Risk Assessment

1 Introduction

Hazard analysis involves identification and quantification of the various hazards (unsafe conditions) that exist in the site. On the other hand, risk analysis deals with the identification and quantification of risks, the on-site equipment and personnel exposed to accidents resulting from the hazards present in the plant. Hazard and risk analysis involves very extensive studies and require a detailed design and engineering information. Assessment of risks on the neighboring population exposed as a result of hazards is analyzed. This requires a thorough knowledge of failure probability, credible accident scenario, vulnerability of population etc. Much of this information is difficult to generate. Consequently, the risk analysis is often confined to maximum credible accident studies. Hazards are inherent to all mining operations since they involve handling of hazardous materials (flammable, explosive, corrosive and toxic materials). The four major steps in risk assessment are; hazard identification, dose response assessment, exposure assessment and risk characterization.

Mining and related activities are associated with several potential hazards to both employees and the public at large. A worker in a mine should be able to work under conditions which are pleasingly safe and healthy. At the same time, the environmental conditions should not spoil his working efficiency. This is possible only when there are sufficient safety measurements taken in the mine. Hence mine safety is one of the most crucial aspects of a working mine. Indeed safety of the mine and employees are taken care by the Metalliferous Mines Regulation 1961 and its subsequent amendments.

1.1 Scope of the study

The risk analysis/assessment study covers the following:

- Site assessment
- Identification of potential hazard areas
- Identification of representative failure cases
- Visualization of the mode of chemical releases and the resulting accident scenarios
- Assess the overall damage potential of the identified hazardous events and impact zones from the accident scenarios
- Furnish specific recommendations on the minimization of the worst accident possibilities
- Preparation of DMP, on-site and off-site emergency plans
- Preparation of occupational and health safety plan.

2 Risk assessment

Risk assessment is essentially a process for identifying, assessing and controlling risks in the work place. The proposed open cast mining mainly comprises of mining, transportation and processing of the bauxite, overburden from the mine site.

The mining industry has witnessed innumerable number of accidents which are categorized as simple & fatal. Even though high priority is given to safety in true spirit, all kinds of accidents occur. Accident or hazardous situations may arise due to occurrence of any one of the following cases:

- Outbreak of fire
- An influx of noxious gases in the mine
- Inundation
- Air blast
- Sudden rush of back fill material
- Subsidence
- Machineries, heavy materials, electrical installation etc.

2.1 Mine blasting risk assessment

➢ **Major risks**

Mine blasting releases a tremendous amount of energy within a very short time and is considered a hazardous operation. An analysis of site-specific risk factors will help in understanding and mitigating possible hazards. A site-specific hazard and risk matrix should be drawn up and discussed during mine blasting and miners' job assignments, safety discussions, and training sessions.

Hazards and causes of explosions for mine blasting accidents include:

- Failure to comply with mine blasting procedures.
- Drill falling from the edge of a bench
- Dust created during the drilling operations
- Noise produced during drilling
- Failure to comply with explosives management procedures.
- Inadequate storage and transportation of explosives.
- Not obtaining legal requirements/clearances
- Negligence.

Material which is projected outside the declared danger zone by a quarry blast is called fly-rock. It may be caused by poor blast design or unexpected zones of weakness in the rock.

➢ **Mitigation measures**

- Ensure the appointed miner/blaster received proper hazard identification and risk assessment training.

- Blaster must make an estimate of the maximum possible distance (bounds of blast area) fly rock could travel from a blast. Furthermore, a blaster should not assume that a blast being fired will behave like other blasts previously fired at the same operation.

2.2 MSIHC Rules 1989 & subsequent amendments

Identification of hazardous chemicals is done in accordance with MSIHC (Manufacture, Storage and Import of Hazardous Chemicals) 1989 and its amendment, 2000. The detail of threshold storage of the fuel as per MSIHC amendment rules, 2000 and quantity of the chemical to be stored at the mining area are given in the following **Table 1.**

Table 1 Details of chemicals and applicability of MSIHC rules

Chemicals	Storage type	Listed in scheduled	Threshold quantity (Tons) as per rules	
			5,7-9,13-15	10-12
HSD (High Speed Diesel)	Tank	1 (part I)	5000	50000
Ammonium nitrate (NH_4NO_3)	Closed bags	1 (part IV)	350	2500

2.3 Inventory of materials

An inventory of chemicals and materials used at the site are given in **Table 2** and their physical properties are given in **Table 3**.

Table 3 Inventory of chemicals at the proposed project site

Chemical	Use	Nature of chemical	Type of storage & No's	Storage quantity
HSD	Fuel for D.G. sets	Flammable	Horizontal - 3 No.	27 KL/week
Ammonium nitrate (NH_4NO_3)	Fuel for blasting	Explosive	Closed bags	10 tons/week

Table 3 Characteristics of chemicals used

Chemical	TLV (mg/m^3)	BP	MP	FP	UEL	LEL
		(°C)			%	
HSD	800	215 – 376	NA	32	6.0	0.6
NH_4NO_3	-	NA	170	NA	NA	NA

TLV	:	Threshold Limit Value	BP	:	Boiling Point
MP	:	Melting Point	FP	:	Flash Point
UEL	:	Upper Explosive Limit	LEL	:	Lower Explosive Limit

2.4 Maximum credible accident (MCA) analysis

MCA analysis is carried out to arrive at hazard distance for worst case scenario. The consequence of all the scenarios is computed and hazard distances are worked out and listed for flammable and possible explosion effects.

2.4.1 MCA analysis for HSD

HSD will be used as fuel for running D.G sets and synthesising ANFO mixture (ANFO is a mixture of 94% ammonium nitrate ("AN") and 6% fuel oil ("FO"). 3 diesel bowsers of 9 kl capacity each are stored at the site.

2.4.2 Fire and explosive index (FEI)

The FEI calculation is a tool to help determine the areas of greatest loss potential in a particular process and also enables one to predict the physical damage that would occur in the event of an incident. The computations of FEI are derived from National Fire Protection Association (NFPA) code using Appendix A or NFPA (49, 704, 325M) or MSDS of chemicals to determine Health (Nh), Flammability (Nf), Reactivity (Nr), and Material Factor (MF) under consideration. The general process hazard (GPH) and specific process hazard (SPH) factors were calculated accordingly.

FEI = MF *(GPH) * (SPH)

The FEI and TI values are ranked into following categories as per **Table 4** and calculated values for HSD are given in **Table 5.**

Table 4 FETI category

S.No	FEI	Category
1	< 65	Low
2	65 ≤ F&EI < 95	Moderate
3	≥ 95	Severe

Table 5 FEI of chemicals used for the proposed project

Chemical/fuel	NFPA classification				GPH	SPH	FEI	FEI category
	N_h	N_f	N_r	M_F				
HSD	1	2	0	10	1.8	2.8	50.4	Low

From the above table, it can be inferred that, HSD comes under low category and nil toxicity.

2.5 Hazard from HSD storage

Diesel is a flammable liquid having a flash point of 32°C. Major hazards from oil storage can be fire and maximum credible accidents from oil storage tank can be

a) Tank fire
b) Pool/dyke fire

a. Tank fire

High Speed Diesel is stored in a floating roof tank; any leak in rim seal or spillage leads to accumulation of vapour which can be a source of ignition and can cause tank fire.

b. Pool / dyke fire

If there is outflow from the tank due to any leakage from tank or any failure of connecting pipes or valves, oil will flow outside and form a pool. When the tank is surrounded by a dyke, it will be restricted within that dyke. After sometime, the vapour from the pool can catch fire and can cause pool or dyke fire.

2.5.1 Heat radiation and thermal damage criteria

The level of damage caused by heat radiation due to fire is a function of the duration of exposure as well as heat flux (i.e. radiation energy onto the object of concern). The damage and fatality due to the exposure time are very important in determining the degree of fatality and corresponding effect distance. However, the variation of likely exposure time is more marked with personnel, due to the possibility of finding shelter coupled with protection of the skin (clothed or naked body). The effect of heat radiation on percentage fatality with variation in exposure time is given in **Table 6**.

Table 6 Effect of heat radiation

Radiation intensity (kW/m^2)	Exposure time (seconds)	Lethality (%)	Degree of burns
1.6	--	0	No Discomfort even after long exposure
4.5	20	0	1st
4.5	50	0	1st
8.0	20	0	1st
8.0	50	<1	3rd
12.0	20	<1	2nd
12.0	50	8	3rd
25.0	--	50	--
37.5	--	100	--

It is observed that the exposed persons normally find shelter or protection from the heat radiation (e.g. against a wall) within 20 seconds. However, exposure time is normally assumed for pessimistic calculation which applies when people do not run away immediately or when no protection is available.

Tank rupture is considered as one of the major accidental scenarios in which a large quantity of HSD will be leaked into the surrounding areas of the storage. If an ignition source is available near the accident site, the leaked fuel will easily catch fire. It is assumed that the complete liquid leaks due to tank rupture and develops into a pool and gets ignited. Hazard distances have been arrived due to the effect of pool fire. For computing the damage distances, Areal Locations of Hazardous Atmospheres (ALOHA) software is used. 1 diesel bowser of 9 kl storage capacity has been considered for the calculations. The effect of heat radiation and subsequent damage distances for HSD is given in **Table 7.** Thermal radiation threat zone and ALOHA contour on site layout are given in **Figure 1** and **2** respectively.

Table 7 Effect of heat radiation due to HSD storage tank (pool fire)

Input data		**Results of computation**	
Spilled quantity	9 kl	Flame length	9 m
Circular opening diameter	3 cm	Max burn rate	30.8 kg/min
Wind speed	2.1 m/s	Total amount burned	1834 kg
Heat Radiation at ground level kW/m^2		**Damage distances (m)**	
8		<10	
4.5		11	
1.6		19	

Figure 1 Threat zone for HSD

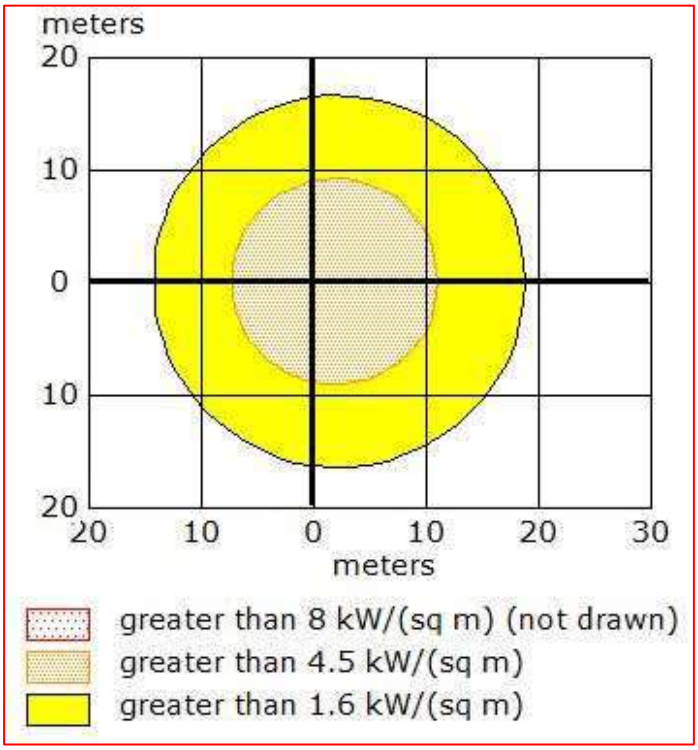
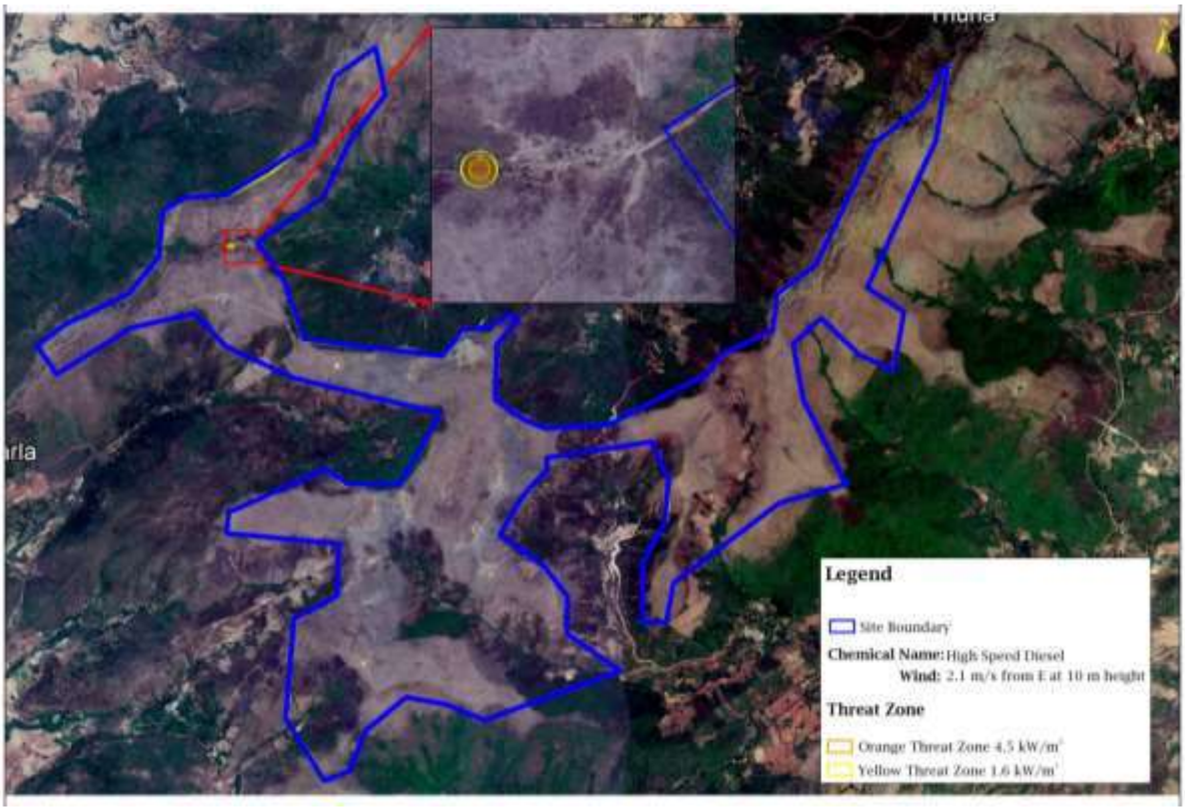


Figure 2 ALOHA contour on site layout



2.6 Fire hazards

- **Source of fire:**

  i) HEMM ii) Diesel storage area iii) Magazine

  - Storage and use of explosives. The storage, handling and use of flammable and combustible liquids pose a special fire hazard for all sectors of the mining industry.
  - Welding and cutting operations are a leading cause of fires in mines. This activity can be expected to occur regularly in a maintenance area.

- **Mitigation measures:**
  - Proper, safe and careful handling and use of explosives by competent blasters having blaster's certificate of competency issued by DGMS.
  - Proper security system to prevent theft/ pilferage, unauthorized entry into magazine area and checking authorized persons to prevent carrying of match box, lights, mobile phones, cigarette or bidi etc.
  - Explosives shall be conveyed in special containers.
  - The holes which have been charged with explosives will not be left unattended till blasting is completed.
  - Before starting charging, clear audible warning signals by sirens will be given so that people nearby can take shelter.
  - **Fire detection and spray system:** Automatic high velocity water spray system will be considered for generator transformers, UAT & ST in the transformer yard. The system comprise of network of underground and above ground piping, deluge valve, sprinkler bulbs, high velocity spray nozzles/projectors. System will be pressurized with water tapped off from hydrant pumps.
  - **Portable Fire Extinguishers:** Fire extinguishers of different types, mainly used for Class 'A', 'B' and 'E' fires, are used. Besides these, trolley mounted extinguisher of about 25 kg capacity shall also be stationed locally at different plant buildings.
  - **Fire detection and alarm system:** Fire detecting system will be provided in the main control room, Motor Control Center (MCC) panel/Power Control Center (PCC) panel, Aux transformers and cable cellar. The signals will be connected to the main fire alarm systems which alert the operator with audio and visual indications on detection of fire.

- **First aid and emergency procedures**

Burns can cause due to catching of fire or handling of ignitable materials. Curative measures for any burns and first aid procedures are given in **Table 8**.

Table 8 First aid for burns

Burns covering small area	Burns covering extensive area
i. Allow cold tap water to run gently over the area or immerse in cold water. ii. It may be necessary to cover with gauze or a clean handkerchief, and bandage.	i. Allow the person to lie down ii. Cover burned areas with a sterile dressing or clean cloth and lightly bandage iii. If clothing is adhering, do not disturb; leave the clothing alone iv. Keep the person warm. If a person is not nauseated, he may have sips of water v. Arrange for immediate medical care

2.7 Vibration impacts

On surface mining, blasting technique may be considered as the most economical method used for fragmenting rocks masses. Nonetheless, only 20-30% of the used energy is served for rocks fragmenting and displacing, while the rest is wasted in the form of ground vibration, air blast, noise and fly-rocks. Both ground vibration and air blast are a matter of great concern as they would result in damage to the existing surface structures and nuisances to the inhabitants in the vicinity of mines.

Discrete requirement is for measuring vibration of pumps, fans, motors, etc. For this, contact type vibration measurement using velocity and/or acceleration type vibration sensors and single/dual channel vibration transmitter located near the equipment shall be envisaged. All precautions related to control of fly rock should be taken during the blasting operations. Safety zone of 300 m as per statutes should be maintained.

2.8 Landslides

Improper excavation causes instability in slope material and on saturation with water, landslides occur. This can happen at any time causing damage to human life and machinery. This can be prevented by making slope angle as per the rock strength and should be kept low in soft and friable lithology. Besides this, all necessary precaution shall be taken to avoid any disaster.

In order to allay dangers due to open cast slope failure, final pit, slope stability estimations have to be made for the existing mines after determining various physical parameters of the ground mass like uniaxial compressive strength, triaxial compressive strength, cohesion, angle of friction, specific gravity of the rock, water pressure etc. Besides, all the structural discontinuities have been plotted in wedge failure. Even then, factor of safety should be determined against overall slope failure as well as against individual bench slope by circular failure, planer failure, and wedge failure. Besides determining factor of safety, the slopes should be monitored at regular intervals by using real time slope stability radar system, to monitor for any possible failure. The well-developed drainage system over the lease area should ensure that storm water does not accumulate in the lease area and therefore hydrostatic pressure remains at a low level.

- **Floods:**

  The area is devoid of any perennial water courses. The water accumulated in the pit is not much to cause the disaster.

- **Seismic activities:**

  The prediction of specific day or time of seismic activity is not possible. However appropriate knowledge and preparation can help to minimize damage in an emergency. Awareness camp can help people to know what actions to be taken to remain safe and healthy in the event of an earthquake.

- **Mitigation measures:**
  - The landslide can be covered with an impermeable membrane
  - Surface water is directed away from the landslide
  - Ground water is drained from the landslide
  - Education and awareness about the impact of landslides is also a must

- **Mock drill exercise for emergency planning periodicity**

  Steps:
  - Test the effectiveness of the communication system
  - Test the speed of the mobilization of the resources
  - Test effectiveness of search, rescue and treatment of casualties
  - Conduct a full rehearsal of the action to be taken during an emergency
  - Prepare the mock drill exercise report along with photographic evidences, covering all points related to deficiencies, deviations, shortcomings, lacunas, constraints etc. encountered during the exercise.
  - The document should be approved by unit head prior to circulation to all.

2.9 Heavy-loaded truck roll over

- **Major risks**

The most common cause for many trucks, on elevated roads, rolling over is the driver's inability to assess the combination of speed, heavy loads, and cornering. Securing the load is also an important factor in vehicle stability. The following list highlights the main risk factors for rollover:

- High center of gravity.
- High speed.
- Load displacement.
- Bad road conditions.
- Driver behavior, aggressive driving and distraction are key issues to address.
- Secondary fault, such as collision with another vehicle, or skidding towards the edge of the road.

➢ **Mitigation measures:**

- Choosing the right vehicle for the job/load
- Reviewing loading and unloading procedures
- Checking the load securing regularly, and before and during the journey
- Choosing the best route possible for the vehicle and load
- Updating knowledge of specific risks for the vehicle

2.10 Equipment related hazards

➢ **Major risks**:

- Many accidents in mining activities can occur due to misuse or negligence during use of the equipment available. Conveyor belts, crushers, hoppers etc. are some major equipment used for mining activities.

- Most of the accidents and injuries related to conveyor belt systems occur because people working with and around them tend to ignore the most basic rule of safety pertaining to these systems. As per this rule, people should never stand, ride, walk, touch or sit on the conveyor belts at any time. But often out of mischief or negligence, people take these systems for granted and overlook this basic rule, which results in health hazards.

- Major fatalities and injuries occur due to man-riding conveyor belts without precaution or necessary safety instructions due to negligence.

Table 9 Probable risks and hazards

Hazard	Risk
Rotating shafts, pullies, sprockets and gears	Entanglement
Hard surfaces moving together	Crushing
Scissor or shear action	Severing
Sharp edge – moving or stationary	Cutting or puncturing
Cable or hose connections	Slips, trips and falls

➢ **Mitigation measures:**

- No conveyor which delivers into a crusher or bunker will be authorized for man-riding.

- Conveyor underpasses will be provided with effective guarding to prevent persons coming into contact with moving parts of the conveyor.

- Suitable guards or handrails will be provided to prevent persons falling or slipping onto the conveyor.

3 DISASTER MANAGEMENT PLAN (DMP)

A disaster is a catastrophic event in which personnel working in the affected area are immediately planed into a chaotic situation, which demands their immediate rescue, medical and social case to restore normalcy. It creates a major emergency inside the plant requiring an Emergency response in accordance with a mine DMP formulated by the management. No high- risk accidents are anticipated, as the project is an open- cast mining operation in a stable area free from land subsidence, earthquake etc. However, in case of an eventuality, the designated mines manager will be managing the situation. The organizational structure for handling any emergency situation is given in **Figure 3**.

A detailed DMP for handling emergencies includes:

- Identification and assessment of major credible risk scenarios anticipated at a particular workplace / activity (Slope failure, subsidence, fly rock fragments, fires, toxic / hazardous / flammable gas release / explosion, inundation etc.)
- Setting up an Emergency response organization identified key personnel at the mine with assigned duties and responsibilities for incident response and emergency response.
- Emergency action plans with implementation procedures by emergency response personnel for each scenario after emergency warning.
- Details of safety measures to prevent accident and disaster.
- Emergency notification by sending warning messages to identified agencies for liaison and stake holders.
- Setting up a permanent organization for completion of emergency and restoration of normalcy by complying with health, safety, and environmental laws and regulations
- Disaster management plan for safe mining particularly for underground mines where toxic fumes and other risks are involved.
- Supplementary response plans under mutual aid
- Any other stipulations made by regulatory agencies for handling emergency situations that may arise either from natural or manmade activities

The Indian Mines Rescue Rules 1985 may be referred to prescribe the organization for conducting rescue operations at opencast mines ensuring safety of life, property and environment and safe rehabilitation of the affected area.

Figure 3 Organization chart for disaster management