Following is the risk ranking based on risk score:

Sl. No	Hazard description	RS	Risk ranking
1.	Machinery	175	I
2.	Ore processing Plant	175	I
3.	Pit slope failure	150	II
4.	Explosive & blasting	105	III
5.	Mechanical loading of wagons & siding	100	IV
6.	Shortage of skilled persons / deployment of unskilled persons	75	V
7.	Dumping of waste rock	50	VI
8.	Unauthorised entry	10.5	VII
9.	Poor supervision	10.5	VII
10.	Fire in HEMM	10.5	VII
11.	Improper surveying	10.5	VII
12.	Environmental issues	9.0	VIII
13.	Training facilities	3.0	IX
14.	Occupational health	3.0	IX
15.	Inundation	0.06	X

3.2 RESULTS & DISCUSSION:

The salient control measures for all the above-mentioned risks (With risk scores > 30) suggested in SMP are as follows.

a) On-the-job training should be imparted under authorised trained trainers & proper record to be maintained. Trainers are to be exposed to "training for trainers" including training on Simulators.

b) To prevent formation of highwall impacting stability, excavation to be done strictly as per the excavation plan. Regular inspection should be carried out to ensure that height & width of the benches are maintained as per permission from DGMS permission conditions.

c) To ascertain the slope stability, scientific study from any scientific agency should be conducted as per DGMS Cir.08/2013.

d) Extra precautions should be taken during monsoon by inspecting the slope, crest and faces daily.

e) Traffic Rules boards to be displayed in Hindi or local language at every relevant place including the opencast workings, workshops, haul roads, spoil/ ore heaps, material yards etc.

f) Fitters/mechanics possessing heavy vehicle driving license to be authorised to carry out test run for HEMM.

g) To prevent unauthorised driving, a system shall be evolved whereby the ignition key and/or cabin key shall always remain with the driver/operator or with specifically designated competent person(s) Cir. No. 1/1989 (7th Safety Conf. Recommendations)

h) A Selection committee should be set up for selection of contractual operators as for regular employees. It should be ensured that only competent /trained operators are deployed to operate HEMM. All HEMM operators shall undergo regular checks to test their driving/operating skill/knowledge at least once in every 5 years by the board constituted by the company (Cir. No. 1/1989 (7th Safety Conf. Recommendations)

i) Vehicles with non-functional safety devices shall not be operated. Record showing the status of all the safety devices to be maintained for each HEMM and in each shift. Proximity warning devices shall be fitted on all the HEMMs.

j) Standing instructions should be given to all the operators to ensure that all guards provided to cover moving parts of machinery are in place. Operators shall not operate the machine when persons are in such proximity as to be endangered due to moving parts of machinery.

k) Vertical HDPE/Fibre pipes should be fixed at interval of not more than 3m with tri colour strips of florescent paint all along the haul roads for improved visibility in foggy weather.

l) School bus route should be changed so that school children do not walk around the railway siding area. SOP should be framed and issued to the Wagon loading in-charge at the siding. Boards in local language, prohibiting unauthorised entry should be displayed at conspicuous places.

m) Guards/ fencing to be provided all along the conveyor belts &these should be interlocked so that the belt is tripped as soon as the guard is removed and shall not re-start till the guard is replaced.

n) As per Reg. 174 of MMR 1961, Guards over conveyor belts rotating parts in Ore handling Plant should be only G1, G2 or G3 type fencing. At the start of shift, the shift supervisor shall personally verify that all the guards over moving parts are in place. Record shall be kept in a bound paged register of the status of the fencing/guard.

o) Painting of structures should be done regularly as per norms with proper quality of paint.

p) Stability to be checked and jointly certified by civil, electrical and mechanical engineers. Structural stability of the steel structures, ore bins & hopper to be verified once every year by an outside expert organisation.

q) Illumination to be increased by providing additional lighting.

r) PME of workers deployed in dust prone areas should be conducted at an interval of 6 months.

s) All persons including the blaster shall take shelter under strong shelter, adequate to protect from flying fragments. Siren shall be blown three times for one-minute duration each, ten minutes before firing. Provisions with regards to taking shelter etc as laid down in Reg.164 of MMR, 1961 should be complied with. Red flags should be fixed along all the entry points to the site of blasting and to demarcate the danger zone. Red shirts and red Helmets may be provided to the blasting crew. Use of these should be enforced so that people can treat their presence in the mine as a danger sign and abstain from entering in to the danger zone at the time of blasting.

t) All hoists &lifts and lifting machines, chains, ropes & lifting tackles shall be thoroughly examined by a competent person once at least every six &twelve months respectively and result shall be recorded in a register as per section 28 & 29 of Factory Act, 1948.

u) Management may train the existing employees and motivate them to clear the competency examinations being conducted by DGMS. Required manpower should be recruited at the earliest to fill up the vacancy on this account.

4.0 CONCLUSION:

Management of safety issues based on assessment of risks not only integrates safety with productivity but also can be used as a very good tool for reduction of costs. The systems stand on the premise that all risks need not be eliminated and different control measures can be adopted for different levels of risks. The key here is to aim for ALARP (as low as reasonably practical), which eventually depends on cost considerations. The system allows prioritization of allocation of scarce resources thereby cutting costs and reducing wastages. This assumes great importance in the current Indian scenario. The other merits of the system are that it is created by the mine operators themselves through considerable brainstorming. This approach let the mine operators/users feel ownership of the system, something that is not cast upon them by experts, Govt. agencies or outsiders, and hence chances of successful implementation is much more.

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Annexure-1

Sample worksheet for calculation of risk score

Major hazard	**Mechanism**	**C**	**P**	**E**	**RS**	**Remarks**
Pit slope failure	Slope failure due to overhang	5	2	10	100	Ore body is on a moderately sloping hillock and top slicing method is adopted hence slope failure due to overhang is considered as only remotely possible.
	Slope failure due to geological disturbances	5	3	10	150	Iron ore formations consist of BHJ/BHQ, Phyllites, and Shale etc. Weathered zone is found to be present in the working area resulting in collapse of the strata. Hence probability is considered as unusual but possible.
	Lack of monitoring of slope stability	5	2	10	100	Pit slope monitoring is done departmentally by visual inspection & surveying. Scientific study has not been conducted by any technical institution. Hence probability is considered as only remotely possible.
	Slope failure due to excess height (creation of high wall)	5	3	10	150	Top slicing method is adopted. During inspection two benches were found merged forming high wall. Hence the probability is considered as unusual but possible.
Machinery	Violation of traffic rules	5	7	5	175	Contractual machineries are deployed and this being a regular operation, the probability is considered as quite possible.
	Unauthorised operation of machinery	5	7	5	175	
	Unskilled operators	5	7	5	175	The operators of HEMM should undergo regular checks to test their driving / operating skills. This is not being done. Hence Probability is considered as quite possible.
	Bypassing safety devices	5	7	5	175	During inspection it was observed that some safety devices were missing and there is all possibility of bypassing the safety devices particularly in contractor's machines. Hence the probability is considered as quite possible.
	Light vehicles moving on haul road without beacon light, siren & red flag inside the active mining area	5	7	5	175	Beacon light, siren & red flag are not used by the vehicles moving within the active mining area. Hence the probability is considered as quite possible.
	Poor visibility due to foggy weather	5	7	5	175	During four months following the monsoon, the visibility is very poor after day light. Lighting has been provided but it needs augmentation. Hence probability is considered as quite possible.
	Non framing of safe operating procedures or safe maintenance procedure	5	3	5	75	SOPs & COPs have been formulated. The probability is considered as unusual but possible considering the non-implementation of the SOPs.
	Maintenance schedule not followed	5	3	5	75	Checklists have been prepared for maintenance of departmental as well as contractual machinery and the schedule is followed. However, it does not cover the status of all the safety features required to be provided on HEMM. Hence such probability is considered as unusual but possible.