7. ADDITIONAL STUDIES

7.1 RISK ASSESSMENT PLAN

The main objective of risk assessment study is to propose a comprehensive but simple approach to carry out risk analysis and conducting feasibility studies for industries, planning and management of industrial prototype hazard analysis study in Indian context.

Risk analysis and risk assessment shall provide details on Risk Assessment techniques used to determine risk posed to people who work inside or live near hazardous facilities, and to aid in preparing effective emergency response plans by delineating a Disaster Management Plan (DMP) to handle on-site and off-site emergencies. Hence, RA is an invaluable method for making informed risk based process safety and environmental impact planning decisions, as well as being fundamental to any decisions while siting a facility. RA is a site or risk specific assessment which is complex and needs extensive study shall involve process understanding, hazard identification, consequence modelling, probability data, vulnerability models/data, local weather and terrain conditions and local population data.

RA may be carried out to serve the following objectives.

- Identification of safety areas
- Identification of hazard sources
- Generation of accidental release scenarios for escape of hazardous materials from the facility
- Identification of vulnerable units with recourse to hazard indices
- Estimation of damage distances for the accidental release scenarios with recourse to Maximum Credible Accident (MCA) analysis
- Estimation of probability of occurrences of hazardous event through fault tree analysis and computation of reliability of various control paths
- Assessment of risk on basis of above evaluation against the risk acceptability criteria relevant to the situation
- Suggest risk mitigation measures based on engineering judgement, reliability and risk analysis approaches
- Delineation / upgradation of DMP
- Safety Reports: with external safety report/ occupational safety report,

The risk assessment report covers the following in terms of extent of damage with resource to MCA analysis and delineation of risk mitigations measures with an approach to DMP.

- Hazard identification - identification of hazardous activities, hazardous materials, past accident records, etc.
- Hazard quantification - consequence analysis to assess the impacts
- Risk presentation
- Risk mitigation measures
- Disaster management plans

Figure 7.1 Risk Assessment - Conceptual Framework

Methods of risk prediction shall cover all the design intentions and operating parameters to quantify risk in terms of probability of occurrence of hazardous events and magnitude of its consequence.

In the sections below, the identification of various hazards, probable risks in the Pharmaceutical unit, maximum credible accident analysis, consequence analysis are addressed which gives a broad identification of risks involved in the unit. Based on the risk estimation for fuel and chemical storage, Disaster Management Plan (DMP) along with recommendations of the risk assessment is given in section 7.4**.**

7.1.1 BACKGROUND

Identification analysis and assessment of hazards and risks provide vital information to the risk management, that what should be the type & capacity of any on-site and off-site emergency plan & what type of safety measures and maintenance is required. Risk and consequence analysis is carried out considering storage and handling of various hazardous raw materials, intermediates and product as well as **manufacturing process.** Many of the chemicals stored at site is in the Part II of schedule I of the named chemicals in the Manufacture, storage, import and handling of chemicals (MSIHC Rules).

None of the listed chemicals are stored in large quantity but limited to a week's stock, as they are all common place items. The stored quantity is several times lower than the threshold quantity permitted. They only need to prepare an On-site emergency plan and keep it active by regular drills.

7.1.2 METHODOLOGY

Rapid Risk Assessment (RRA) is a means of making a systematic analysis of the risks from hazardous activities, and forming a rational evaluation of their significance, in order to provide input to a decision making process. The term 'quantitative rapid risk analysis' is widely used, but strictly this refers to the purely numerical analysis of risks without any evaluation of their significance. The study has been conducted based on the premises of a traditional Quantitative Risk Assessment. The purpose of Risk Assessment is to develop mitigation measures for unacceptable generators of risk, as well as to reduce the overall level of risk to "As Low As Reasonably Practical" (ALARP).

- Collection of data/information with respect to facility, process, hazardous chemicals etc.
- Collection of meteorological data.
- Identification of hazardous chemicals as per the Manufacture, Storage and Import of Hazardous Chemicals (MSIHC) Amendment Rules - 2000.d
- Screening of hazardous nature of each chemical and confirmation with Fire Diamond.
- Tabulation of chemical as well as physical properties and storage details for each hazardous chemical.
- Identification of hazard associated with each chemical.
- Identification of release type and determine release rates.
- Simulation of each identified hazardous chemical for consequence analysis using **ALOHA (Areal Locations of Hazardous Atmospheres).**

ALOHA is an air dispersion model developed by Environmental Protection Agency (EPA, USA), can be used as a tool for predicting the movement and dispersion of gases. It predicts pollutant concentrations downwind from the source of a spill, taking into consideration the physical characteristics of the spilled material. Input parameters to ALOHA model are location name, latitude and longitude of location, its elevation, building type, building surroundings, wind speed, direction (from meteorological department), wind measuring heights, ground roughness, cloud cover, stability class, inversion, humidity, tank type and orientation, tank dimension, state of chemical, temperature inside the stank, diameter of opening, leak type and height of opening ALOHA software was used to model the effects of each scenario taking into consideration the usual atmospheric conditions as well as the worst case atmospheric conditions. ALOHA is a computer program designed specially for use by people responding to chemical releases, as well as for emergency planning. ALOHA models key hazards - toxicity, flammability, thermal radiation (heat) and overpressure (explosion, blast, force) - related to chemical releases that result in toxic gas dispersions, fires and/or explosions. ALOHA allows for the specification of concentration limits for the purpose of consequence assessment (e.g., assessment of human health risks from contaminant plume exposure). ALOHA refers to these concentration limits as level-of-concern (LOC) concentrations. Safety analysis work uses the Emergency Response Planning Guidelines (ERPGs) and Temporary Emergency Exposure Limits (TEELs) for assessing human health effects for both facility workers and the general public. Analysts have generally applied the American Industrial Hygiene Association (AIHA) ERPGs9 and TEELs 10 for the purpose of assessing human health effects for both facility workers and the general public. Recently, another alternative has become available to analysts. The National Advisory Committee for Acute Exposure Guideline Levels for Hazardous Substances (NAC/AEGL Committee) has been developing acute exposure guideline levels (AEGLs) to assist federal and state agencies and private sector organizations with their need for short-term hazardous chemical exposure information in terms of five emergency exposure periods (10 and 30 min, 1 h, 4 h, and 8 h)

7.1.3 DAMAGE CRITERIA USED IN THE ALOHA

(a) Thermal Damage

A Level of Concern (LoC) is a threshold level of thermal radiation, usually the level above which a hazard may exist. ALOHA uses three threshold values (measured in kilowatts per square meter) to create the default threat zones:

- Red: 10 kW/(sq. m.) -- potentially lethal within 60 sec;
- Orange: 5 kW/(sq. m.) -- second-degree burns within 60 sec; and
- Yellow: 2 kW/(sq. m.) -- pain within 60 sec.

The thermal radiation effects that people experience depend upon the length of time they are exposed to a specific thermal radiation level. Longer exposure durations, even at a lower thermal radiation level, can produce serious physiological effects. The threat zones displayed by ALOHA represent thermal radiation levels; the accompanying text indicates the effects on people who are exposed to those thermal radiation levels but are able to seek shelter within one minute.

Below are some effects at specific thermal radiation levels and durations (on bare skin):

Radiation Intensity (kW/m^2)	Time of severe pain (s)	Time for 2nd degree burns (s)
1	115	663
2	45	187
3	27	92
4	18	57
5	13	40
6	11	30
8	7	20
10	5	14
12	4	11

Source: Federal Emergency Management Agency et al. 1988.

(b) Overpressure:

Overpressure, also called a blast wave, refers to the sudden onset of a pressure wave after an explosion. This pressure wave is caused by the energy released in the initial explosion – the bigger the initial explosion, the more damaging the pressure wave. Pressure waves are nearly instantaneous, traveling at the speed of sound.

An Overpressure Level of Concern (LoC) is a threshold level of pressure from a blast wave, usually the pressure above which a hazard may exist.

ALOHA uses three threshold values to create the default threat zones:

Red : 8.0 psi (destruction of buildings);

Orange : 3.5 psi (serious injury likely); and

Yellow : 1.0 psi (shatters glass).

The following table relates overpressure values to the structural and physiological effects produced.

Overpressure* (psi)	Expected Damage
0.04	Loud noise (dB); sonic boom glass failure
0.15	Typical pressure for glass failure
0.4	Limited minor structural damage
0.50 - 1.0	Windows usually shattered
0.7	Minor damage to house structure.
1.0	Partial demolition of houses; made uninhabitable.
1.0 - 2.0	Corrugated metal panels fail and buckle. Housing wood panels blown in.
1.0 - 8.0	Range for slight to serious injuries from flying glass and other missiles
2.0	Partial collapse of walls and roofs of houses.

2.0 - 3.0	Non reinforced concrete or cinder block walls shattered
2.4 - 12.2	Range for 1-90% eardrum rupture among exposed populations
2.5	50% destruction of home brickwork
3.0	Steel frame building distorted and pulled away from foundation
5.0	Wooden utility poles snapped
5.0 - 7.0	Nearly complete destruction of houses
7.0	Loaded train cars overturned.
9.0	Loaded train box cars demolished.
10.0	Probable total building destruction
14.5 - 29.0	Range for 1-99% fatalities among exposed populations due to direct blast effects

*Note: * These are peak pressures formed in excess of normal atmospheric pressure by blast and shock waves.*

(c) Hazardous Fragments:

One of the major hazards associated with any explosion is flying debris (hazardous fragments) propelled by the explosion's pressure wave. Hazardous fragments come from two primary sources: container fragments and debris from the surrounding area.

If an explosion is likely to occur, first responders must be aware of the possibility of hazardous fragments and take necessary precautions to shield responders and others from the potentially fatal fragments. Some hazardous fragments may be projected into areas well beyond those affected by the thermal or overpressure explosion hazards.

(d) Toxic release:

For toxic release, there are several hazard classification systems in use. Some chemicals have not been classified in every system. ALOHA determines its default toxic Level of Concern (LOC) values based on the following:

1) Acute Exposure Guideline Levels (AEGLs)

Acute Exposure Guideline Levels (AEGLs) are Toxic Levels of Concern (LOCs) that is used to predict the area where a toxic gas concentration might be high enough to harm people. The guidelines define three-tiered AEGLs as follows:

AEGL-1: The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

AEGL-2: The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

AEGL-3: The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

Each of the three levels of AEGL -- AEGL-1, AEGL-2, and AEGL-3 -- is developed for Formaldehyde (37% solution) for which this is applicable for this unit. AEGLS are available for each of five exposure periods: 10 minutes, 30 minutes, 1 hour, 4 hours, and 8 hours. ALOHA only includes AEGL values with an exposure period of 60 minutes.

2) The Emergency Response Planning Guidelines (ERPGs)

The American Industrial Hygiene Association (AIHA) has issued three levels of ERPG values based on toxic effect of the chemical for use in evaluating the effects of accidental chemical releases on the general public. The Emergency Response Planning Guidelines (ERPGs) are Toxic Levels of Concern (LOCs) that is used to predict the area where a toxic gas concentration might be high enough to harm people. The ERPGs are three-tiered guidelines with one common denominator: 1-hour contact duration. Each guideline identifies the substance, its chemical and structural properties, animal toxicology data, human experience, existing exposure guidelines, the rationale behind the selected value, and a list of references.

ERPG 1: The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined, objectionable odor.

ERPG 2*:* The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.

ERPG 3: The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life threatening health effects.

The most important point to remember about the ERPGs is that they do not contain safety factors usually incorporated into exposure guidelines. Rather, they estimate how the general public would react to chemical exposure. Just below the ERPG-1, for example, most people would detect the chemical and may experience temporary mild effects. Just below the ERPG-3, on the other hand, it is estimated that the effects would be severe, although not life-threatening. The ERPG should serve as a planning tool, not a standard to protect the public.

3) Temporary Emergency Exposure Levels (TEELs)

There are three TEEL levels that are important for responders to consider:

TEEL-1: Maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing other than mild transient health effects or perceiving a clearly defined objectionable odour.

TEEL-2: Maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

TEEL-3: Maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing life-threatening health effects.

4) Immediate Dangerous to Life or Health (IDLH)

Immediately Dangerous to Life or Health (IDLH) level is a limit originally established for selecting respirators for use in workplaces by the National Institute for Occupational Safety and Health (NIOSH). A chemical's IDLH is an estimate of the maximum concentration in the air to which a healthy worker could be exposed without suffering permanent or escape-impairing health effects. We recommend that appropriate respirator (as per NIOSH) be kept handy/easily available.

The IDLH was not designed to be an exposure limit for the general population. It does not take into account the greater sensitivity of some people, such as children and the elderly. Note: For AEGLs, ERPGs and TEELs, the rank number increase with the hazard level, so that AEGL-3 is more hazardous than AEGL-1. Typically, the “3” values are used for the most hazardous (red) threat zones because they represent the threshold concentration above which health effects may be life threatening.

7.1.4 DETAILS OF STORAGE FACILITIES

The raw materials (required for the manufacture of products) are stored in underground tanks, drums, containers (for liquid raw materials) and bags (for solid raw materials) which are in turn stored in the raw materials storage area. The details, mode of storage and the quantity of raw materials is as per details below in Table 7.1. An examination of the inventory shows that the flammable chemicals will be stored at site and these need extra care in order to eliminate any slight chance of an ignition. Additional care is needed especially in the solvent storage area. Further, solvents will be kept in drums in a licensed shed. A separate warehouse is proposed for bag storage and carbouys, However compatibility should be checked w.r.t chemicals stored in bags, as there is a chance of mix up with other chemicals and consequent hazardous situation.

Hazardous chemicals have been identified using the Schedule-I, Part-II of MSIHC Rules - 2000. The chemicals having hazardous nature but not listed in the said notification are screened and confirmed using "Fire Diamond" [National Fire Protection Association (NFPA) Diamond] classification. The project will store and handle number of flammable chemicals. List of such chemicals and their storage capacity is given in Table 7.1. The hazardous chemicals selected for the present study is based on the nature of hazardous chemicals as per NFPA and their storage capacity.

Table 7.1 Details of Solvent Storage Details

S. No	Name of the chemical	Storage	MOC/Mode of storage	Max storage Capacity (KL)	Usage per Year (KL)	Storage parameter	
						Temp	Pressure
1	Toluene	U/G	MS	45	135	Atm	Atm
2	DMF	Barrel	HDPE	6	18	Atm	Atm
3	Acetone	U/G	MS/HDPE	46	138	Atm	Atm
4	Hexane	Barrel	MS BARREL	12	36	Atm	Atm
5	DNS	U/G	MS/HDPE	221	663	Atm	Atm
6	Methanol	U/G	MS/HDPE	120	360	Atm	Atm
7	THF	Barrel	MS/HDPE	12	36	Atm	Atm
8	Pyridine	Barrel	MS/HDPE	8	24	Atm	Atm
9	MTBE	Barrel	MS/HDPE	16	48	Atm	Atm
10	EDC	Barrel	MS/HDPE	31	93	Atm	Atm
11	MDC	Barrel	MS/HDPE	34	102	Atm	Atm
12	Isopropanol	Barrel	MS/HDPE	16	48	Atm	Atm
13	Ethyl Acetate	U/G	MS/HDPE	21	63	Atm	Atm

Table 7.2 Classification of National Fire Protection Association (NFPA)

Quadrant	Code	Meaning
Health Hazard	**4**	Too dangerous to enter - vapour or liquid
	3	Extremely hazardous - use full protection
	2	Hazardous - use breathing apparatus
	1	Slightly hazardous
	0	Like ordinary material
Flammability Hazard	**4**	Extremely flammable.
	3	Ignites at normal temperatures
	2	Ignites when moderately heated
	1	Must be preheated to burn.

	0	Will not burn
Reactivity Hazard	**4**	May detonate - evacuate area if materials are exposed
	3	Strong shock or heat may detonate - use monitors
	2	Violent chemical change possible
	1	Unstable if heated - use normal precautions
	0	Normally stable.

Table 7.3 Details of hazardous chemicals

S. No.	Raw Material	Avg. Qty (T/Year)	NFPA RATING		
			NF	NH	NR
1.	Orotic acid	96.0	1	1	0
2.	Epichorohydrin	45.0	3	3	2
3.	Morpholine	18.0	3	3	0
4.	Phosphorous trichloride	6.0	0	3	2
5.	Phosphorous oxy chloride	10.8	0	4	2
6.	Malononitrile	3.6	1	3	2
7.	Nitric acid	54.0	0	3	0
8.	Hydroquinone	24.0	1	2	0
9.	Sulphuric acid	39.0	0	3	2
10.	Hydrochloric acid (gas)	270.0	0	3	1
11.	Phosphorous pentaoxide	45.0	0	3	2
12.	Orthophosphoric Acid	63.0	0	3	0
13.	Benzoyl chloride	27.0	2	2	0
14.	Tetra Hydrofuran	75.0	3	2	0
15.	Potassium Hydroxide	28.8	0	3	2
16.	Sodium Hydroxide	105.0	0	3	2
17.	Formaldehyde	25.5	2	3	0
18.	Toluene	135.0	3	2	0
19.	Acetone	138.0	3	1	0
20.	Hexane	36.0	3	2	0
21.	THF	36.0	3	2	0
22.	Pyridine	24.0	3	2	0
23.	EDC	93.0	3	2	0
24.	Ethyl Acetate	63.0	3	2	0

7.1.5 CONSEQUENCE ANALYSIS

Consequence analysis helps to identify the vulnerable sections based on the impact. Essentially this is a tool to understand the damage distances that can arise from thermal radiation, blast overpressure or Toxic release.

The accident scenarios assumed are based on standard Preliminary Hazard Identification techniques (F& EI) which includes study of chemicals, combining quantity with dangerous properties, past accident data, possible process and storage hazards and engineering judgment based on the facility.

The common hazards anticipated are

- Spills in the event of failure of Pump seals while transferring material or leak in storage container
- Toxic release condition from Storage or pipeline leakage
- Flash fire explosion in the plant due to sudden release of flammable material

Thus fires, explosions and toxic release are the consequences which are analysed through various scenarios explained and models developed. ALOHA has been used for modelling.

COMMON INPUT USED FOR MODELING:

SITE DATA:

Location: HOUSR TALUK, KRISHNAGIRI, TN, INDIA

Building Air Exchanges Per Hour: 0.89

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)

Wind: 5 meters/second from E at 3 meters

Ground Roughness: open country   Cloud Cover: 5 tenths

Air Temperature: 36° F   Stability Class: D

No Inversion Height   Relative Humidity: 39%

7.1.6 CONSEQUENCES ANALYSIS FOR FAILURE SCENARIOS OF HAZARDOUS CHEMICALS FOR (TOLUENE)

CHEMICAL DATA:

Chemical Name: TOLUENE   Molecular Weight: 92.14 g/mol

AEGL-1 (60 min): 67 ppm   AEGL-2 (60 min): 560 ppm   AEGL-3 (60 min): 3700 ppm

IDLH: 500 ppm   LEL: 11000 ppm   UEL: 71000 ppm

Ambient Boiling Point: 107.0° C

Vapor Pressure at Ambient Temperature: 0.010 atm

Ambient Saturation Concentration: 11,532 ppm or 1.15%

SOURCE STRENGTH:

Direct Source: 2 liters/min

Source State: Liquid

Source Temperature: 36° C

Release Duration: 60 minutes

Release Rate: 1.71 kilograms/min

Total Amount Released: 102 kilograms

THREAT ZONE:

Model Run: Heavy Gas

Red : 11 meters --- (3700 ppm = AEGL-3 [60 min])

Orange: 20 meters --- (560 ppm = AEGL-2 [60 min])

Yellow: 58 meters --- (67 ppm = AEGL-1 [60 min])

Flammable Area of Vapor Cloud

Model Run: Heavy Gas

Red : 11 meters --- (6600 ppm = 60% LEL = Flame Pockets)

Yellow: 14 meters --- (1100 ppm = 10% LEL)

Overpressure (blast force) from vapor cloud explosion

Type of Ignition: ignited by spark or flame

Level of Congestion: congested, Model Run: Heavy Gas

Red : LOC was never exceeded --- (8.0 psi = destruction of buildings)

Orange: 11 meters --- (3.5 psi = serious injury likely)

Yellow: 21 meters --- (1.0 psi = shatters glass)

Figure 7.2 Toluene - Thread Zone from Vapour Cloud Explosion

Figure 7.3 Toluene - Toxic Thread Zone

7.1.7 CONSEQUENCES ANALYSIS FOR FAILURE SCENARIOS OF HAZARDOUS CHEMICALS FOR (ACETONE)

CHEMICAL DATA:

Chemical Name: ACETONE Molecular Weight: 58.08 g/mol

AEGL-1 (60 min): 200 ppm AEGL-2 (60 min): 3200 ppm AEGL-3 (60 min): 5700 ppm

LEL: 26000 ppm UEL: 130000 ppm

Ambient Boiling Point: 53.1° C

Vapor Pressure at Ambient Temperature: 0.10 atm

Ambient Saturation Concentration: 115,664 ppm or 11.6%

SOURCE STRENGTH:

Direct Source: .2 liters/sec Source State: Liquid

Source Temperature: 36° C Release Duration: 1 minute

Release Rate: 155 grams/s Total Amount Released: 9.29 kilograms

THREAT ZONE:

Model Run: Heavy Gas

Red : 16 meters --- (5700 ppm = AEGL-3 [60 min])

Orange: 22 meters --- (3200 ppm = AEGL-2 [60 min])

Yellow: 99 meters --- (200 ppm = AEGL-1 [60 min])

Threat Modeled: Flammable Area of Vapor Cloud

Red : 11 meters --- (26000 ppm = LEL)

Orange: 11 meters --- (15600 ppm = 60% LEL = Flame Pockets)

Yellow: 26 meters --- (2600 ppm = 10% LEL)

Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.

Threat Modeled: Overpressure (blast force) from vapor cloud explosion:

Ignited by detonation

Red : 13 meters --- (8.0 psi = destruction of buildings)

Orange: 18 meters --- (3.5 psi = serious injury likely)

Yellow: 37 meters --- (1.0 psi = shatters glass)

Figure 7.4 Aceton - Thread Zone from Vapour Cloud Explosion

7.1.8 CONSEQUENCES ANALYSIS FOR FAILURE SCENARIOS OF HAZARDOUS CHEMICALS FOR (MALONONITRILE)

CHEMICAL DATA:

Chemical Name: MALONONITRILE Molecular Weight: 66.06 g/mol

AEGL-1 (60 min): N/A AEGL-2 (60 min): 0.77 ppm AEGL-3 (60 min): 2.3 ppm

LEL: 29000 ppm UEL: 190000 ppm

Ambient Boiling Point: 213.9° C

Freezing Point: 31.7° C

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)

Wind: 5 meters/second from E at 3 meters

Ground Roughness: open country Cloud Cover: 5 tenths

Air Temperature: 36° F Stability Class: D

No Inversion Height Relative Humidity: 39%

SOURCE STRENGTH:

Direct Source: 1.5 kilograms/hr Source Height: 0

Release Duration: 60 minutes

Release Rate: 25 grams/min

Total Amount Released: 1.50 kilograms

THREAT ZONE:

Model Run: Gaussian

Red : 25 meters --- (3 ppm = PAC-1)

Orange: 29 meters --- (2.3 ppm = AEGL-3 [60 min])

Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.

Yellow: 50 meters --- (0.77 ppm = AEGL-2 [60 min])

Threat Modeled: Flammable Area of Vapour Cloud

Red : less than 10 meters (10.9 yards) --- (17400 ppm = 60% LEL = Flame Pockets)

Yellow: less than 10 meters (10.9 yards) --- (2900 ppm = 10% LEL)

Note: Threat zone was not drawn because effects of near-field patchiness

Figure 7.5 Malononitrile - Toxic Thread Zone

7.1.9 CONSEQUENCES ANALYSIS FOR FAILURE SCENARIOS OF HAZARDOUS CHEMICALS FOR (ETHYL ACETATE)

CHEMICAL DATA:

Chemical Name: ETHYL ACETATE Molecular Weight: 88.11 g/mol

PAC-1: 400 ppm PAC-2: 400 ppm PAC-3: 10000 ppm IDLH: 2000 ppm

LEL: 21800 ppm

UEL: 115000 ppm Ambient Boiling Point: 74.0° C

Vapor Pressure at Ambient Temperature: 0.036 atm

Ambient Saturation Concentration: 40,128 ppm or 4.01%

SOURCE STRENGTH:

Direct Source: 5 liters/min Source State: Liquid

Source Temperature: equal to ambient Release Duration: 60 minutes

Release Rate: 4.6 kilograms/min Total Amount Released: 276 kilograms

THREAT ZONE:

Model Run: Heavy Gas

Red : 11 meters --- (10000 ppm = PAC-3)

Orange: 39 meters --- (400 ppm = PAC-2)

Yellow: 16 meters --- (2000 ppm = IDLH)

Threat Modeled: Flammable Area of Vapor Cloud

Red : 11 meters --- (21800 ppm = LEL)

Orange: 11 meters --- (13080 ppm = 60% LEL = Flame Pockets)

Yellow: 15 meters --- (2180 ppm = 10% LEL)

Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.

Threat Modeled: Overpressure (blast force) from vapor cloud explosion

Type of Ignition: ignited by detonation

Model Run: Heavy Gas

Red : 15 meters --- (8.0 psi = destruction of buildings)

Orange: 20 meters --- (3.5 psi = serious injury likely)

Yellow: 42 meters --- (1.0 psi = shatters glass)

Figure 7.6 Ethyl Acetate: Thread Zone from Vapour Cloud Explosion

7.1.10 CONSEQUENCES ANALYSIS FOR FAILURE SCENARIOS OF HAZARDOUS CHEMICALS FOR (N-HEXANE)

CHEMICAL DATA:

Chemical Name: N-HEXANE Molecular Weight: 86.18 g/mol

AEGL-1 (60 min): N/A AEGL-2 (60 min): 2900 ppm AEGL-3 (60 min): 8600 ppm

IDLH: 1100 ppm LEL: 12000 ppm UEL: 72000 ppm

Ambient Boiling Point: 65.4° C

Vapor Pressure at Ambient Temperature: 0.067 atm

Ambient Saturation Concentration: 74,538 ppm or 7.45%

SOURCE STRENGTH:

Direct Source: 5 liters/min Source State: Liquid

Source Temperature: equal to ambient Release Duration: 60 minutes

Release Rate: 3.38 kilograms/min Total Amount Released: 203 kilograms

THREAT ZONE:

Threat Modeled: Overpressure (blast force) from vapor cloud explosion

Type of Ignition: ignited by spark or flame

Red : LOC was never exceeded --- (8.0 psi = destruction of buildings)

Orange: 12 meters --- (3.5 psi = serious injury likely)

Yellow: 23 meters --- (1.0 psi = shatters glass)

Figure 7.7 Hexane Thread Zone from Vapour Cloud Explosion

Threat Modeled: Flammable Area of Vapour Cloud

Model Run: Heavy Gas Note: Threat zone was not drawn

Red : 11 meters --- (12000 ppm = LEL)

Orange: 11 meters --- (7200 ppm = 60% LEL = Flame Pockets)

Yellow: 20 meters --- (1200 ppm = 10% LEL)

7.1.11 CONSEQUENCES ANALYSIS FOR FAILURE SCENARIOS OF HAZARDOUS CHEMICALS FOR (ISOPROPANOL)

CHEMICAL DATA:

Chemical Name: ISOPROPANOL Molecular Weight: 60.10 g/mol

PAC-1: 400 ppm PAC-2: 400 ppm PAC-3: 12000 ppm IDLH: 2000 ppm

LEL: 20000 ppm UEL: 127000 ppm Ambient Boiling Point: 79.5° C

Vapor Pressure at Ambient Temperature: 0.012 atm

Ambient Saturation Concentration: 13,210 ppm or 1.32%

SOURCE STRENGTH:

Direct Source: 5 liters/min Source State: Liquid

Source Temperature: 36° C Release Duration: 60 minutes

Release Rate: 3.85 kilograms/min Total Amount Released: 231 kilograms

THREAT ZONE: Model Run: Gaussian

Threat Modeled: Flammable Area of Vapour Cloud

Red : 11 meters --- (20000 ppm = LEL)

Orange: 11 meters --- (12000 ppm = 60% LEL = Flame Pockets)

Yellow: 21 meters --- (2000 ppm = 10% LEL)

Note: Threat zone was not drawn for short distances.

Threat Modeled: Overpressure (blast force) from vapour cloud explosion: ignited by spark or flame

Red : LOC was never exceeded --- (8.0 psi = destruction of buildings)

Orange: less than 10 meters (10.9 yards) --- (3.5 psi = serious injury likely)

Yellow: 19 meters --- (1.0 psi = shatters glass)

Figure 7.8 Isopropanol - Thread Zone from Vapour Cloud Explosion

7.1.12 CONSEQUENCES ANALYSIS FOR FAILURE SCENARIOS OF HAZARDOUS CHEMICALS FOR (PHOSPHORUS TRICHLORIDE)

Chemical Name: PHOSPHORUS TRICHLORIDE

Molecular Weight: 137.33 g/mol

AEGL-1 (60 min): 0.34 ppm AEGL-2 (60 min): 2 ppm AEGL-3 (60 min): 5.6 ppm

IDLH: 25 ppm Ambient Boiling Point: 72.6° C

Vapor Pressure at Ambient Temperature: 0.053 atm

Ambient Saturation Concentration: 59,053 ppm or 5.91%

SOURCE STRENGTH:

Direct Source: 3 liters/hr Source State: Liquid

Source Temperature: equal to ambient Release Duration: 10 minutes

Release Rate: 80.4 grams/min Total Amount released: 804 grams

THREAT ZONE:

Model Run: Heavy Gas

Red : 27 meters --- (15 ppm = ERPG-3)

Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.

Orange: 62 meters --- (3 ppm = ERPG-2)

Yellow: 158 meters --- (0.5 ppm = ERPG-1)

Red : 35 meters --- (5.6 ppm = AEGL-3)

Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.

Orange: 60 meters --- (2 ppm = AEGL-2)

Yellow: 150 meters --- (0.34 ppm = AEGL-1)

Figure 7.9 Phosphorus Trichloride - Toxic Thread Zone

7.1.13 CONSEQUENCES ANALYSIS FOR FAILURE SCENARIOS OF HAZARDOUS CHEMICALS FOR (METHANOL)

CHEMICAL DATA:

Chemical Name: METHANOL Molecular Weight: 32.04 g/mol

AEGL-1 (60 min): 530 ppm AEGL-2 (60 min): 2100 ppm AEGL-3 (60 min): 7200 ppm

IDLH: 6000 ppm LEL: 71800 ppm UEL: 365000 ppm Ambient Boiling Point: 61.9°C

Vapor Pressure at Ambient Temperature: 0.045 atm

Ambient Saturation Concentration: 49,877 ppm or 4.99%

SOURCE STRENGTH:

Direct Source: 5 liters/min Source State: Liquid

Source Temperature: equal to ambient Release Duration: 60 minutes

Release Rate: 4.05 kilograms/min Total Amount Released: 243 kilograms

THREAT ZONE:

Model Run: Gaussian

Red : 11 meters --- (5000 ppm = ERPG-3)

Orange: 25 meters --- (1000 ppm = ERPG-2)

Yellow: 58 meters --- (200 ppm = ERPG-1)

Threat Modeled: Flammable Area of Vapor Cloud

Red : less than 10 meters (10.9 yards) --- (71800 ppm = LEL)

Orange: less than 10 meters(10.9 yards) --- (43080 ppm = 60% LEL = Flame Pockets)

Yellow: 13 meters --- (7180 ppm = 10% LEL)

Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.

Figure 7.10 Toxic Thread Zone

7.1.14 CONSEQUENCES ANALYSIS FOR FAILURE SCENARIOS OF HAZARDOUS CHEMICALS FOR (PYRIDINE)

CHEMICAL DATA:

Chemical Name: PYRIDINE Molecular Weight: 79.10 g/mol

PAC-1: 3 ppm PAC-2: 6.9 ppm PAC-3: 3600 ppm IDLH: 1000 ppm

LEL: 18000 ppm] UEL: 120000 ppm

Ambient Boiling Point: 111.6° C

Vapor Pressure at Ambient Temperature: 0.0070 atm

Ambient Saturation Concentration: 7,769 ppm or 0.78%

SOURCE STRENGTH:

Direct Source: 5 liters/hr Source State: Liquid

Source Temperature: equal to ambient Release Duration: 60 minutes

Release Rate: 83.4 grams/min Total Amount Released: 5.00 kilograms

THREAT ZONE:

Model Run: Heavy Gas Toxic zone

Red : 11 meters --- (1000 ppm = IDLH)

Orange: 44 meters --- (6.9 ppm = PAC-2)

Yellow: 67 meters --- (3 ppm = PAC-1)

Threat Modeled: Overpressure (blast force) from vapor cloud explosion : ignited by spark or flame

Red : LOC was never exceeded --- (8.0 psi = destruction of buildings)

Orange: 11 meters --- (3.5 psi = serious injury likely)

Yellow: 20 meters --- (1.0 psi = shatters glass)

Figure 7.11 Pyridine - Toxic Thread Zone

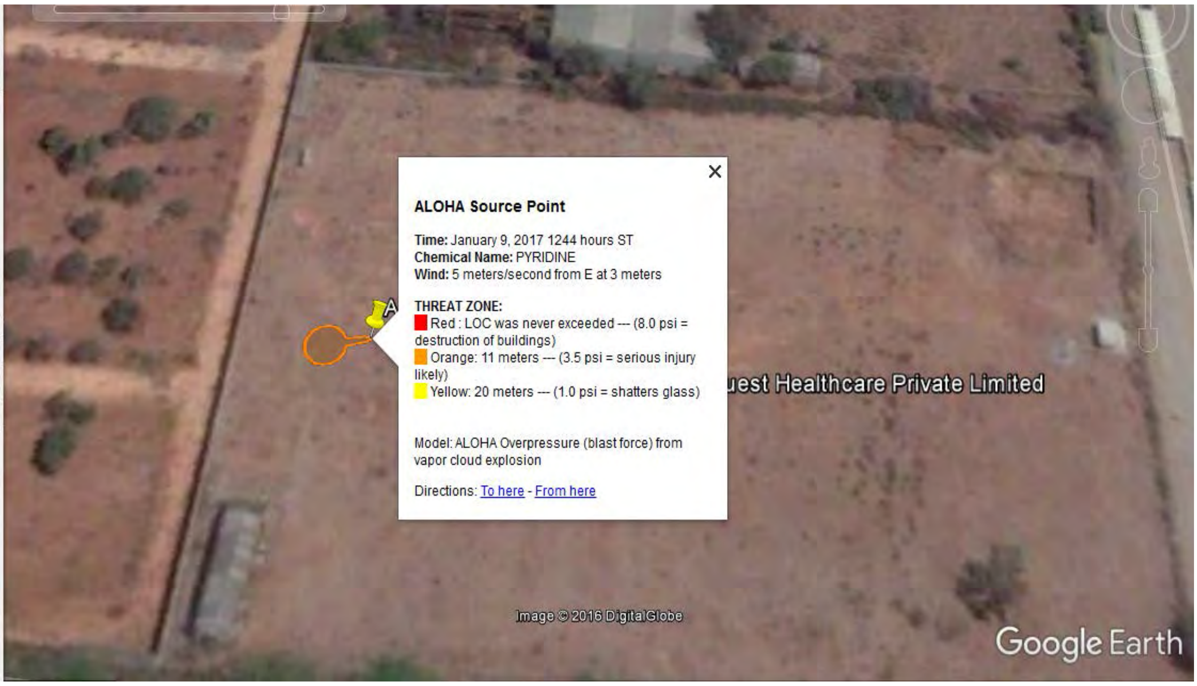


Figure 7.12 Pyridine - Thread Zone from Vapour Cloud Explosion

7.1.15 CONSEQUENCES ANALYSIS FOR FAILURE SCENARIOS OF HAZARDOUS CHEMICALS FOR (PHOSPHORUS OXYCHLORIDE)

Chemical Name: PHOSPHORUS OXYCHLORIDE

Molecular Weight: 153.33 g/mol

AEGL-1 (60 min): N/A   AEGL-2 (60 min): N/A   AEGL-3 (60 min): 0.85 ppm

Ambient Boiling Point: 101.5° C

Vapor Pressure at Ambient Temperature: 0.011 atm

Ambient Saturation Concentration: 11,984 ppm or 1.20%

SOURCE STRENGTH:

Direct Source: 2 liters/hr   Source Height: 0

Source State: Liquid

Source Temperature: 36° C

Release Duration: 60 minutes

Release Rate: 54.9 grams/min

Total Amount Released: 3.29 kilograms

THREAT ZONE:

Model Run: Heavy Gas

Red : 72 meters --- (0.85 ppm = PAC-3)

Orange: 96 meters --- (0.48 ppm = PAC-2)

Yellow: 96 meters --- (0.48 ppm = PAC-1)

Figure 7.13 Phosphorus Oxychloride - Toxic Thread Zone

7.1.16 CONSEQUENCES ANALYSIS FOR FAILURE SCENARIOS OF HAZARDOUS CHEMICALS FOR (HYDROGEN CHLORIDE)

Chemical Name: HYDROGEN CHLORIDE

Molecular Weight: 36.46 g/mol

AEGL-1 (60 min): 1.8 ppm AEGL-2 (60 min): 22 ppm AEGL-3 (60 min): 100 ppm

IDLH: 50 ppm

Ambient Boiling Point: -86.9° C

Vapor Pressure at Ambient Temperature: greater than 1 atm

Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

SOURCE STRENGTH:

Direct Source: 1 liters/min Source State: Liquid

Source Temperature: 36° C Release Duration: 60 minutes

Release Rate: 727 grams/min

Total Amount Released: 43.6 kilograms

Note: This chemical may flash boil and/or result in two phase flow.

THREAT ZONE:

Model Run: Gaussian

Red : 26 meters --- (150 ppm = ERPG-3)

Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.

Orange: 72 meters --- (20 ppm = ERPG-2)

Yellow: 195 meters --- (3 ppm = ERPG-1)

Figure 7.14 HCL - Toxic Thread Zone

7.1.17 RECOMMENDATIONS

The Hazard Analysis and Risk Assessment has shown that since the Plant handles chemicals in small quantities and chemicals involved none of the accident scenarios will contribute to major onsite risk and no offsite risk. The maximum impact of any spill, leak is limited to having localized impacts/ hazards at the operating personnel / plant personnel level.

Proper ventilation to be provided in process areas to prevent built up of flammable vapours that may lead to explosion.

While no serious risk is expected, Management is advised to review and ensure safety of drums and containers storing chemicals/solvents from accidental spills or people being exposed to it. Some specific measures to eliminate and/or mitigate these hazards are given below:

- Regular Inspection of storage drums, cans should be carried out
- Firefighting should be readily available.
- Access to the raw materials storage should be kept clear at all times to enable fire engines to reach them at the shortest time.
- Elimination of all sources of ignition near or around the storage area, equipment and pipelines carrying flammable substances.
- Enforce strict adherence to safety standards and laws (e.g., full compliance to the supplier's instructions)

7.1.18 SAFE PRACTICE TO BE FOLLOWED FOR HAZARDOUS CHEMICALS HANDLING, STORAGE, TRANSPORTATION AND UNLOADING

No	Activity	Scenario	Mitigation measures
1.	Unloading and storing of drums	Leaks, splash or fire	Unloading ramp Drum cushioning Trained operators Sorbent pads Respirator with face shield and chemical clothing. Fire extinguisher and hydrant Checking compatibility before storing. Availability of eye wash/shower facility nearby.
2.	Charging to reactors and service tanks	Leaks, splash or fire	SOP for activity Precautions against ESD Leak containment facility Trained operators Sorbent pads Respirator with face shield and chemical clothing. Fire extinguisher and hydrant Availability of eye wash/shower facility Nearby.
3.	Unloading to storage Tanks.	Leaks, splash or fire	SOP for activity Tanker loading and unloading permit. Precautions against ESD Leak containment facility Trained operators Sorbent pads Respirator with face shield and chemical clothing. Fire extinguisher and hydrant Availability of eye wash/shower facility nearby.

7.2 DISASTER MANAGEMENT PLAN

7.2.1 Introduction

Emergency planning is an integral part of the overall loss control program and is essential for any well run organization. This is important for effective management of an accident / incident to minimize losses to people and property, both in and around the facility. The important aspect in emergency management is to prevent by technical and organizational measures, the unintentional escape of hazardous materials out of the facility and minimize accidents and losses. Not only are unrecognized hazardous conditions which could aggravate and emergency situation be discovered, the emergency planning process also brings to light deficiencies such as lack of resources necessary for effective emergency response. Emergency planning also demonstrates the organizations commitment to the safety of employees and increases the organizations safety awareness.

7.2.2 Objectives of Disaster Management Plan

The objectives of the plan is to describe the facility's emergency response organization, the resources available and response actions applicable to deal with various types of emergencies that could occur at the facility with the response organization structure being deployed in the shortest time possible during an emergency. Thus, the objectives of emergency response plan can be summarized as.

- Rapid control and containment of the hazardous situation.
- Minimizing the risk and impact of event / accident,
- Effective rehabilitation of the affected persons and prevention of damage to property

In order to effectively achieve the objectives of emergency planning, the critical elements that form the backbone of the plan are:

- Reliable and early detection of emergency and careful planning.
- The command, Co-ordination, and response organization structure alone with efficient trained personnel.
- The availability of resources for handling emergences.
- Appropriate emergency response actions.
- Effective notification and communication facilities.
- Regular review and updating of the plan.
- Proper training of the concerned personnel.

7.2.3 Defining a Disaster

A disaster can be defined as an 'occurrence of such magnitude so as to create situation in which normal pattern of life within a facility is suddenly disrupted, adversely affecting not only the personnel and property within the facility but also in its vicinity'.

Such an occurrence may result in on- site implications like:

- Fire and / or explosion,
- Leakage of flammable material,
- Leakage of toxic material etc., all of which may lead to temporary / permanent damage to the surroundings.

Incidents having off – site origins can be:

- Natural calamity like earthquake, cyclone etc.,
- Air raids / marine attack.
- Crashing of aircrafts or flying objects.

Other incidents which can also result in a disaster are:

- Agitation / forced entry by external group of people
- Sabotage

An important aspect of the disaster is its unforeseen nature. Thus, by definition itself, a disaster is impossible to control completely. However, occurrence of events which lead to a disaster may be minimized through proper technology and engineering practices.

7.2.4 Declaring Fire Emergency

1. Any one discovering a fire shall attempt to put out the fire by using the first aid firefighting appliances.
2. Simultaneously, he would shout FIRE, FIRE, FIRE/THEE, THEE, THEE (in local language) till the assistance arrives.
3. Any one or his colleagues who hears, shall immediately inform the Shift In-charge and Control Room over phone or in person giving the exact location of the emergency.
4. The Incident Controller on hearing the incident of emergency, would proceed to the scene of emergency and assess the situation and decide whether a major emergency exists or is likely to escalate into major one.
5. If a major one, he would activate the on-site emergency plan by sounding the siren to code and informs the Store Controller.

6. The key personnel would report to the emergency control centre and take respective charge

7.2.5 Declaring Chemical leakage or fire in the Storage Area

1. Any person discovering Chemical leakage or fire would immediately inform the control room giving the exact location of leakage or fire.
2. The Incident Controller would proceed to the storage to assess the situation. Meanwhile, the person discovering fire shall try to extinguish it, if it is safe to do so, using suitable fire extinguishers.
3. If the leakage could be attended safely, he would call the maintenance and get it attended
4. Chemical leakage from storage Drum shall be collected and not allowed to spread.
5. If the leakage is very heavy, the Store Controller shall be informed and on his confirmation, he would take suitable action.
7. If the leakage has caught fire, the Incident Controller would initiate the On-site Emergency Plan by operating the siren to emergency code. The Site Controller would be informed.

7.2.6 Recovery Procedures

1. The procedures outlined in this section are intended for re-establishing normal operations at the earliest after an emergency. In addition, the procedure also provides for determining the cause of the accident, so that such incidents can be prevented in future.
2. The following are the requirements of a recover procedure :
   a. Incident investigation
   b. Establishing a recovery team
   c. Damage Assessment
   d. Clean-up and restoration
   e. Post-Emergency and Recovery Reporting.
3. Store Controller would arrange to organize suitable teams for the above tasks.

7.2.7 Incident Investigation

Incident investigation should be taken up to determine the cause of the emergency and the means of preventing any such occurrences again.

Procedure

i. The investigation team should immediately seal off the incident scene and commence its investigation to minimize the loss of any physical evidence.

ii. The investigation of the scene should include:
- Photographing the area.
- Determining the point of origin of the fire/leak/explosion, if applicable.
- Noting any unusual items in the area or any damage that is in consistent with the type of incident.

iii. Written or recorded statements are to be taken from all store keeper involved, potential witnesses and others who might have pertinent knowledge about the incident.

Report

i. A final report is to be prepared to include the most probable cause(s) and recommend corrective measures.

ii. The report should consider:
- Failure of Storage containers
- Failure of maintenance
- Failure of procedures
- Inadequate training
- Human error etc.

Corrective Actions

i. The investigation team is also responsible for conducting a review of response activities during the emergency to evaluate the adequacy of training, equipment and procedures.

ii. The Store Controller is responsible for ensuring that all corrective actions are taken to ensure better responses to emergencies to prevent recurrence of the incident, if any in future.

7.2.8 Recovery Team

- **Purpose**

In order to facilitate the restoration of the company after an emergency, a team known as Recovery Team is to be constituted by Store Controller to manage recovery activities, including damage assessment.

- **Organization**

The number of persons in the Recovery Team would vary depending on the nature of the incident and the extent of recovery operations. As a general rule, however, individuals representing Maintenance, Production, Safety, Quality Control, Personnel, Accounts, Engineering etc should be involved.

The recovery team is responsible for damage assessment, clean up and salvage operations and the restoration of the storage activities. A primary function of the recovery team would be to assess the damage to structures, equipment and materials.

- **Clean-up and Restoration Operations**

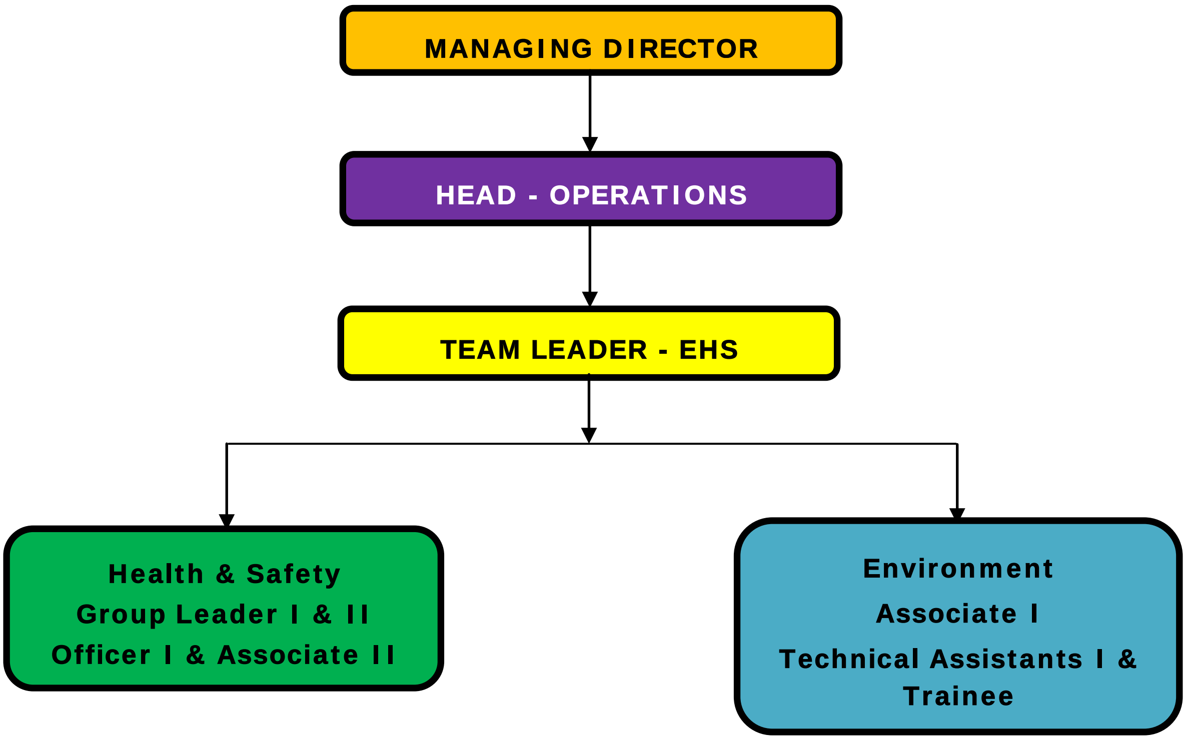
As soon as incident investigations are completed and restoration plans have been made, clean up and restoration activities should commence.

- **Post-Emergency Recovery Reports**

    i. The Officer-in-charge of Safety is to hold review sessions with emergency response personnel to evaluate the following:
        - The adequacy of emergency response procedures.
        - The adequacy of the investigation of the cause of the incident.
        - Summaries the post-emergency activities.

    ii. A full report is to be prepared and copies given to all persons concerned. The final report would summarize all previous reports and reviews as mentioned in this section

Key Personnel and Responsibilities Assigned to Them in Case of an Emergency



<u>Control crew</u>: Team who are well trained and technically who are able to control the corresponding emergency

<u>Rescue Crew</u>: Team response for Cordon the emergency area and alert the workers to send the safe assembly points

Checker Crew: Team Response for checking any affected persons any fatality all around the plant and report to EC

Manpower Counting crew: Team Responsible for counting nos of person inside the premises during emergency

Liaison/Supporting Crew: Team Responsible to ensure necessary PPEs Communication, access, clearing the routes

7.2.9 Outside Organizations that may extend help during On-Site Emergency

Types of Accidents

a. Fire in storage Area.
b. Bomb threat, terrorism, act of war, earth quake.

Table 7.4 Assistance from External Agencies

Incident	External Agency	Assistance
Fire / explosion spillage, natural disasters.	**SPICOT Fire Station** SIPCOT Ph. I Hosur, Tamil Nadu 635126 India +91 4344 276 699.	Fire fighting and rescue augmentation.
Injury/illness	**Narayana Hrudalaya Super Speciality Clinics - Hospital** Sunnambu Jeebi Hosur, Tamil Nadu 635125 India +91 4344 246 111	Medical help augmentation.
Theft / sabotage /bomb threat /terrorism /war.	**SIPCOT Police Station - State Police Department** SIPCOT Ph. I, Hosur, Tamil Nadu - 635126	Law and order, safety and security augmentation.
All incidents	Neighbourhood organization	Consumables, manpower, technical help augmentation.

7.2.10 Safety Precautions for Storage and Handling of Chemicals/ Solvents

For handling chemicals/solvents, the management of Quest Healthcare Private Limited will have to adopt a practice of preventive and predictive maintenance. All the storages will be inspected regularly.

Precautions for storage and handling of Chemicals/Solvents:

- Stored with proper enclosures and marked properly.
- Proper ventilation shall be provided
- Sufficient fire extinguishers and PPE shall be provided

- Flame proof fittings shall be provided where required
- Smoking will be prohibited
- Protection against lightning provided.
- Precautions against ignition sources are taken.
- Sufficient access for firefighting is provided in the plant
- All employees have been provided with adequate and appropriate PPE like masks, gloves, helmet, chemical suits, safety shoes