Bhagyanagar Chlorides Pvt. Ltd.

RISK ASSESSMENT REPORT
Chapter 7 of EIA Report

Contents (HARA Report)

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Chapter 7

Risk Assessment & Disaster Management Plan

7.0 Introduction

Hazard is an intrinsic property of a chemical substance at a given point and at given plant of certain phenomenon that can have an adverse effect on the human life and health, on the environment or on anything else you consider important. Hazard is anything (e.g. condition, situation, practice, behavior) that has the potential to cause harm, including injury, disease, death, environmental, property and eq uipment damage and Risk is the likelihood, or possibility, that harm (injury, illness, death, damage etc.) may occur from exposure to a hazard.

The principal objective of the risk assessment study is to identify and quantify the major hazards and the risk associated with various operations of the proposed project, which may lead to emergency consequences (disasters) affecting the public safety and health.

Risk analysis: provides a r elative measure of the likelihood and severity of various possible hazardous events by critically examining the plant storages, process and operating units, deal with different materials in their production, some of which are hazardous in nature i.e. flammable, explosive, toxic and corrosive. Fire, explosion, toxic release or combinations of these are the hazards associated with industrial plants using hazardous chemicals. Risk Assessment has now been developed to improve upon the integrity, reliability and safety of the plant.

Scope of study involves hazard identification and analysis, evaluation of risks due to the Maximum Credible Accident (MCA) analysis, consequence analysis and preparation of DMP by evaluation of risks due to fire/explosion and toxic dispersion. Based on this information, an emergency preparedness plan will be prepared to mitigate the consequences.

7.1 Hazard identification *(ToR No. 3.9)*

Identification of hazards is of primary significance in the analysis, quantification and

cost effective control of accidents involving chemical handling and process thereof. A classical definition of hazards states that hazard is in fact the characteristics of system/ plant/ process that present potential for the accident. Hence, all the component sofa system/ plant/ process need to be thoroughly examined to assess the potential for initiating or propagating an unplanned events/sequence of events, which can be termed as an accident.

Estimation of probability of unexpected event and its consequences form the basis of quantification of risk in terms of damage to property, environment and personnel. Therefore, the type, quantity, location and condition of release of toxic or flammable substances have to be identified in order to estimate its damaging effects, the area involved, and the possible precautionary measures required to be taken.

Once a hazard is identified, it is necessary to evaluate it in terms of the risk it presents to the employees and the neighbouring community. In principle, both probability and consequences will be considered.

The following two methods for hazards identification have been employed in the study:

- Identification of major hazardous units based on Manufacture, Storage and Imports of Hazardous chemicals Rules, 1989 of Government of India and
- Amended rules1994 & 2000 and Identification of Fire-Explosion and Toxicity Index (FE&TI)

7.2 Identification of Major Hazard Installations based on GOI Rules, 1989 as amended in 1994 & 2000

By studying accidents occurred in Indian industries in over a few decades, a specific legislation covering major hazard activities has been enforced by Government of India in 1989 in conjunction with Environment Protection Act, 1986. This is referred here as GOI rules 1989. For the purpose of identifying major hazard installations the rules employ certain criteria based on toxic, flammable and explosive properties of chemicals.

7.2.1 Indicative Criteria for Identification of Toxic, Flammable & Explosive Chemicals (GOI Rules, 1989) & Amended rules 1994 & 2000

(a) Toxic Chemicals:

Chemicals having the following values of acute toxicity and which owing to their physical and chemical properties are capable of producing major accidents:

Sl. No.	Toxicity	Oral toxicity LD50 (mg/kg)	Dermal toxicity LD50 (mg/kg)	Inhalation toxicity LC50 (mg/l)
1.	Extremely toxic	1-50	1-200	0.1-0.5
2.	Highly toxic	51–500	201-2000	0.5-2.0

(b) Flammable Chemicals:

Flammable gases: Gases which are at 20˚C and at standard pressure of 101.3 KPa are:

1. Ignitable when in a mixture of 13% or less by volume with air or
2. Have a flammable range with air of at least 12 % points regardless of the lower flammable limits.

Note: The flammability will be determined by tests or by calculation in accordance with methods adopted by International Standards Organization (ISO Number 10156 of 1990) or by Bureau of Indian Standards 1446 of 1985.

i. Extremely flammable liquids: Chemicals which have flash point lower than or equal to 23˚C and boiling point less than 35˚C
ii. Very highly flammable liquids: Chemicals which have a flash point lower than or equal to 23˚C and boiling point higher than 35˚C.
iii. Highly flammable liquids: Chemicals which have a flash point lower than or equal to 60˚C but higher than 23˚C.
iv. Flammable liquids: Chemicals which have a flash point higher than 60˚C but lower than 90˚C.

(c) Explosives:

An explosive means a solid or liquid or pyrotechnic substance (or a mixture of substances) like:

i. Which is in itself capable of producing gas by chemical reaction at such a temperature and pressure and at such a speed as to cause damage to the surroundings?
ii. Which is designed to produce an effect by heat, light, sound, gas or smoke or a combination of these as a result of non-detonative self-sustaining exothermic chemical reaction?

7.3 Hazard Analysis of different Processes / Operation Units

A systematic analysis of the chemicals and the quantities of storage of chemicals has been carried out to determine threshold quantities as notified by GOI Rules 1989 and the applicable rules are identified. The results are summarized in **Table 7.1**.

From the above table it can be inferred that there would be Hazardous chemicals stored at the proposed site, which would attract the GOI rules 4,5,7-9 and13-15,as the quantity likely to be stored at site lies above the stipulated threshold quantities.

Table 7.1: Description of applicable provisions of GOI rules 1989 as Amended in 1994 & 2000

Applicable Rules	Description
4	**Identify Major accident** Take adequate steps to prevent major accidents. Provide information to persons working on-site impart training, provide equipment and antidotes
5	Notification of major accidents to concerned authority. If any major accident occurs occupier to inform concerned authority as listed in SC-5 and submit report as per the format in SC-6 (applies after commencing of the activity)
7	Notification of site to competent authority
8	Updating of site notification following changes in threshold quantity
9	Transitional provision for the existing activity
10	Preparation of safety reports for commencement of activity
11	Updating of safety reports based on modification
12	Provision of further information on safety reports to the authority
13	Preparation of on-site emergency plan by the occupier
14	Preparation of off-site emergency plan by the occupier
15	Information to be given to persons liable to be affected by a major accident
17	Collection, development and dissemination of information on hazardous Chemicals employed by the occupier
Occupier will develop information in the form of safety data sheet as specified in SC-9. Every container of the hazardous chemical will be labeled with name of the manufacturer or importer of the hazardous chemical.	

7.4 Storage Facilities of Hazardous Chemicals

The maximum storage capacities, daily consumption, type of storage and physical status of each hazardous chemical proposed to be used for manufacturing various products are given in **Table 7.2**. The project proponent deals with different materials in their production, some of which are hazardous in nature i.e. flammable, explosive, toxic and corrosive. Fire, explosion, toxic release or combinations of these are the hazards associated with industrial plants using hazardous chemicals. Chemicals consumed in this plant are in solid, liquid and gaseous form and observed that some of these chemicals are hazardous in nature. The Hazard analysis is required for these chemicals. The information on Material safety data sheet (MSDS) for all the identified hazardous chemicals is presented in **as Annexure-XXXV.**

Table 7.2: List of Hazard Chemicals, Daily Consumption, and Maximum Storage Capacity

S. No.	Name of the Material	Daily Consumption (kg/day)	Maximum Storage facility	Nature of the Material	Type of Storage
1.	Acetone	4645	10 KLx3 nos	IB Flammable	HDPE Tank TFA
2.	Acetic acid	584.0	200 lit X 15 nos	Combustible & Corrosive	HDPE drums Ware house
3.	Acetic anhydride	2713	20 KL	Flammable & Toxic	HDPE drum TFA
4.	Aluminum	12132	25 kg x 2400 nos	Solid	Ingots
5.	Acetyl chloride	267	200 lit. x70 nos	Flammable	HDPE drums
6.	Benzo trichloride	11250	20 KL x 3 nos	Acid, toxic and corrosive	HDPE Tank TFA
7.	Benzyl alcohol	336	200 lit. x 8 nos	Combustible	HDPE drum
8.	Benzyl chloride	413.3	200 lit x 11	Toxic, flammable	HDPE Drums
9.	Chlorine(g)	55478	900 kg x 132 nos	Toxic	Horizontal cylinders
10.	Chloro acetic acid	3100	20 KL	Toxic & corrosive	HDPE tank TFA
11.	Chloro acetyl chloride	183.3	200 lit.x 5 nos	Toxic	HDPE drums
12.	Diethyl amine	516.9	200 lit.x 13 nos	Flammable	HDPE drums
13.	Dimethyl formamide	244	200 lit.x 7 nos	IB Flammable	HDPE Drums
14.	1,4 Dioxane	3100	250 lit. x62 nos	Flammable & Toxic	HDPE drums
15.	Ethylene dichloride	5947	10 KLx 3 nos	I B flammable	HDPE tank TFA
16.	Hydrogen	21	100kgx1	Highly Flammable	100 kg cylinder
17.	n- hexane	933	200 lit.x 25 nos	I B flammable	HDPE drums
18.	IPA	2183.3	20KL	I B flammable	HDPE tank TFA
19.	Methanol	10600	20 KLx3nos	I B flammable	HDPE TANK TFA
20.	Methylene dichloride	2885	200 lit. x 75 nos	Flammable &Toxic	HDPE drums
21.	Phosphorous Oxychloride	82	200 lit. x3nos	Toxic	HDPE drums
22.	Sodium hydride	195.3	200 lit. x 5nos	Flammable	HDPE drums
23.	Sulfuric acid	69.7.7	50 lit. x 7nos	Toxic	HDPE Drums
24.	Thionyl Chloride	91.0	200 lit.x 3 nos	Toxic	HDPE Drums
25.	Toluene	18893.0	20 KLx5 nos	I B Flammable	HDPE Tank T F A
26.	Xylene	900	200 lit x23	IC Flammable	HDPE drums

7.5 Potential Hazards

The following are the potential areas in existing /proposed expansion project that can lead to major accidents.

- Solvents/ hazardous chemicals in tank form area.
- Solvent / Hazard chemical storage (drums) in ware houses.

- Different Hazard cylinders at dedicated sites.
- Hazard handling and process area
- Coal handling and storage area
- Electrical Zone

7.6 Hazard Analysis *(ToR No. 3.9)*

Identification of hazards is an important step in Risk Assessment as it leads to the generation of accidental scenarios. Hazard identification involves the identification of hazard prone chemicals in each process / operations unit as well as the location of the processes / operations in the plant and its storage. Once a hazard is identified, it is necessary to evaluate it in terms of the risk it presents to the employees and the neighbouring community. In principle, both probability and consequences will be considered.

Nature of the hazard most likely to accompany the hazardous material is its spill or release airborne toxic vapours / mists and fire/ explosion due to large storage or processes in its handling. On release, the hazardous substance can cause damage on a large scale. The extent of the damage is dependent upon the nature of the release, the physical state of the material and the micro-meteorological condition prevailing at the time of accident. As part of Risk Analysis, the damage distances are computed based on probable meteorological conditions.

List of hazardous chemicals along with maximum storage facility, per day consumption Flash Ignition Point (FIP), Boiling Point (BP) along with IDLH, TLV, UEL and LEL values is presented in **Table 7.3**. Further material analysis are made as per NFPA rating along with material factor is presented in **Table 7.4**. Classification of Flammable / Combustible liquids and description of National Fire Protection Agency (NFPA) classification are presented in **Tables 7.5 and 7.6** respectively. Storage of hazard chemicals mainly solvents in respective tanks in tank form area. Apart from tank form area the hazard chemicals are also storing in specified drums mostly in ware house and gas cylinders at dedicated areas, details of storage of chemicals are depicted in plant layout **Fig.7.1**.

Table 7.3: Hazardous materials properties, rating and TLV value

Sl. No.	Raw Material	Physical Status of Chemical	Rating	Melting Point (^oC)	Boiling Point (^oC)	Flash Point (^oC)	IDLH (ppm)	TLV Value (ppm)	LEL (%)	UEL (%)
1.	Acetic Acid	Liquid	3	17	118.1	39	50	10	4	19.9
2.	Acetone	Liquid	1	-95.35	56.5	-20	2500	1000	2.15	13
3.	Acetic anhydride	Liquid	2	-73.1	140	49	200	5	2.7	10.3
4.	Acetyl chloride	Liquid	3	-112	52	4	-	-	7.3	19.0
5.	Aluminum	Solid	1	660	2327	N/A	-	15 mg/m^3	N/A	N/A
6.	Benzyl alcohol	Liquid		-15.2	205.3	93	-	-	1.3	13
7.	Benzyl Chloride	Liquid	3	-43	179	67.2	10	1	1.3	7.1
8.	Benzo trichloride	Liquid			219	97	-	-	2.1	6.5
9.	Chlorine	Gas	3	-101	-34	N/A	10	0.5	N/A	N/A
10.	Chloro acetic acid	Liquid	3	63	189	150	-	-	8	-
11.	Chloro acetyl chloride	Liquid	3	-22	105	N/A	-	2 mg/m^3	N/A	N/A
12.	Diethyl amine	Liquid	3	-50	55	-	200	25	1.8	10.1
13.	Dimethyl formamide	Liquid	3	-60.4	150.3	58	500	-	2.2	15.2
14.	1,4 dioxene	Liquid	2	11.8	101.1	18.3	500	100	2	22
15.	Ethylene Dichloride	Liquid	2	-35.4	83.4	33	50	10	6.2	16.0
16.	Hydrogen	Gas	0	-259.2	-423	N/A	-	--	4	74
17.	Hexane	Liquid	3	6.47	69	-23	1100	500	1.2	7.7
18.	Isopropyl Alcohol	Liquid	1	-89	82.5	11.7	2000	400	2	12.7
19.	Methanol	Liquid	1	-97	65	12	6000	200	6	36
20.	Methylene dichloride	Liquid	2	-96.7	39.6	14	2300	50	12	19
21.	Phosphorus oxy chloride	Liquid	8	1.1	105.8	-	0.85	0.1	n/a	n/a
22.	Sodium Hydride	Solid	4.3	-	-	-	-	5 mg/m^3	N/A	N/A
23.	Sulfuric acid	Liquid	3	-35	270	N/A	14 mg/m3	1 mg/m^3	N/A	N/A
24.	Thionyl Chloride	Liquid	3	-104.5	76	N/A	-	1	N/A	N/ A
25.	Toluene	Liquid	2	-95	110.6	4.4	500	25	1.1	7.1
26.	Xylene	Liquid	3	-25	144	32.2	900	100	0.9	6.7

Note: Chemical Listing and Documentation of Revised IDLH Values (as of 3/1/95)

Table 7.4: Hazard Maximum Storage and NFPA Rating

S. No.	Description	Physical Status of Chemical	Maximum storage	NFPA Rating			
				Nh-health	Nf-Fire	Nr-Reaction	Material Factor (MF)
1	Acetic Acid	Liquid	200 lit x 15nos	3	2	1	14
2	Acetone	Liquid	10 KL x 3 nos	1	3	0	16
3	Acetic anhydride	Liquid	20 KL	3	2	1	14
4	Acetyl chloride	Liquid	200 lit.x 70nos	3	3	2	24
5	Aluminum	Solid	25 kg x2400nos	1	0	0	1
6	Benzyl alcohol	Liquid	200 lit.x 8nos	1	1	0	4
7	Benzyl Chloride	Liquid	200 lit. X11nos	2	2	1	14
8	Benzo trichloride	Liquid	20 KLx3nos	2	1	0	4
9	Chlorine	Gas	55478 kg (900 kg x 132nos)	4	0	0	1
10	Chloro acetic acid	Liquid	20 KL	3	0	1	14
11	Chlore acetyl chloride	Liquid	200 lit. x5nos	3	1	0	4
12	Diethylamine	Liquid	200 lit. x13nos	3	3	0	16
13	Dimethyl formamide	Liquid	200 lit.x7nos	2	2	2	24
14	1,4 Dioxane	Liquid	250 lit. x62nos	2	3	1	16
15	Ethylene Dichloride	Liquid	10 KL x 3nos	3	3	0	16
16	Hydrogen	Gas	100 kg x 1no.	0	4	0	21
17	n-Hexane	Liquid	200 lit. x 25nos	2	3	0	14
18	Isopropyl Alcohol	Liquid	20 KL	1	3	0	16
19	Methanol	Liquid	20 KL x3nos	1	3	0	16
20	Methylene chloride	Liquid	200 lit. x75nos	3	1	0	4
21	POCl3	Liquid	200 lit. x3nos	4	0	2	24
22	Sodium hydride (60%)	Solid	200 lit. x 5nos	3	3	2	24
23	Sulfuric acid	Liquid	50 lit. x 7nos	3	0	2	24
24	Toluene	Liquid	20 KL x 5nos	2	3	0	16
25	Thionyl chloride	Liquid	200 lit. x 3nos	4	0	2	24
26	Xylene	Liquid	200 lit. x23nos	2	3	0	16

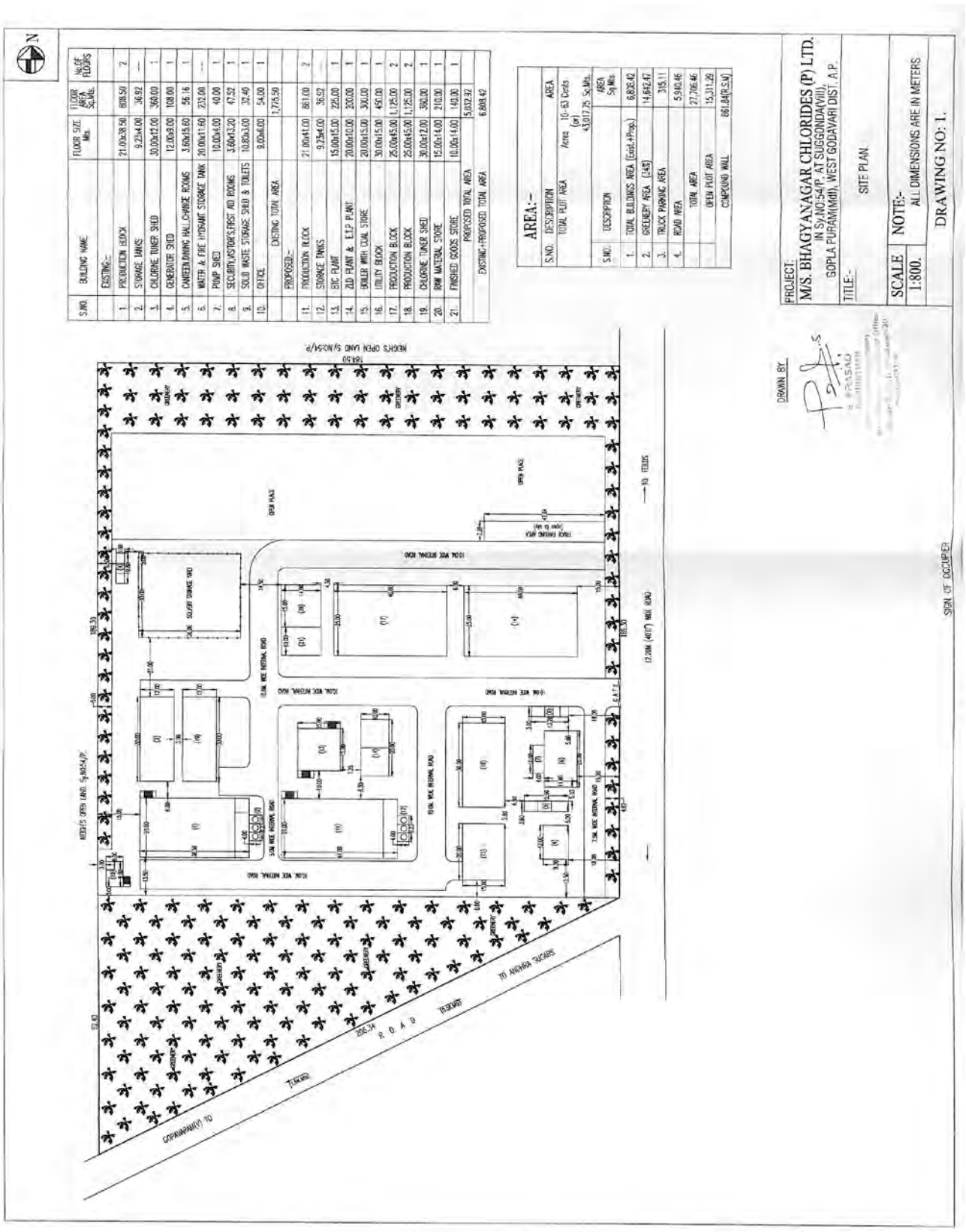
Table 7.5: Classification of Flammable/Combustible Liquids

Class IA flammable liquid	Flash Point below 22.78°C and Boiling Point below 37.78°C.
Class IB flammable liquid	Flash Point below 22.78°C and Boiling Point at or above 37.78°C.
Class IC flammable liquid	Flash Point at or above 22.78°C and below 37.78°C.
Class II combustible liquid	Flash Point at or above 37.78°C and below 60°C.
Class IIIA combustible liquid	Flash Point at or above 60°C and below 93.33°C.
Class IIIB combustible liquid	Flash Point at or above 93.33°C.

Table 7.6: Description of National Fire Protection Agency (NFPA) Classification

Rating Nh	Type of possible injury	Rating Nf	Susceptibility of material to burning	Rating Nr	Susceptibility to release of energy
4	Materials which on very short exposure could cause death or major residual injury even though prompt medical treatment is given	4	Materials which will rapidly or completely vaporize at atmospheric pressure and normal ambient temperature or which are readily dispersed in air and which will burn readily	4	Materials which in themselves are readily capable of detonation or of explosive decomposition or reaction at normal temperatures and pressure
3	Material which on short exposure could cause serious temporary or residual injury even though prompt medical treatment is given	3	Liquids and solids that can be ignited under almost all ambient temperature conditions	3	Materials which in themselves are capable of detonation of explosive reaction; but require a strong initiating source or which must be heat ed under confinement before explosively with water
2	Materials which on intense or continued exposure could cause temporary, incapacity or possible residual injury unless prompt medical treatment is given	2	Materials that must be moderately heated or exposed to relatively high ambient temperature before ignition can occur	2	Materials which in themselves are normally unstable and r eadily undergo violent chemical change but do not detonate. Also materials which may react violently with water to form explosive mixture
1	Materials which on exposure would cause irritation but only minor residual injury even if no treatment is given	1	Materials that must be preheated before ignition can occur	1	Materials which in themselves are normally stable, but which can become unstable at elevated temperatures and pressure or which may react with water
0	Materials which on exposure under fire conditions would offer no hazard beyond 0 that of ordinary combustible material	0	Materials that will not burn	0	Materials which in themselves are normally stable, even under fire exposure conditions and which are not reactive with water

Nh- Health, Nf- Fire, Nr-Reaction



S.NO.	BUILDING NAME	FLOOR SIZE Mts.	FLOOR AREA Sq.Mts.	NO.OF FLOORS
	EXISTING:-			
1.	PRODUCTION BLOCK	21.00x38.50	808.50	2
2.	STORAGE TANKS	9.23x4.00	36.92	—
3.	CHLORINE TUNER SHED	30.00x12.00	360.00	1
4.	GENERATOR SHED	12.00x9.00	108.00	1
5.	CANTEEN,DINING HALL,CHANGE ROOMS	3.60x15.60	56.16	1
6.	WATER & FIRE HYDRANT STORAGE TANK	20.00x11.60	232.00	—
7.	PUMP SHED	10.00x4.00	40.00	1
8.	SECURITY,VISITOR'S,FIRST AID ROOMS	3.80x13.20	47.52	1
9.	SOLID WASTE STORAGE SHED & TOILETS	10.80x3.00	32.40	1
10.	OFFICE	9.00x6.00	54.00	1
	EXISTING TOTAL AREA		1,775.50	
	PROPOSED:-			
11.	PRODUCTION BLOCK	21.00x41.00	861.00	2
12.	STORAGE TANKS	9.23x4.00	36.92	—
13.	ETP PLANT	15.00x15.00	225.00	1
14.	ZLD PLANT & ETP PLANT	20.00x10.00	200.00	1
15.	BOILER WITH COAL STORE	20.00x15.00	300.00	1
16.	UTILITY BLOCK	30.00x15.00	450.00	1
17.	PRODUCTION BLOCK	25.00x45.00	1,125.00	2
18.	PRODUCTION BLOCK	25.00x45.00	1,125.00	2
19.	CHLORINE TUNER SHED	30.00x12.00	360.00	1
20.	RAW MATERIAL STORE	15.00x14.00	210.00	1
21.	FINISHED GOODS STORE	10.00x14.00	140.00	1
	PROPOSED TOTAL AREA		5,032.92	
	EXISTING+PROPOSED TOTAL AREA		6,808.42	

Fig. 7.1: Plant Layout

7.6.1 Fire and Explosion Index

Fire and Explosion Index (FEI) is useful in identification of areas in which the potential risk reaches a certain level. It estimates the global risk associated with a process unit and classifies the units according to their general level of risk. FEI cover aspects related to the intrinsic hazard of materials, the quantities handled and operating conditions. This factor gives index value for the area which could be affected by an accident, the damage to property within the area and working days lost due to accidents. The method for evaluation of FEI involves the determination of Unit Hazard Factor and the determination of Material Factor (MF). Fire and explosion index is then calculated as the product of Material Factor (MF) and Unit Hazard Factor.

- The Unit Hazard Factor is obtained by multiplication of General Process Hazard (GPH) factor and Special Process Hazard (SPH) factor. GPH factor is computed according to presence of exothermic reactions and loading and unloading operations. The penalties due to each of these reactions/operations are summed up to compute GPH factor. Similarly, SPH factor can be evaluated for the operations close to flammable range or pressures different from atmospheric pressures. Penalties of these operations for both factors can be obtained from Dow's FEI index form.

Material Factor for a given chemical is evaluated from NFPA indices of danger, health, flammability and reactivity data. It can be directly obtained from Dow's Fire and Explosion Index Hazard classification Guide of American Institute of Chemical Engineers, New York. The Material Factor for a given substance in the process unit gives intrinsic potential to release energy in case of fire or an explosion.

FEI Range	Degree of Hazard
0 – 60	Light
61 – 96	Moderate
97 – 127	Intermediate
128 – 158	Heavy
159 and Above	Severe

7.7 MCA Analysis *(ToR No. 8.3)*

As part of Environmental Impact Assessment / Environmental Management Plan (EIA/EMP), the risk due to the Maximum Credible Accident (MCA) scenario will be quantitatively assessed. MCA stands for an accident with maximum damage distance, which is believed to be probable. In practice the selection of accident scenarios for MCA analysis is carried out on the basis of engineering judgement and expertise in the field of risk analysis especially in accident analysis.

The MCA analysis involves ordering and ranking of various sections in terms of potential vulnerability. The data requirements for MCA analysis are:

- Operating manual
- Flow diagram and P&I diagrams
- Detailed design parameters
- Physical and chemical properties of all the chemicals
- Detailed plant layout
- Detailed area layout

MCA analysis encompasses defined techniques to identify the hazards and compute the consequent effects in terms of damage distances due to heat radiation, toxic releases, vapour cloud explosion etc. A list of probable or potential accidents of the major units in the arising due to use, storage and handling of the hazardous materials are examined to establish their credibility. Depending upon the effective hazardous attributes and their impact on the event, the maximum effect on the surrounding environment and the respective damage caused can be assessed.

7.7.1 Event Tree Analysis

The accident scenarios of hazard chemicals can be divided into the following categories.

- Flammable gases
- Liquefied gas or boiling liquid release under pressure
- Non boiling liquid release
- Toxic gas release

Different consequences of accidental release of hazard due to undesirable conditions of failure are possible depending on type of event such as continuous or instantaneous releases in gas / vapour / liquid. Event Tree Analysis for rupture and leak scenarios for continuous/ instantaneous release of gas/liquid and for delayed or immediate ignition or toxic cloud. Typical flow chart of accidental release of hazardous chemicals is given in **Fig. 7.2.**

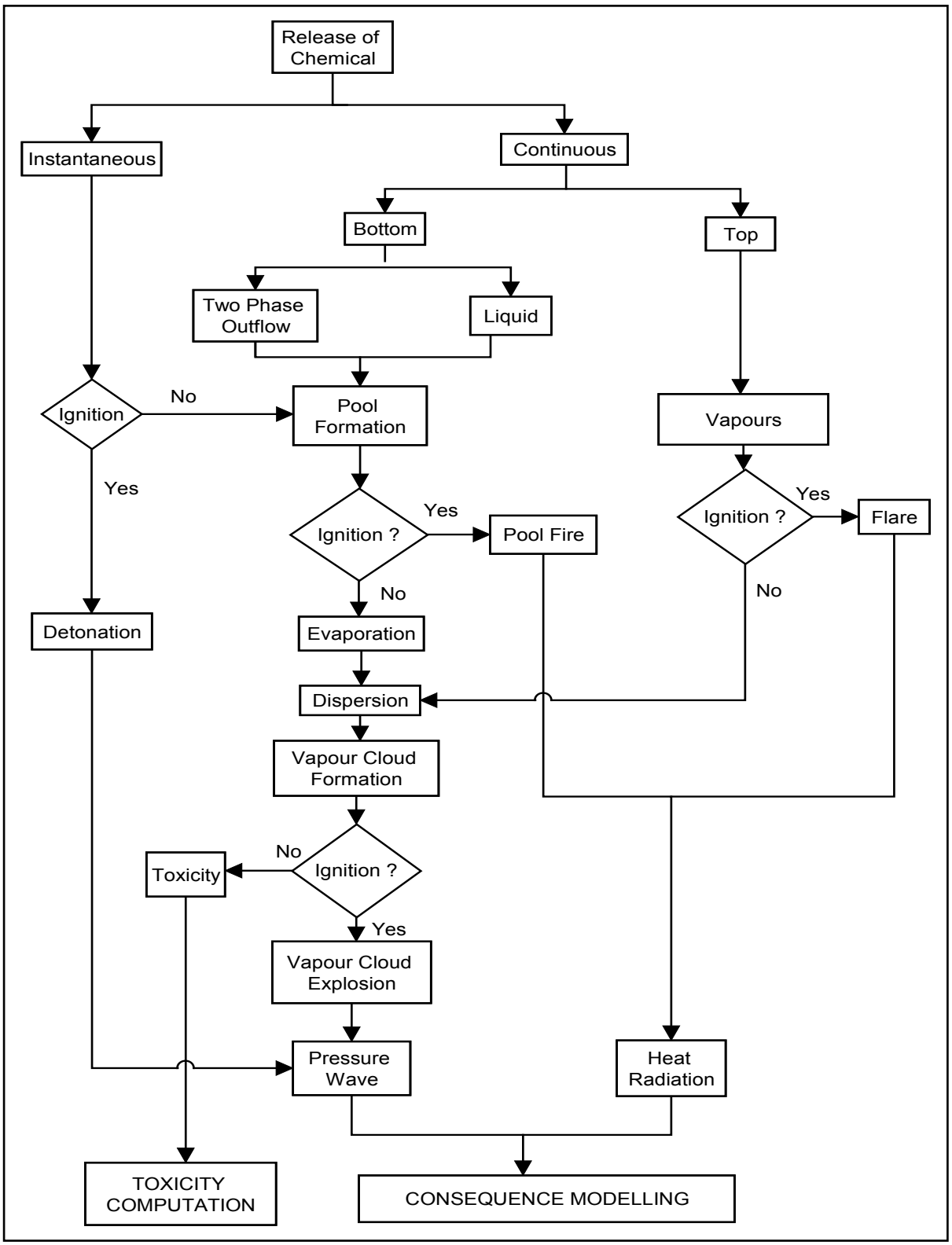


Fig. 7.2: Typical Flow Chart of Accidental Release of Hazardous Chemicals

7.7.2 Methodology of modeling exercise

7.7.2.1 Source Model

Source models represent the material release process. They provide useful information for determining the consequences of an accident including the rate of material release, the total quantity released and the physical state of the material. The source models that are used repeatedly are:

- Flow of liquid through a hole in a tank/ pipe
- Flow of vapour through holes in a tank/pipe
- Flow of vapour through pipes
- Flowing liquids
- Liquid pool evaporation or boiling

The purpose of source model is to determine:

- The form of material released is solid/ liquid/ vapour
- The total quantity of material released
- The rate at which it is released

7.7.2.2 Dispersion Model

Dispersion model describes the transportation of air borne toxic material away from the accident site and in to the surrounding areas. After the release, the airborne toxic substances are carried away by the wind in a characteristic plume or a puff. The maximum concentration of toxic material occurs at the point of release. The concentration at downwind is less due to turbulent mixing and dispersion of toxic substances with air. A number of parameters that affect the atmospheric dispersion of toxic material are wind speed, atmospheric stability, general conditions such as buildings, water bodies and trees, height of release and initial movement of the material released.

7.7.2.3 Fire and Explosion Scenarios

Flammable substances on release may cause Jet fire and less likely unconfined vapour cloud explosion causing possible damage to the surrounding area. The extent of damage depends upon the nature of the release. The release of flammable materials and subsequent ignition result in heat radiation wave or vapour cloud depending upon the flammability and its physical state. Damage distances due to release of hazardous materials depend on atmospheric stability and wind speed. It is important to visualize the consequence of the release of such substances and the damage caused to the surrounding areas.

- First, before the ignition, a cloud of sufficient size must have been formed. Normally ignition delays of few minutes are considered the most probable for generating the vapour cloud explosions
- Second a sufficient amount of the cloud must be within the flammable range of the material to cause extensive overpressure.
- Third, the flame speed determines the blast effects of the vapour cloud explosions, which can vary greatly

Combustible materials within their flammable limits of (UEL and LEL) may ignite and burn if exposed to an ignition source of sufficient energy. On process plants, this normally occurs as a result of a leakage or spillage depending on the physical properties of the material and the operating parameters. The event Classification of fire and explosion scenarios is described in **Table 7.7**.

Table 7.7: Event Classification

Type of Event	Explanation
BLEVE	Boiling Liquid Expanding Vapor Explosion; may happen due to catastrophic failure of refrigerated or pressurized gases or liquids stored above their boiling points, followed by early ignition of the same, typically leading to a fire ball
Explosion	A release of large amount of energy that form a blast wave
Fireball	The burning of a flammable gas cloud on being immediately ignited at the edge before forming a flammable/explosive mixture.
Flash Fire	A flammable gas release gets ignited at the farthest edge resulting in flash-back fire
Jet Fire	A jet fire occurs when flammable gas releases from the pipeline (or hole) and the released gas ignites immediately. Damage distance depends on the operating pressure and the diameter of the hole or opening flow rate.
Pool Fire	Pool fire is a turbulent diffusion fire burning above a horizontal pool of vaporizing hydrocarbon fuel where the fuel has zero or low initial momentum
Vapor Cloud Explosion	Explosion resulting from vapor clouds formed from flashing liquids or non-flashing liquids and gases

7.7.2.4 Models for the Calculation of Heat load and Shock Waves

If a flammable gas or liquid is released, damage resulting from heat radiation or explosion may occur on ignition. Models used in this study for the effects in the event of immediate ignition (torch and pool fire) and the ignition of a gas cloud will be discussed in succession. These models calculate the heat radiation or peak overpressure as a function of the distance from the torch, the ignited pool or gas cloud. The physical significance of the various heat loads is depicted in **Table 7.8.**

Table 7.8: Various Physical Effects Due to Heat Radiation

Flux / Intensity (KW / m²)	Thermal Effects
49	3rd degree burns Severe burns due to fire ball zone
37.5	100% lethality Severe burns, 80% or more leading to 100% fatality
25	50% lethality Severe burns due to explosion of gas, within lower and upper limit leading to 50% fatality
12.5	1% lethality Burns and injuries due to exposure to thermal radiation
4.5	First degree burns Blistering and first degree burns due to exposure to thermal radiation
1.6	No perceptible discomfort

BLEVE: If the liquid is stored under pressure at a temperature above its boiling point, the initial physical explosion that breaks the receptacle produces a sudden decompression giving rise to a massive evaporation of the saturated liquid. This is known as Boiling Liquid Expanding Vapour Explosion (BLEVE). These explosions are of great destructive power due to the high increase in pressure caused by the sudden incorporation of liquid into the gas phase. The ignition of BLEVE produces a mass of gases at high temperature known as 'fireball' with significant thermal effects. Historically, BLEVEs have been produced with some frequency and have almost caused human casualties**.**

7.7.2.5 Model for Pressure Wave

A pressure wave can be caused by gas cloud explosion. The following damage criteria are assumed as a result of the peak overpressure of a pressure wave: 0.03 bar over pressure wave is taken as the limit for the occurrence of wounds as a result of flying fragments of glass. Physical significance of various pressure waves is depicted in **Table 7.9.** Methodology (Yellow book) and Software applied for the study TNO and also EPA based one.

Table 7.9: Over Pressure Effect of Explosion

S. No.	Pressure (psig)	Damage
1	0.03	Occasional breaking of large glass windows already under strain
2	0.1	Breakage of small windows under strain
3	0.3	" Safe distance " (probability 0.95 no serious damage beyond this value); projectile limit; some damage to house ceiling; 10% window glass broken
4	1.0	Partial demolition of houses, made uninhabitable
5	1-2	Corrugated asbestos shattered; corrugated steel and aluminum panels, fastenings fail followed by buckling wood panels (standard housing) fastening fail, panels blown in
6	1.3	Steel frame of clad building slightly distorted
7	3.0	Heavy machines (3000lb) in industrial building suffered little damage; steel frame building distorted and pulled away from foundations
8	5.0	Wooden utility pollen
9	7.0	Loaded train vapour over turned
10	10.0	Probable

7.7.3 Consequence of MCA Analysis

Based on the hazard identification and nature of hazard occurrence, MCA scenario is short listed below.

- Pool fire due to rupture / leakage and accumulation
- Fire/ explosion of flammable gas / vapour
- Dispersion of Toxic gas

7.7.3.1 Pool Fire/ Vapour cloud explosion

This scenario was visualized for flammable/ combustible liquid storage tanks mainly solvents in tank form areas solvents i.e. Acetone, Methanol, IPA, ethylene dichloride, acetic anhydride and toluene are storing in tank form area. Other selected solvent are storing in HDPE drums i.e. Acetyl chloride, Benzyl alcohol, Methylene dichloride, Dimethyl formamide, Diethyl amine, 1,4 dioxane, Acetic acid, n- Hexane and Xylene. For the same various heat radiation levels are analyzed for selected stability class and wind velocity. The damage distances for pool fire due to leak and catastrophic rupture (BLEVE) of storage tank for heat radiation of 37.5, 12.5 and 4.5 Kw/m² are given in **Table 7.10**. Pressure wave's values are also calculated for vapour cloud explosion and reported for damage distance due to over pressure 0.3, 0.1 and 0.03 bar in Table 7.10. Detail analysis is carried out for identified most hazard flammable liquids including flammable gas Hydrogen (100 kg cylinder).

Table 7.10: Consequences of MCA Analysis – Storages
(*Distances in meters)*

Hazard Material	Scenario	Heat Radiation (KW/m^2) - Meters			Over Pressure (bar) - Meters		
		37.5	12.5	4.5	0.3	0.1	0.03
Acetic anhydride 20 KL	Pool Dia. 4.51 m	-	-	<10	-	-	-
	VCE/BLEVE	LOC	183	322	365	409	622
Acetone 10 KL x 3nos	Pool Fire Dia.3.3 m	-	-	<10	-	-	-
	VCE / BLEVE F.B dia. 115 m	92	183	310	312	350	534
Ethylene Dichloride 10 KL x 3nos	Pool fire Dia. 3.19 m	-	-	<10	-	-	-
	VCE/BLEVE F.B. Dia. 134 m	LOC	120	221	212	248	422
IPA 20 KL	Pool Fire Dia.4.65 m	-	-	<10	-	-	-
	VCE/ BLEVE F.B dia. 145 m	120	235	398	451	498	727
Methanol 20 KL x3nos	Pool fire – Dia.4.51 m	-	-	<10	-	-	-
	VCE/ BLEVE F.B dia. 145 m	81	186	322	within LOC	253	334
Toluene 20 Kl x 5nos	Pool Fire Dia.4.51 m	-	10	18	-	-	-
	BLEVE F.B dia. 150 m	151	282	472	529	585	849
Ware house							
Acetyl chloride 200 lit. x 70nos	IA Flammable F.B. Dia. 35 m	Never	33	61	14	24	56
Diethyl amine 200 lit. x 13nos	VCE/BLEVE F.B. Dia. 30 m	31	59	98	30	44	96
Dimethyl formamide 200 lit. x 7nos	VCE/BLEVE F.B. Dia. 33 m	25	51	88	38	50	111
1,4 Dioxane 250 lit. x 62nos	VCE/BLEVE FB dia. 37 m	28	57	97	40	53	121
Methylene dichloride 200 lit. x 75nos	VCE/BLEVE	Line of control	21	46	<10	15	36
N-Hexane 200 lit. x 25nos	VCE/BLEVE F.B. dia. 29 m	34	62	104	39	46	86
Xylene 200 lit. x 23nos	Un confined Pool Fire- Area 10 sq.m I C flammable	-	<10	14	-	-	-
Hydrogen 100 Kg Cylinder	VCE / BLEVE 4"' leak	10	12	20	10	27	54
	Total burn (UVCE)	275	525	862	154	209	406

Other hazard chemicals are storing in specified MS and HDPE drums of different capacity in Ware house as well as specific hazard storage area. The material are storing are flammable, combustible, toxic and corrosive in nature. The capacity of drum is considered as source strength to estimate for effect of heat radiation and over pressure. In this plant two type of gas cylinders i.e. Hydrogen and chlorine are storing at dedicated areas. It is observed that there is a specified area to store 900 kg chlorine cylinders and has a proposal to facilitate for storage of maximum of 132 cylinders including existing one.

Flammable liquids: Analysis indicate that Confined pool fire of IB flammable liquids Acetone, Methanol, IPA and Toluene heat radiation effect covers 10 to 18 m from center of pool, wherein pool radius is maximum of 5.0 m and in all the cases heat radiation effect of 37.5 KW/ m^2 within the pool only. In the case of catastrophic rupture of storage tank with ignition radiation effect 4.5 KW/m^2 up to maximum distance vary from 310 to 475 m and overpressure effect of 0.03 bar varies 334 to 849 m.

In the case of flammable liquids, which are stored in ware house mainly Acetyl chloride, Methylene dichloride, Dimethyl formamide, Diethyl amine, 1,4 dioxane, n- Hexane and Xylene are stored in 200 lit.drums, whereas Dioxane in 250 lit.drums, due to leak/ rupture of drums with ignition radiation effect 4.5 KW/m^2 covers a distance from 46 to 104 m, whereas damage distance of pressure wave VCE from 56 to 121 m. MCA analysis indicate that all the predicted values of damage distances are within in the plant mainly on-site area including lower and upper explosive limits. It is also indicate that effect of heat radiation is mainly at the site of incident, which is due to instantaneous release of material spread over unconfined area and by spark/ ignition thermal radiation and vapour cloud explosion occurs and causes effect on-site area.

Over pressure in 'psi' against damage distance and effect of heat radiation due to BLEVE for Methanol, Toluene and n- Hexane is shown in **Annexure-XXXVI, XXXVII and XXXVIII** along with respective heat radiation and pressure wave isopleths. It occurs only due to ignition/spark/detonation of vapour cloud, however it is observed that average concentration of exposure limit less than LEL, hence vapour cloud explosion unlikely occurs.

Flammable gas: Hydrogen is considered as **Class 2** flammable gas, there is a proposal usage of one 100 kg cylinder and going to store at dedicated area. Analysis indicate that heat radiation effect 4.5 KW/m^2 covers a distance of 20 m and over pressure effect 0.03 bar up to 54 m in case of 4" leak, whereas delayed ignition occurs after release of material, radiation effect 4.5 KW/m^2 covers a distance of 862 m and over pressure effect 0.03 bar up to 406 m.

7.7.3.2 Toxic Releases (gases/ vapors)

The toxic hazard chemicals are going to be used by proponent in their proposed plant and are mainly Chlorine Gas. Apart from chlorine, other identified toxic chemicals are a acetyl chloride, Chloro acetyl chloride, Benzyl chloride, Benzo tri chloride, Methyl dichloride, Ethylene dichloride, Phosphorus oxy chloride and Thionyl chloride including sulfuric acid, which are selected on basis of IDLH and TLV value for the study. Some of the chemicals flammable as well as toxic i.e. Acetyl chloride, Methylene dichloride and Ethylene dichloride are selected for toxic dispersion. For the purpose of risk assessment study, consequences due to release of these toxic elements are analyzed for estimation of damage distances due to toxic releases. Consequences results are reported in **Table 7.11**. A scenario was visualized by considering leak and release of Chlorine from 900 kg cylinder. Due to leak, continuous and instantaneous release of material spread over unconfined area causes, gas travels towards wind ward direction. Consequence analysis indicate that IDLH concentration of Chlorine 10 ppm covers a distances up to 600 m and 2600 m at wind ward side of plant for leak and instantaneous release respectively.

In the above cases of material stored in drums, due to leak/ rupture of drums damage distance of IDLH vary 560 to 1127 m. The damage contour of Benzyl chloride, Chlorine and Sulfuric acid are shown in **Annexure-XXXIX, XXXL and XLI** respectively. For all these toxic hazard are predicted and distance of exposure of IDLH level as well as for TLV (PEL) are reported in Table 7.11.

Sulphuric acid: There is a proposal to store in ware house in drums and capacity of drum 50 L in ware house premises at atmospheric condition. Under rupture of drum forms unconfined pool and effect within the plant premises, Sulphuric acid fumes IDLH value (15 mg/m^3) effect towards windward side and covers a distance of 115 m. If any small/ large spill, its consequences on- site only. For the same specific precautionary measures are to be followed as per MSDS guidelines and the same are attached at Annexure-XXXV**.**

Table 7.11: Consequence Analysis for Toxic Release Scenario

Scenario Considered	IDLH (ppm)	TLV (ppm)	Leak Size (mm)	Source Strength (kg/sec)	Weather	IDLH Distance (m)	TLV (m)
Acetic anhydride 20 KL	200	5	Confined pool 17 sq.m	0.0022	2D	10	59
Benzo Tri chloride 20 KL x 3nos	5.3 mg/m^3-pac3	0.7 mg/m^3-pac2	Confined pool 17 sq.m	0.00028	2 D	20	58
Ethylene dichloride-10 KL x 3nos	50	10	Confined pool 8 Sq.m	0.0034	2D	34	77
Methylene Chloride 200 lit. x 75nos	2300	50	Un Confined pool	4.39	2D	129	855
Acetyl chloride 200 lit. x 70nos	56 PAC3	9.4 PAC2	Un Confined pool	3.67	2D	832	1700
Benzyl chloride 200 lit. x 1no.	10	1	Leak	0.061	2D	208	695
			instantaneous	3.66	2D	560	2400
Chloro acetyl chloride 200 lit. x 5nos	2 mg/m^3	0.2 mg/m^3	Leak	0.078	2D	1300	4300
			instantaneous	4.69	2D	4000	8600
Chlorine 900 kg cylinder, 62nos	10	1	Leak	0.25	2D	908	3100
			instantaneous	15	2D	2600	6600
Sulphuric Acid 50 lit. x 7nos	15 mg/m^3	1 mg/m^3	Leak/ Unconfined pool	0.0141	2D	115	458
Phosphorus oxy chloride 200 lit. x 3nos	0.85	0.1	Leak	0.0929	2D	855	2600
			Instantaneous	5.55	2D	3000	6100
Thionyl Chloride 200 lit. x 3nos	14	1.0	Leak	0.0905	2D	200	886
			Instantaneous	5.43	2D	1127	3100

PAC- Protection action criteria

7.7.3.3 Handling of Hazardous Materials

- **Material hazards:** Coal is the major fuel for Boilers and High Speed Diesel (HSD) Oil for DG sets.
- **Process hazards** due to loss of containment during handling of hazardous materials or processes resulting in fire, explosion, etc.
- **Mechanical hazards** due to "mechanical" operations such as welding, maintenance, falling objects etc. - basically those NOT connected to hazardous materials.
- **Electrical hazards:** electrocution, high voltage levels, short circuiting, etc.

Out of these, the material and process hazards are the one with a much wider damage potential as compared to the mechanical and electrical hazards, which are by and large limited to only very small local pockets.

7.8 Risk mitigation measures

Consequences analysis indicate that the damage distances for fire and explosion situations and IDLH distances due to toxic release of hazardous chemicals fall well within the plant site as well as outside the boundary specially in the case of instantaneous release of Chlorine, Thionyl chloride, Chloro acetyl chloride and phosphorus oxy chloride storage of individual one. Apart from these other toxic chemicals are Benzyl chloride, methyl Dichloride, Ethylene Dichloride including sulfuric acid for the same distance of effect is reported.

In the case of combustible and flammable liquid, effect of pool fire distance is on-site and its effected area up to maximum of 18 m from center of pool. Delayed ignition /spark of vapour cloud of the solvent tanks Methanol, IPA, Acetone, Acetic anhydride and toluene over pressure effect crosses plant boundary including effect of radiation.

For the above incorporating certain mitigation measures at source of release, the consequences to the members of public in and outside the plant will be further reduced. Since the scope of the risk assessment studies cover the risk mitigation measures based on Maximum Credible Accident (MCA) analysis, certain general and specific recommendations are suggested and listed in this chapter. In this regard, the recommended mitigation measures for natural disasters are also included.

7.8.1 General

The industry will be provided appropriate independent fire combat facility and personal protection system and also will have a mutual aid with industries located in and around Bhagyanagar chlorides Pvt. Ltd., Saggonda (v), West Godavari district. On-site/ Off-site emergency plan with effective fire combat facility has been established. However, further suitable mitigation measures with fire protective equipment is to be upgraded.

- Surrounding population needs to be aware of the safety precautions to be followed in case of any toxic release from proposed plant.
- Proposed buildings possibly made to withstand external blast waves and windows will be made of blast resistant glass with strong frame.
- Fire protection system will be in place in accordance with the requirements of NFPA standards. Design requirements and Safe engineering practices will have full capability for early detection and suppression of fire

- Fire prevention and code enforcement is one of the major areas of responsibility for the fire service. The details of the fire-fighting systems and capabilities may be worked out with fire & safety personnel.

7.8.1.1 Fire Prevention and Protective Equipment

Fire-fighting facility equipment to be provided for proposed plant to utilise the same as when required. The following fire-fighting facility is to be checked, if not procured and maintain the same as in case of basic fire preventive measures.

- Water
- Water Tenders
- Foam Tenders
- Fire hydrant and monitor nozzle installation
- Dry powder extinguisher
- Water fog and sprinkler system
- Mobile Fire-fighting equipment
- DCP fire extinguishers
- CO_2 Fire extinguishers
- High expansion foam generator
- For large fire Dry chemical, CO_2 and alcohol resistant foam.
- First aid appliances
- Fire extinguishers will be tested periodically and will be kept in operational mode
- Critical switches and alarm will be kept in-line
- Shut off valves, isolation will be easily approachable in emergencies
- Signboard for toxic or flammable hazard and no smoking signs and type of risk will be provided at various locations
- A wind direction pointer will also be provided at storage site, tanks and location of drums storage. So that in emergency the wind direction can be directly seen accordingly downwind population cautioned especially in toxic gas release.
- The sufficient/adequate space in the storage areas such that to escape from fire and at the same time it will allow emergency procedures to be mobilized.
- Dykes are to be provided for solvent storage tanks of proposed one, whereever necessary. It may be provided and keep safe distance between tanks to avoid domino effect in case of fire.
- The fire proofing materials will have adequate adhesion, strength and durability in the area.
- Seal all the waste in vapour tight plastic bags for eventual disposal or incineration.

- Use face shield, PVC gloves, and safety boots while handling and contaminated clothing has to be removed immediately.
- In case of accidental release, shut-off leaks without risk. Prevent spillage from entering drains or water sources.
- For small spills, take up with sand or other non-combustible material and placed into closed containers for later disposal.
- For large liquid spills, build dyke far ahead of the spill to contain the spilled material for reclamation or disposal as per environmental safety guidelines and decontaminant the area.
- Cool containers/ drums with flooding quantity of water until well after fire is quit.
- Periodical mock drills will be conducted so as to check the alertness and efficiency of the DMP.
- In any case of large fire occurs**,** cool the tanks/ drums with flooding quantity of water until fire is quit.

7.8.1.2 Solvent Storage Tanks / Drums Handling Precautions

Storage tanks: At present 9 storage tanks are proposed in tank form area. Solvents such as Methanol, Acetone, toluene, Ehylene dichloride, acetic anhydride and I sopropyl alcohol, Chloro acetic acid, Benzo trichloride if any will be transferred to the day tank situated at the production block with the help of mechanical seal pump through pipe lines from the tank, from day tank to reaction vessel unloading by gravity.

Drums: Most of the hazard Chemicals/ solvents are storing in ware house i., Benzyl chloride, Thionyl chloride, Methylene dichloride and acetyl chloride including acids if any material will be transferred from respective drums (MS and HDPE)/ carboys to the day tank situated at the production block with the help of AODD pump through pipe from the drums and from day tank to reaction vessel.

The storage and handling of hazardous chemicals in a chemical industry is inevitable, and they carry inherent characteristic risk to the employees due to the properties of chemicals such as toxicity & flammability. Accident due to fire and explosion by flammable substances are possible in process industry. The disastrous effect of fire, explosion and release of toxic fumes in storage and production area, occurs due to inappropriate design, improper storage, improper handling, poor maintenance or deficiencies in the operation of the plant. Chemical in any form can be stored, handled and used if their physical, chemical and hazardous properties are thoroughly understood and necessary precautions are taken. Chemicals are handled in standard containers like MS, HDPE drums, Carboys, etc. All the chemicals are to be arranged and stored in accordance with their compatibility, dry, well ventilated, with flame proof electrical equipments and lighting. All the chemicals are to be

provided with identification labels.

Each chemical has its specific character. Hence, chemicals do not co-exist. They need their independent space, while storing. When two chemicals come in contact may generate heat, and gases by-product. Ambient temperature and moisture can trigger the reaction. Halogenated compounds acquire aggravated properties. It is only wise to treat every chemical as toxic.

Chemicals are potential enough to destroy the flesh and the skin is ultrasensitive to chemicals. Chemicals on contact, the affected parts of the body will be washed thoroughly with plenty of water for at least 15 minutes, to dilute the aggressive nature of the chemical, as water is the only universal solvent and the best diluent. Then only further treatment is to be followed.

Eye wash/drench shower is to be provided at a strategic location for emergency purpose. Chemical safety data sheets and handling procedure, First aid measures are to be prepared and displayed for information and safety of the working personnel. The common safety data of the raw materials and solvents are given in **Table 7.12.**

Table 7.12: Safety data which are common to all raw materials and solvents

1. Fire Fighting Measures	
Extinguisher media	Water spray, dry chemical and carbon dioxide or foam as appropriate for surrounding fire and materials. In case of fire of water/air reactant chemicals like sodium boro hydride, water/foam shall not be used. Dry sand, dry chemical/lime may be used.
Special firefighting procedure	As with all fires, evacuate personnel to safe area. Fire fighters should use self-contained breathing apparatus and protective clothing.
Unusual fire and explosion hazard	This material is assumed to be combustible. As with all dry powders it is advisable to earth the mechanical equipment in contact with dry material to dissipate the potent buildup of static electricity.
Firefighting Procedures	As with all fires, evacuate personnel to a safe area. Fire fighters should use self-contained breathing apparatus and protective clothing.
2. Physical Hazards	
Hazardous Decomposition Products	When heated to decomposition, materials emit toxic fumes under fire conditions.
Hazardous Polymerization	Will not occur
3. Health Hazard Information	
Adverse Effects	Adverse effects may include dizziness, fainting, headache, and diarrhea, and nausea, loss of taste, dry cough, rash fever, joint pain, and unusual tiredness. Possible allergic reaction occurs to material if inhaled, ingested or in contact with skin.
Acute	Possible eye, skin, gastro-intestinal and/or respiratory tract irritation.

Chronic	Possible hyper sensitization
Inhalation	May cause irritation. Remove to fresh air.
Eyes	May cause irritation. Flush out with copious quantity of water by keep opening both eyelids of the affected eye/s. Obtain medical attention immediately.
Skin	May cause irritation. Flush out with copious quantity of water.
Ingestion	May cause irritation. Flush out mouth with required quantity of water by gargling. Obtain medical attention immediately.
4. First Aid Measures	
Precautions to consider	Persons developing hypersensitive (anaphylactic) reactions must receive immediate attention; material may be irritating to mucous membranes and respiratory tract. When handling, avoid all contact and inhalation of dust, fumes, mists, and/or vapors associated with the material. Keep container tightly closed and use with adequate ventilation. Wash thoroughly after handling. Individuals working with chemicals should consider all chemicals to be potentially hazardous even if their individual nature may be uncharacterized or unknown.
Emergency and first aid procedures	Remove from exposure. Remove contaminated clothing. Person developing serious hypersensitive reactions must receive immediate medical attention. If a person is not breathing, give artificial respiration. If breathing is difficult, give oxygen. Obtain medical attention immediately.
5. Exposure Controls / Personal Protection	
Respiratory protection	Use the NIOSH approved respirator, if it is determined to be necessary by an industrial hygienic survey involving air monitoring. In the event of a respirator is not required, an approved dust mask will be used.
Ventilation	Recommended
Protective gloves	Rubber
Eye protection	Safety goggles/face shield
Other protective clothing	Appropriate laboratory apparels/Apron. Protect exposed skin.
6. Handling / Spill / Disposal Measures	
Handling	As a general rule, when handling the materials, avoid all contact and inhalation of dust, mists, and/or vapors associated with the material. Wash thoroughly with soap water after handling.
Storage	Store in airtight containers. This material should be handled and stored as per label instructions to ensure product integrity.
Spill response	Wear approved respiratory protection, chemically compatible gloves and protective clothing. Wipe up spillage or collect spillage using a high efficiency vacuum cleaner. Avoid breathing dust. Place spillage in an appropriately labeled container for disposal. Wash out the spilled site thoroughly.

Measures to Avoid Evaporation

Keep chemical holding tank/ containers/ drums tightly closed. Keep away from, sparks, flame and sources of ignition. Avoid utilizing common shed for different hazard chemicals specially in compatible chemical in same shed, if not keep at safe distance.

At present most of the chemicals are going to be receive in HDPE drums /carboys are stored in a ware house. The ware house floors have to be made of impervious and the room is well ventilated. MS drums are to be stored on spill containment pallets. In case of any leakage from the drum, it will collect in the tub space provided in the pallet itself as containment.

Drums are transferred from ware house to manufacturing area along with spill pallets. It is necessary to store of drums in a cool, dry, well-ventilated area away from incompatible substances sufficient buffer space should be provided between containers/ drums, so that it can be isolated during leak/ spill and respective remedial measures can be undertaken to minimize the effect on- site area. If any chemical to be dispensed for part quantities, the dispensing operation will be done in the dispensing room with local exhaust ventilation system connected to scrubber.

Following contaminant procedure and safety systems is to be followed to minimise/ avoid release of hazard chemical and to control at source if leak/ spill of gas/ vapor/ liquid.

Spill containment procedure:

1. In case of minor spill isolate the chemical/ material
2. Neutralize the spill with the chemical as mentioned below

CHEMICALS / NEUTRALISING	ACID (CORROSIVE)	WATER REACTIVE	CAUSTICS	OXIDIZER	REDUCER	POISON	AIR REACTIVE	FLAMMABLE	ALKALI METALS
ABSORBING AGENT	Polypropylene pad, Brooms & Sand	Polypropylene pad & Broom	Polypropylene pad, Broom & sand	Polypropylene pad & Brooms	Polypropylene pad & Brooms	Polypropylene pad & Brooms	Polypropylene pad & Brooms	Polypropylene pad, Brooms & sand	Dry sand /Mineral oil
NEUTALIZER	Sodium Bi Carbonate (or) Soda Ash	Sodium Bi Carbonate (or) Soda Ash & Special Dry Powder (TEC)	Weak Acid (5% Hydrochloric acid)	5% sodium thiosulphate solution & Powder	5% sodium hypo chlorite solution	5% sodium hypo chlorite solution	Sodium Bi Carbonate (or) Soda Ash & Mineral oil	Activate Charcoal	Nil
DECONTAMINATER	Water and to be checked by pH paper	Water	Water and to be checked by pH paper	Water	Water	Solvent for water reactive and then with water	Water	Water	Mineral oil and then with water

3. Sweep the area
4. Decontaminate the area with suitable decontaminer as mentioned in the above table

It is also necessary every chemical industry to be maintained spill control kit with minimum of these items is to be followed and updated in regular interval.

1. Sorbent rolls
2. Sorbent brooms
3. Sorbent pads
4. Air tight goggles

5. Half face cartridge mask
6. Chemical resistant suit
7. Antistatic gloves
8. PVC gloves

Safety Systems

1. Designated areas with proper indication flammable/ toxic / explosive &safety sings
2. Double earthing systems
3. Flame arrestor to the vent
4. Flame proof transferring pumps
5. Handling precautions/sop protocol
6. Pressure Gauges
7. Level indicators
8. Flame proof lighting to storage yard

Personal Protective Equipment's (PPEs)

Personal Protective Equipment's (PPEs) provides additional protection to workers exposed to workplace hazards in conjunction with other facility controls and safety systems. Selection of PPE will be based on the hazard and risk ranking and will be according to the criteria on performance and testing established. The generally recommended measures for use of PPEs in the work place are given in **Table 7.13.**

Table 7.13: Recommended Personal Protective Equipment's

Objective	Workplace Hazards	Suggested PPEs
Eye and face protection	Flying particles, molten metal, liquid chemicals, gases or vapors, light radiation.	Safety glasses with side-shields, Chemical splash glasses protective shades, Fiber glass resistant to most chemicals etc.
Head protection	Falling objects, inadequate height clearance, and overhead power cords.	Plastic helmets with top and side impact protection.
Hearing protection	Noise, ultra-sound.	Hearing protectors (ear plugs or ear muffs)
Foot protection	Failing or rolling objects, points objects. Corrosive or hot liquids.	Safety shoes and boo ts for protection against moving and failing objects, liquids and chemicals.
Hand protection	Hazardous materials, cuts, vibrations, extreme temperatures.	Gloves made of rubber, PVC coated gloves or synthetic material (Neoprene), leather, steel, insulation materials, etc.
Respiratory protection	Dust, fogs, fumes, mists, gases, smokes, vapors	Facemasks with appropriate filters for dust removal and air purification (chemical, mists, vapors and g ases). Canisters for toxic gas Single or multi-gas personal monitors, if available.
	Oxygen deficiency	Portable or supplied air (fixed lines). Onsite rescue equipment.
Body / leg protection	Extreme temperatures, hazardous materials.	Fire Entry Suit; Insulating clothing, body suits, aprons etc. of appropriate materials Stud safety shoes, PVC knee boots

7.8.2 Specific Recommendations

Specific attention to be made during storage, transport and handling mode specially for combustible, flammable/ explosive and toxic material.

The major hazard situations in the unit are: The pool fire occurs due to

- Possible rupture/ leak of storage tanks / drums
- Dispersion of liquid to confined or unconfined area
- Ignition of releasing liquid/ vapour

To prevent accident due to fire and explosion, it is necessary to know:

- The fire and explosion properties of the material
- The nature of fire and explosion process and
- The procedure to reduce fire and explosion

To avoid or reduce Vapour Cloud Explosion (VCE) to minimise dispersion of flammable vapour by operating water/ foam tenders and to avoid further dispersion by maintaining water/ foam curtain.

- Sudden release of large quantity of flammable vapour, typically this phenomenon occurs when a storage tank containing suspended and pressurized liquid ruptures
- Dispersion of vapour in nearby areas while mixing with air
- Ignition of the released vapour cloud

Vapor clouds are normally ignited at the edge as they drift and stop further spreading of the cloud in that direction causes Unconfined Vapour Cloud Explosion (UVCE).

Boiling Liquid Expanding Vapour Explosion (BLEVE) is caused by sudden failure of the container due to any cause. The primary cause is usually an external flame impinging on the shell of a vessel above the liquid level weakening' the container and leading to a sudden shell rupture. A pressure relief valve does not protect against this mode of failure. BLEVE can occur due to any mechanism that results in the sudden failure of the container allowing a superheated liquid to flash typically increasing its volume over 200 times. This is sufficient to generate a pressure wave and fragments. If the released liquid is flammable a fireball may result. However vapour cloud explosion unlikely occur in M/s. Bhagyanagar chlorides, being released vapour cloud in most of the cases below the LEL as per analysis.

The major incompatibilities is a guide to the storage and handling of chemicals and which combinations to eliminate accidents if any. Each chemical has specific character and hence all the chemicals will not be stored in one storage shed, being not supposed to mixed,

stored together, during storage and handling. It is the nature of chemicals that they do not co-exist. The major incompatibilities for storage and handling of hazard chemicals presented in **Table 7.14** and specific precautionary measures have to be taken for case by case for following accidental release of hazard chemicals.

Table 7.14: Major incompatibilities for storage and handling of hazardous chemicals

Chemical	**Incompatible with**
Acetic acid	Solvents, oxidizing agents, water, other chemicals
Acetyl chloride	Strong oxidisers
Acetic anhydride	Water, steam, mineral acids, oxidizing materials, alcohols, or amines may cause violent reaction. Contact with strong caustics will cause violent reaction and spattering. Corrosive to copper, brass, bronze, and iron
Acetone	H_2SO_4, HNO_3, Oxidizing agents, H_2O_2 and Chloroform.
Aluminum	Strong oxidisers
Benzyl alcohol	Mixtures with sulfuric acid decomposes explosively at 180C
Benzyl chloride	Oxidizers, acids, copper, aluminum, magnesium, iron, zinc, tin [**Note:** Can polymerize when in contact with all common metals except nickel & lead. Hydrolyzes in H_2O to benzyl alcohol.]
Benzo trichloride	Acids, acid fumes, oxidizers steam
Chlorine (g)	Reacts explosively or forms explosive compounds with many common substances such as acetylene, ether, turpentine, ammonia, fuel gas, hydrogen & finely divided metals
Chloro acetyl chloride	Reacts with oxidising agents and alkalies
Clhoro acetic acid	Incompatibility with various substances: Not available
Dimethyl formamide	Highly flammable liquid & polymerisable, may violently with broad range of chemicals, alkaline metals, acid hydrides, bromine, chlorine and carbon tetra chloride.
Diethyl amine	Extremely flammable, Strong oxidizers, Strong acids, cellulose nitrate
1,4 Dioxane	Strong oxidizers, de carbonate , tri ethynyl aluminum
Ethylene dichloride	Strong oxidizers, caustic, chemically active metals Al, Na, K and liquid ammonia
n-Hexane	Strong oxidizers
Hydrogen	May react violently with oxidants.
Iso Propyl Alcohol (IPA)	Strong oxidizers, Acetaldehyde, chlorine, Ethylene oxide, acids and Isocyanate
Methanol	Other chemicals
Methylene dichloride	Strong oxidizers, caustic, chemically active metals Al, Na, K and conc. Nitric acid.
Phosphorus oxy chloride	Water combustible material, carbon disulfide, dimethyl formamide, metals
Sulphuric acid	Organic materials, chlorates, carbides, water powdered metals
Sodium Hydride	Water, oxygen, carbon dioxide, carbon tetra chloride, Acetylene, Metal halides, Acids and alkalies
Toluene	Strong acids, combustible and flammable substances, oxidizing agents
Thionyl chloride	Alkalis, oxidizing agents, other chemicals.
o- xylene	Strong oxidizing agents and strong acids

7.8.2.1 Combustible Materials

Industry proposed to store acetic acid in 200 L capacity drums. MCA analysis of acetic acid indicates that effect of heat radiation is close to edge of pool. In case of acetic acid for small fire -water and for large fire dry chemical, alcohol foam, water spray and keep source of ignition neutralize with dilute sodium carbonate.

7.8.2.2 Flammable – Pool Fire/ vapor cloud Explosions / BLEVE

There are several flammable liquids are storing in tanks/ drums in tank form area as well as in ware house. Flammable liquids are mainly Acetone, IPA, Acetic anhydride, Methanol, Ethylene dichloride and Toluene solvents are storing in horizontal storage tanks in tank form area where as other flammable liquids are stored in drums and few of these are also considered as toxic as well as flammable storing mostly in HDPE drums of capacity 200/ 250 lit in ware house. In case of leak or catastrophic rupture of storage tanks in tank form area and drums in ware houses, total material taken as source strength and forms a pool in respective dyke and unconfined pool in case of drums.

In the case of leak, pit tank is to be provided in tank form area to collect leaked solvent as precautionary measure to collect and disposed accordingly and simultaneously leakage control with safe precautionary measures. If pool fire occurs, start using the fire hydrant points, water sprinklers, water monitor and foam gun kept near the tank farm area. In case of unconfined pool of flammable liquid in ware house, spill containment procedure to be followed and if ignited fire-fighting measures and take follow up action.

- Evacuate all the personnel in the tank farm area.
- Stop all activities/loading unloading in the tank farm area
- Cordon off the area and do not allow any person inside tank farm.
- Follow emergency procedure for fire protection measures in solvent storage tank form area.

If ignition takes after vapour cloud formation or BLEVE takes due to exposure of storage tank by external heat or any other means. Result causes over pressure and heat radiation effect on-site area and crosses plant boundary (off-site) area closed by plant. The risk mitigation measures is as follows:

- All solvent tanks having condenser cooling with flame arrestor provided.
- Appropriate fire-fighting system is to be applied in case of accidental release of other flammable liquids.
- Lightening arrestors provided to near tank
- Breather valves facility with Nitrogen blanketing provided to all
- MCP provided inside the solvent tank farm area

In the above case use alcohol form, water spray or fog, cool containing water jet to prevent pressure buildup or auto ignition or explosion. In case of small fire due to leak of flammable liquid / vapour appropriate fire-fighting system may be deployed accordingly on basis of Risk level.

7.8.2.3 Toxic Releases

Industry is proposed to handle proposed Acetic anhydride, Chloro acetic acid, Ethylene dichloride, Methyl dichloride and Benzo trichloride in tank form area, where as sulfuric acid, Acetic acid, Thionyl chloride, Benzyl chloride, Methyl Dichloride, acetyl chloride and others in drums in ware house.

Chlorine 900 kg cylinders in dedicated storage area and storage area have a facility of maximum 132 cylinders, which is considered as most hazard prone area in proposed activity.

Acetyl chloride & Thionyl chloride: Industry has a facility to store acetyl chloride maximum of 200 lit. x 70 drums, Whereas Thionyl chloride maximum of 200 lit. x 3 drums though it is in liquid form once accidental leak or complete discharge of chemical, it spill over in unconfined area and evaporates and move towards wind ward direction causes severe health effect, being its PAC3 (Protection action criteria 1) and IDLH values are 50, and 14 ppm respectively and once exposed get medical aid immediately.

It reacts with water may release flammable and toxic gases and vapors may be heavier and moves along the ground level towards down wind. Ask the people to vacate the area and to move for fresh air towards crosswind side. For spill/ fire dry chemical may be used, If water is only media flooding of water necessary as in any fire and wear breathing apparatus during operation.

Benzyl chloride and Benzo Tri chloride: Benzyl chloride is considered as combustible III chemical and also considered as toxic. Industry storing at a time maximum capacity of 200 lit. of 11 drums, rupture of drum causes instantaneous releases of liquid and spill over unconfined area, toxic gases, vapors generates, move towards safe side (cross wind/ upwind side if possible) as in above. Immediate first aid measures as well as gets medical aid immediately. In the case of Benzo trychloride is stored in 20 KL x 3 HDPE tanks are proposed with suitable dyke.

Small Spill: Absorb with an inert material and put the spilled material in an appropriate waste disposal.

Large Spill: Absorb with an inert material and put the spilled material in an appropriate waste disposal. Be careful that the product is not present at a concentration level above TLV. Check TLV on the MSDS and with local authorities.

It is highly in compactable with most of the metals and polymerise when contact with common metals and strong oxidizer. Hence, specific attention is to be made accordingly during emergency action plan (on-sit/ off-site). For spill over small/ large to control use inert dry material- sand silica, saw dust, acid binder etc. do not allow exposed adsorbent water ways.

Be careful that the product is not present at a concentration level above TLV of Benzyl chloride and P AC2 of Benzo trichloride. Do not breathe gas/fumes/ vapor/spray. Wear suitable protective clothing. In case of insufficient ventilation, wear suitable respiratory equipment. If ingested, seek medical advice immediately and s how the container or the label. Avoid contact with skin and eyes. Keep away from incompatibles such as metals, alkalis.

Sulfuric Acid (50 kg drums x 8 nos)

Wear appropriate personal protective clothing to prevent skin contact and avoid breathing vapors. Avoid contact with eye, Wear appropriate eye protection to prevent eye contact. The worker should immediately wash the skin when it becomes contact with acid Filling/ Transfer operation should be stopped immediately in the event of:

- Uncontrolled leakage occurring
- A fire occurring in the vicinity
- Lightning and thunder storm

In case of small leaks increase ventilation and allows gas to vent, bounding with sand earth dilute spill with water. In case of large spell use water fog, to dampen cloud of sulphuric /nitric acid fumes to reduce vapours.

Acetic acid: There is a provision of storage in 200 L x 15 drums, daily consumption 584 Kg/day. It is fuming / corrosive liquid and it is incompatible with bases, oxidisers and reducing agents.

Small Spill: Dilute with water and mop up, or absorb with an inert dry material and place in an appropriate waste disposal container.

Large Spill: Stop leak if without risk. Absorb with DRY earth, sand or other non-combustible material. Do not get water inside container. Do not touch spilled material. Use water spray curtain to divert vapor drift and prevent entry into sewers, provide exhaust ventilation or other engineering controls to keep the airborne concentrations of vapors below Threshold limit value. A self-contained breathing apparatus should be used to avoid inhalation of the product. Leaked material disposed to basements or confined areas of dike and disposed.

Chloro Acetyl chloride & Chloro Acetic acid: There is a provision of storage Chloro acetyl chloride in 200 lit. of 5 HDPE drums, whereas chloro acetic acid in 20 KL HDPE tank. In case of Chloro acetyl chloride **-** Keep container tightly closed and in a well-ventilated area.

SMALL FIRE: Use DRY chemical powder, LARGE FIRE: Use water spray, fog or foam. Do not use water jet.

Procedure for cleaning if spillover: Carefully throw polypropylene booms / pillows around and on the spill to prevent the spread of the spill. Absorb the spill with polypropylene pads and squeeze the pads into disposable container. Pour dry sand on the spill and collect into disposable container. Neutralize the contaminated area with soda ash. Wash the contaminated area with water and send to ETP till washings pH is 6.0 – 7.5.

In case of chloro acetic acid**- Small Spill:** Use appropriate tools to put the spilled material in a convenient waste disposal container. If necessary: Neutralize the residue with a dilute solution of sodium carbonate.

Large Spill: Stop leak if without risk. Do not get water inside container. Do not touch spilled material. Use water spray to reduce vapors. Collect the material in dyke if needed later collect in disposable container. Eliminate all ignition sources. Call for assistance on disposal. Neutralize the residue with a dilute solution of sodium carbonate. Send the disposable container containing acid liquid to effluent treatment plant, disposable container containing polypropylene pads, Booms to Incinerator and disposable container containing contaminated sand to ETP Sludge drying beds for proper detoxification.

Methylene dichloride & Ethylene dichloride: It is toxic by ingestion. Exposure in an enclosed area may be very harmful. Methylene chloride is storing in 200 lit PVC drums, whereas ethylene dichloride is storing in 10 KL x 3 HDPE tanks. It is potentially incompatible absorbents and strong oxidiser, chemically active metals such as Na, K, Al, Mg being it is halogenated organic compound.

Spill / Leak: Small spill -take up with sand, earth or other non-combustible absorbent material, whereas for large spill - dyke far ahead of liquid spill for later disposal. Prevent entry into waterways, sewers, basements or confined areas. Use personal protection equipment; ensure adequate ventilation and all source of ignition.

Small Fire: Dry chemical, CO_2 or water spray. In case of **Large Fire**: Dry chemical, CO_2, alcohol-resistant foam or water spray. Move containers from fire area if you can do it without risk. Dyke fire-control water for later disposal; do not scatter the material. Fight fire from maximum distance or use unmanned hose holders or monitor nozzles. Flooding of water is to be applied to containers until well after fire is out.

Chlorine: Liquid chlorine 6 nos. of one-ton chlorine cylinders (900 kg) are stored in the chlorine storage shed.

Consequences of chlorine release: Rupture of SS line after chlorine cylinder. The rupture of 6mm copper tubing connection will cause spreading of toxic gas in the factory, which is considered as the worst case, and not likely to occur.

- In case of leak evacuate the people to safe area and responders must wear SCBA and PVC suit, use emergency kit for arresting leaks.
- The emergency kit provided for chlorine leak from toner can also be used.
- Always stand in upwind direction while attending to chlorine leak.
- Use Ammonia torch for detecting the exact location of leak.
- Follow the procedure for arresting leak: Emergency chlorine leak detection and alarm system, Manual scrubber system to be provided with canopy hood and Scrubber consists of minimum of one tonne of caustic solution.

The personal protection and safety system, on site air masks in the chlorine cylinders storage area, SCBA sets provided at storage area and control at source**,** Fire hydrant system provided to the area, Eye shower provided at the area. One set of emergency chlorine kit and including public address system for emergency communication and Wind sack to be available to identify the direction of wind.

Aluminium: There is a provision of aluminium storage of 2400 nos. of 25 kg ingots, during reaction with chlorine aluminium chloride fumes will be generated and recovered the same as powder. Avoid fugitive emissions of aluminium chloride fumes during recovery.

Sodium hydride: It is dangerous when exposed to air, moisture, water and it is incompatibilities for water, oxygen, carbon dioxide, carbon tetrachloride, halogens, acetylene, metal halides, ammonium salts, oxides, oxidizing agents, acids, alcohols, chlorinated organic compounds, many other substances.

Accidental release measures: Immediately cover the spillage with Ternary Eutactic Chloride (TEC) based dry powder and mix. Collect the spillage into a polyethylene bag under nitrogen atmosphere, kept in disposable container. Again wipe the contaminated area with Ternary Eutactic Chloride (TEC) based dry powder and collect the wiping into a polyethylene bag under nitrogen atmosphere, kept in disposable container. Sodium hydride decomposed by adding methanol to reduce the hydride concentration, after that add water.

Other chemicals: Dioxins, phosphorus oxy chloride, etc.

Most of the hazard chemicals are storing in ware houses in specified drums in liquid and solid form, these chemicals flammable, toxic as well as corrosive in nature, and storing in ware house.

Small spillage: Any hazardous chemical spill that does not involve highly toxic, highly reactive, or explosive chemicals in a situation that is not life threatening. This type of spill present a manageable physical or health hazard to personnel who, when wearing proper Personal Protective Equipment's (PPEs), will not be exposed to any chemical at a level that exceeds any level or permissible exposure.

Smaller Spillage Response & Cleanup Procedure: If the spillage is of smaller quantity, cleanup the spilled material with suitable absorbent as per MSDS and collecting suitable portable container and send it to Effluent Treatment Plant (ETP) where it will be treated / incinerated.

Large spillages: Any hazardous chemical spill involves highly toxic, highly reactive, explosive or life threatening chemicals **(OR)** Any spill situation that presents significant fire, explosion or other physical or health hazard risks, particularly if a person may be or has been significantly exposed, contaminated or injured to such an extent that medical or other assistance is required. The occurrence of spill to building internally or externally that will adversely impact to the external environment.

Large Spillage Response & Cleanup Procedure

- The area should be immediately evacuated particularly downwind area and restrict access to the area until completion of recovery and cleanup.
- Eliminate all ignition sources and provide adequate ventilation depending upon the chemical.
- Stop or reduce leak if safe to do so.
- Contain the material with earth sand or absorbent material which does not reactive with spilled material.
- Recovery and cleanup should be done the trained personnel only. The person cleaning the material will wear required Personal Protective Equipment's (PPEs) such as respiratory cartridge mask, safety goggles, gumboots, PVC Suit and rubber hand gloves etc.
- Do not touch the spilled material and avoid prolonged and repeat exposure to toxic
- Prevent spilled material entering waterways, sewers or drainages.
- Ground the containers if the spilled materials generate the static electricity.
- Vacuum/ sweep up the spilled material in approved, portable and suitable containers as mentioned the MSDS.
- Place the containers with covers, labels and in suitable locations.
- After recovering the material, cleanup the area with suitable absorbent material as mentioned in the MSDS.
- Flush the area with water if it is required.

Disposal of Larger Spillages Materials:

- After recovering the material, sent it to Effluent Treatment Plant (ETP).
- Depending on the nature (physical & chemical properties) of material either the material is to be neutralized or incinerated or it will send for treatment and land filling

However in all the cases of above and other chemicals are used by the proponent follow MSDS/ NIOSH data sheet guide lines for First aid, accidental release measures, fire-fighting if any.

7.8.3 Hazard Control Measures

1. Procedures and actions will be well defined and known to all operating personnel's for safe shut down of plant in case of failure of any power, instrumentation, cooling water, air, etc.
2. All the storage tanks will be provided with temperature indicator, pressure gauge and safety valves as depending upon the process and operating parameters.
3. Plant specific HAZOP studies will be carried out using P & IDs for identification of hazards during operation considering deviation of operational parameters, their possible cause of material loss and consequence and safeguards.
4. Interlocks and DCS control will be provided during reaction process.
5. All the motors and other rotating equipment machines will be provided with suitable safety guards.
6. Existing fire extinguishers fixed / movable will be upgraded in the plant area.
7. Movable fire tenders may be arranged, being it need of hour during emergency.
8. Flame arrestors will be provided at all vent lines for proposed solvent tanks.
9. Suitable first aid fire extinguishers, such as, DCP, CO_2 & foam type will be kept in every plant area at easily approachable spots. Fire hydrant points with sufficient length of hose reel will be provided at major emergency spots.
10. Bound walls, bonded wire fencing, detached storage area will be kept away from probable ignition sources; Dykes should be provided by giving sufficient space provision between all liquid storage tanks.
11. Safety shower and eye washer will be installed at storages/ handling of hazard, process/ operation units
12. Sufficient space will be provided for free movement in the plant area. Avoid transfer of hazard material from storage to process units by manually if any.
13. Safe distances have been considered between storages and process operation units and utilities in designing of plant lay out.
14. Regarding all components of the plant proper certificate will be taken. Testing and inspection will not be compromised before deliveries.

15. Certificate of structure stability will be taken from competent person.
16. Insulation of piping will be provided as per requirement.
17. All elevated structures will be provided with lightening arrestors.
18. All exposed parts of moving machineries will be provided with suitable guards for personnel safety.
19. All piping and equipment will be provided with earthing connection and it will be tested regularly.
20. Safety valves & rupture disc will be provided to prevent over pressure in tanks/ vessels and reactors.
21. SOP will be available of safe shut-down of plant during any emergency.

7.8.4 Mitigation Measures for Natural Disasters *(ToR No. 7.13)*

(A) **Flood:** Mitigation measures can be structural or non-structural. Structural measures use technological solutions, like flood levels that is only possible when local seasonal heavy rains occur. There is no possibility of water logging area is slightly sloppy (undulated elevated terrain). However, the following procedure is followed in case of flooding.

- Focus resources on minimizing the spread of water into other areas of the plant:
- Stop all operations immediately. Close all valves of solvent storage tank
- Switch off power supply to avoid electrocution due to short circuit.
- Protect property and records by removing items from floors and/or covering with water resistant coverings.
- Evaluated information will be disseminated to personnel.
- Shift the water reactive material to elevated places like racks / building. Attempt to move items of value to “higher ground” if possible
- Activate the onsite warning and instructional system as necessary.
- Follow unit shut down procedures and Shut down electrical power.
- Control water flow by dyke arrangement using sandbags, and or pumping.
- Start up after checking and clearing water from each and every unit

(B) **Cyclones and Severe Storms:** Location of M/s Bhagyanagar chlorides is at elevated area when compared with surrounding area of plant (Godavari river) and is not in flood prone area, being location of site is around 45 MSL. However during storm and if any flood water enters from outside plant area, land use management will provide protection from wind and storm surge.

- Engineering of structures would with stand wind forces and building will be constructed with wind-resistant capacity. Securing elements such as metal sheeting, roofing, and fences will be done to avoid severe damages.

Cyclone and severe weather warning systems will be installed and awareness regarding cyclone risk and evacuation plan will be addressed.

(C) Earthquake: The factory premises is situated in Saggonda village, Gopalapuram Mandal (close to Kovvur town) which falls under Zone I I under Seismic zone, classification and accordingly the probability and impact will be least to moderate. However steps will be taken for personal structural mitigation in earthquake prone areas includes seismic retrofits of property.

- Precautionary measure such as securing items inside a building to enhance household seismic safety.
- Stay away from glass, windows, outside doors and walls, and anything that could fall lighting fixtures or furniture.
- Stay inside until the shaking stops after that it is safe to go outside
- Do not attempt to move to a different location inside the building or try to leave.
- DO NOT use the elevators

7.9 Disaster Management Plan *(ToR No. 7.13)*

7.9.1 Introduction

A major emergency is one, which has the potential to cause serious injury or loss of life. It may cause extensive damage to property and serious disruption, both inside and outside a pl ant. Sometimes, it requires the assistance of outside emergency services to handle it effectively. Emergency may be caused by a number of factors, e.g. plant failure, human error, natural calamities, crash or sabotage, if any other means. Several Government agencies, both at the Central and State levels, are entrusted with the responsibility of ensuring safety and management of hazardous chemicals under Acts and Rules made for the purpose. Despite these measures, the possibility of accidents cannot be ruled out. In order to be ready to face risk of accidents during processing, a disaster management plan will be prepared to mitigate the impact.

The purpose of this DMP is to give an approach to detail organizational responsibilities, actions, reporting requirements and support resources available to ensure effective and timely management of emergencies associated to production operations in the site. The overall objectives of DMP are to:

- Minimize the occurrence of Leak/ Catastrophic events leading to human, property and material damage/losses by a suitable policy initiative.
- Prevent injury, loss of life or damages by a timely and appropriate response of emergency preparedness plan for on-site and off-site area of M/s Bhagyanagar

chlorides obtain early warning of emergency conditions so as to prevent impact on personnel, assets and environment;

- Activate and ens ure involvement of all personnel and ag encies in emergency response planning and community preparedness.
- Immediate response to emergency scene with effective communication network and organized procedures.
- Involve citizens and ot her emergency response team members in design, testing and implementation of the DMP

The results of MCA analysis of the Risk Assessment (RA) study is to be used in the preparation of this DMP. To safeguard personnel to prevent injuries or loss of life by protecting personnel from the hazard and ev acuating personnel from an installation when necessary, provide guidance to help stake holders take appropriate action to prevent accidents involving hazardous substances and to mitigate adverse effects of accidents that do nevertheless occur and to minimize the impact of the event on t he installation and t he environment by:

- Minimizing the hazard as far as possible
- Minimizing the potential for escalation
- Containing any release

This is achieved by describing procedures to deal with emergencies affecting personnel, equipment, third party contractors, local communities or the environment.

7.9.2 Key Elements of Disaster Management Plan

Following are the key elements of Disaster Management Plan:

- Basis of the plan
- Accident/ emergency response planning procedures
- On-site Emergency Preparedness Plan
- Off-site Emergency Preparedness Plan

Basis of the Plan: Identification and assessment of hazards is crucial for on-site emergency planning and it is therefore necessary to identify what emergencies could arise in production of various products and their storages including hazard transfer pipe line. Hazard analysis or consequence analysis gives fire, explosive and toxic scenarios due to accidental release of flammable/ toxic chemicals from storage (tanks / containers / drums) and any other means**.**

Accident/ Emergency Response Planning Procedures: There are four emergency levels of incident management and response to industrial accidents that the public should be aware of:

Level I*:* An incident has occurred and can be controlled by facility personnel. The situation is under control

Level II*:* An incident has occurred the situation is not under control but is confined. The incident is confined to a small area or to a fixed-site and does not pose a threat of spreading to a larger area or off-site.

Level III*:* An incident has occurred the situation is not under control and protective action may be necessary for the surrounding or off-site area.

Level IV: An incident has occurred and the situation is not under control. Actions by more than first responders or facility personnel are necessary. Incident involving a severe hazard or an area which poses an extreme threat to life and property and will probably require an evacuation.

Emergency rarely occurs therefore activities during emergencies require coordination of higher order than for planned activities and will be carried out according to fixed time schedule or on a routine day-to-day basis. To effectively coordinate emergency response activities, an organizational approach to planning is required. The important areas of emergency planning are Organization and Responsibilities, Procedures, Communication, Transport, Resource requirements and Control centre.

Offsite emergency requires additional planning over and above those considered under on-site plans, which will be properly integrated to ensure better coordination. An emergency core group (ECG) is constituted to pool and analyze the necessary information for effective decision making.

Emergency core group (ECG) consists of different task of specific coordinators i,e, plant general manager, plant manager of process and maintenance, Engineering group, Safety officer and Fire officer, who in turn mobilise and formulate requisite number of action teams who will provide necessary emergency response.

An emergency action groups (EAG) will be constituted as a part of first response team. Thus the first response team for the plan includes all the members of both ECG and EAG. The constituents have been assigned specific responsibilities for the plan. The responsibility of managing on-site crisis lies solely with the concerned organization, whereas the organization structure for off-site emergency includes both Local/ State government agencies. The functions of the ECG are:

- Formulation and implementation of emergency plan.
- Provide guidance / making basic policy decisions.
- Convening the emergency core group meeting after receipt of emergency call.
- Review of operational preparedness of emergency machinery

- Hold periodic mock/ training to ensure optimum preparedness at operational levels
- Develop and update various hazard scenarios, and cascading effect based on the on-site plan
- Mobilize the financial resources for expenditure in case of emergency
- Depute nodal officer with the district or state authority for off-site crisis
- Transfer the information collected from the advisory group to EAG
- Liaises with external and mutual aid agencies and identify cases where material aid is needed
- Provide information on the incident to district, state / level authorities and if needed call for assistance from competent bodies
- Liaises with press / media to report the emergency
- Declare rehabilitation centers in case of evacuation of people.
- Takes care of emergency situation like continual health care, re-establishment and creation of social compatibility
- Declare all clear, once everything is normal

Emergency action group (EAG) is the front line team which responds based on the instructions given by ECG. It coordinates among itself for various activities. The functions of EAG are:

- Rushes to the emergency area
- Make systematic assessment of hazard
- Liaises with emergency control centre
- Warns the personnel of an impending danger
- Cordon off the people and control the traffic
- Render first aid medical service
- Seek rehabilitation centers

7.9.3 On-site Emergency Preparedness Plan

An on-site emergency is caused by an accident that takes place in the plant itself and the effects are confined to the factory premises involving only the people working in the factory. On-site emergency plan to deal with such event and it is responsibility of the occupier and also mandatory.

The preparation of an on-site emergency plan and furnishing relevant information to the District Emergency Authority for the preparation of the off-site emergency plan are statutory responsibilities of the occupier of every industry and other units handling hazardous substances. An on-site emergency plan will contain the following key elements:

- Basis of the plan

- Hazard analysis
- Accident prevention procedure/ measures
- Accident/ emergency response procedure /measures and
- Recovery procedure.

7.9.3.1 Purpose

- To protect persons and property of process/ operation equipments in case of all kinds of accidents/ emergencies
- To inform people and surroundings about emergency if it is likely to adversely affect them.
- To inform authorities including helping agencies (doctors, hospitals, fire, police transport etc.) in advance, and also at the time of actual happening
- To identify, assess, foresee and work out various kinds of possible hazards their places, potential and damaging capacity and area

➢ In case of M/s Bhagyanagar chlorides, MCA analysis indicates that the following places required Emergency preparedness plan.

➢ Storage tank of flammable liquid in tank form area and specified tank - pool fire/ vapour cloud explosion / fire ball.

➢ Pool fire (confined) radiation effect (4.5 KW/m^2) in case of flammable liquids i.e. Acetone, Methanol, Acetic anhydride, IPA, Toluene and in others vary from 7 to 15 m from edge of pool. Radiation effect of fatality is within. In case of delayed ignition/ spark of vapour cloud due to leak / release of flammable liquid causes damage inside and out side plant, however it is unlikely occurs, being material holding in confined pool and possibility of average LEL value within limits. Catastrophic rupture under BLEVE also unlikely occurs, only it is due to exposure of storage tanks by external heat or sabotage.

➢ **Location of drums (HDPE and MS) and container** storages are in ware house – fire/ explosion/ toxic release

➢ There are hazard flammable/ toxic and corrosive liquids are storing in drums i.e. Acetyl Chloride, Benzyl chloride, Dioxane, Dimethyl formamide and others. In case of leak or rupture it will spread of liquid over un-confined area and forms vapour cloud and under spark/ ignition people exposed to heat radiation effect, whereas in the case of dispersion of toxic gas/ vapour even it may cross over plant boundary, need off-site emergency preparedness plan.

➢ Most of the flammable liquid are storing in drums of different capacity, emergency level depends on extent of material release and vapour cloud formation. Delayed ignition or spark explosion causes thermal radian and over pressure effect mainly

within plant boundary. In case of spillage of toxic chemicals material released to atmosphere as gas/ vapor form dispersed towards downwind direction covers off-site area, if delayed in control at source mainly thionyl chloride, benzyl chloride and phosphorous oxychloride being considered including acid fumes as toxic.

- **Location of gas cylinders storage:** In the proposed unit gas cylinders of chlorine (900kg), and highly flammable gas cylinders Hydrogen (100 kg) at dedicated areas - leak of cylinders such as Chlorine gas dispersed towards downwind side and covers on-site as well as off-site area, which depends on type of leak and duration, where as in case of hydrogen cylinder radiation and over pressure effect mainly on-site as well as off-site disaster depends on dur ation of leak before ignition. However, various precautionary measures suggested to avoid the possible leak and t o minimise duration of leak by controlling at source.
- **Location of material transfer points** (Process/operation unit)–fire/ explosion/ toxic release – however depends on material and extent of material leaked/ releases.

In order to handle disaster/emergency situations, an organizational chart entrusting responsibility to various personnel of industrial unit will be available as shown in **Fig. 7.3.**

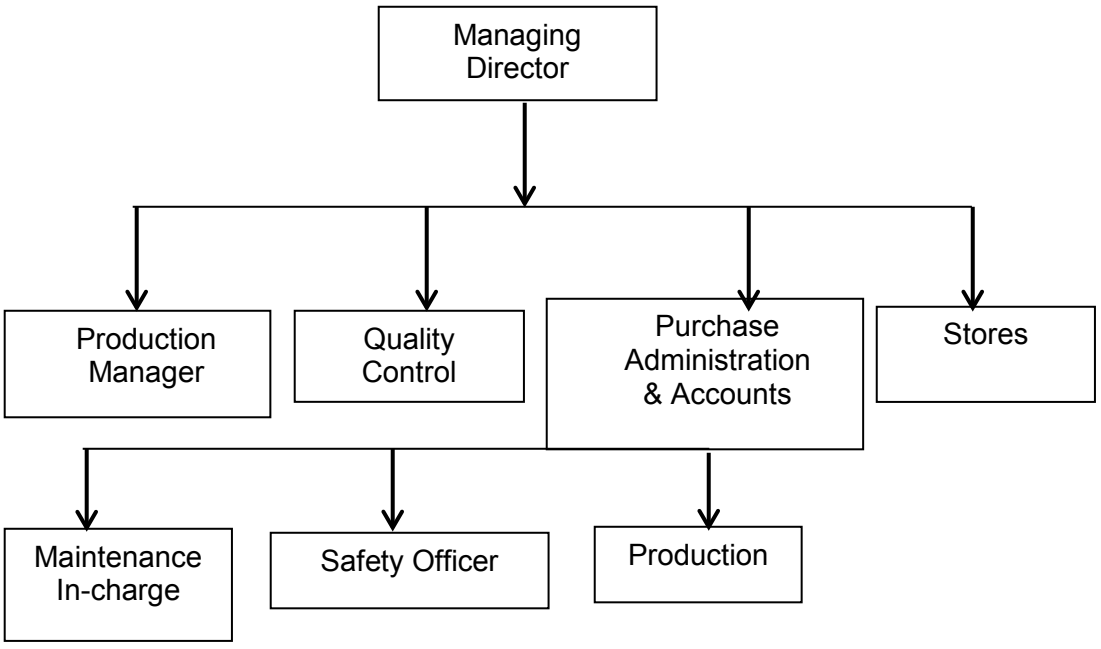


Fig. 7.3: Factory Management Organisation Chart

7.9.3.2 Accident Prevention Procedures / Measures

A separate plan is provided to deal with the situations, which necessitate emergency action. The emergency response plan includes details of the organizational response to emergencies and the safety precautions to be observed in preventing loss of life and damage to property. Risk mitigation measures based on consequence analysis are recommended above based on the consequences analysis.

Fire Prevention Planning and Measures

Fire is one of the major hazard apart from toxic gas in this unit, Fire prevention and code enforcement is the area of responsibility of the fire service. Safe operating practices reduce the probability of an accidental fire on a plant. Personnel understand their duties and responsibilities and be attentive to conditions that might lead to fire. The following precautions are recommended:

- There will be provision for safe handling and storage of dirty rags, trash and waste oil flammable liquids and chemicals spilled on platform cleaned immediately
- Containers of paints and hydrocarbon samples, gas cylinders for welding and cutting stored properly.
- Cutting and w elding operations conducted in accordance with safe procedures. Smoking restricted to designated platform areas and " no smoking" areas clearly identified by warning signs
- Particular attention given to oil pumps, seals; diesel and g as engines which are potential source of ignition in the event of a failure

Basic Actions

- The basic actions required to handle any emergency are as follows:
- Operation of emergency shut-down systems
- Maintenance of communication ECG/ EAG groups as long as possible
- Persons to be nominated to prepare for evacuation
- Liaison with fire-fighting agencies local government/ private agencies required.
- Effective internal communication by public address system and walkie-talkie sets

Communication Link

A multi-user wireless paging system with selective call facility is useful for promptly locating key operating personnel in the plant, both during normal conditions and dur ing emergencies. A public address (PA) system with loud speaker installed at vital installations can be extremely useful during emergencies. Adequacy and efficiency of fire-fighting and fire detection equipments, personal, detective measures and medical aids will be ens ured through proper communication link.

There are various facilities available in the site for communication:

- Intercom facility
- Public addressing system
- Walkie Talkies, Mega phone
- Mobile phone facility at security

7.9.3.3 Before Emergency

- Prepare a plan for installations of storage and process/ operation equipments clearly indicating probable areas of various hazards like fire, explosion, toxic releases etc. Locations of assembly points, fire station, telephone room, first aid or ambulance room, emergency control room, main gate, emergency gates, will be noted in plot plan.
- The fire protection equipment will always be kept in good operating condition and fire- fighting system periodically tested. The training regarding fire-fighting techniques provided to all officers/ employees.
- There will be a regular mock fire drill periodically; record of such drills be maintained. Every employee or authorized person working in the plant be familiarized with the fire alarm signal and know the location of closed by fire alarm point; Assign key personnel and alternate responsible for site safety. In case of toxic liquid/ gas suitable adsorbent and inert material (sand, earth) and water to arrange at site of storage and process/ operation units including absorbents.

7.9.3.4 During Emergency

- In the event of fire from accidental release of flammable gas or liquid, a person seeing the incident will follow the laid down procedure in the plant and report as follows:
  - Will dial the nearest telephone
  - Will state his name and exact location of emergency
  - Will contact affected officers on duty and will remain at the location of site to guide crew
  - Perform no other duties that may interfere with their primary responsibilities
- Notify the attendant if they experience any warning signs or symptoms of exposures or dangerous condition and exit the permit space when instructed by attendant
- In case fire emergency, person activate the nearest available push button type instrument which will automatically sound an alarm in fire control room indicating the location of fire
- In case of toxic liquid drum leak/ rupture, immediately isolated and control not to spread and border the liquid with inert material (earth, sand if any non-reactive). Control leak if possible. However it depends on material to material as per MSDS sheet.
- Adsorbed material depose environmental friendly not to contaminant water and soil. And toxic flooded with water also controlled, and neutralised if necessary.

7.9.3.5 After Emergency

- Report injuries or blood/ body fluid exposures to the appropriate supervisor, immediately wash wounds and skin sites by soap and water. Provide information to the relevant public authority and community including other closely located facilities regarding the nature of hazard and emergency procedure in event of major accident. Record and discuss the lessons learned and the analysis of major accident.

7.9.4 Off-site Emergency Preparedness Program

Emergency is a sudden unexpected event, which can cause serious damage to personnel life, property and environment as a whole, which necessitate delineating Off-site emergency plan to combat any such eventuality. In Off-site disaster management plan, many agencies like Revenue, Public Health, Fire Services, Police, Civil Defence, Home Guards, Medical Services and other Voluntary organization are involved. Thus, handling of such emergencies requires an organized multidisciplinary approach.

Evacuation of people, if required, can be done in orderly way. The different agencies involved in evacuation of people are civil administration, non Govt. organizations, factory Inspectorate including mutual aid partners of industrial unit and Police authorities.

In the present case off-site emergency is mainly occurs fire explosion, fire ball and toxic dispersion causes people in and outside of plant exposed to heat radiation, shock waves and toxic vapour/ gas. Organisation chart of typical Off-site emergency plan is shown in **Fig. 7.4.**

Fire: Effects of fire on population will be mainly due to thermal radiation. In such cases, houses situated to the proximity of disaster need to be evacuated, although a severe smoke hazard due to fire is to be reviewed periodically**.**

Explosion: An explosion will give a very little time to warn population and areas affected may be much longer than that in case of fire. The effects of explosion on population will be mainly due to shock waves, flying splinters, collapse of structures and simultaneously exposure to thermal radiation.

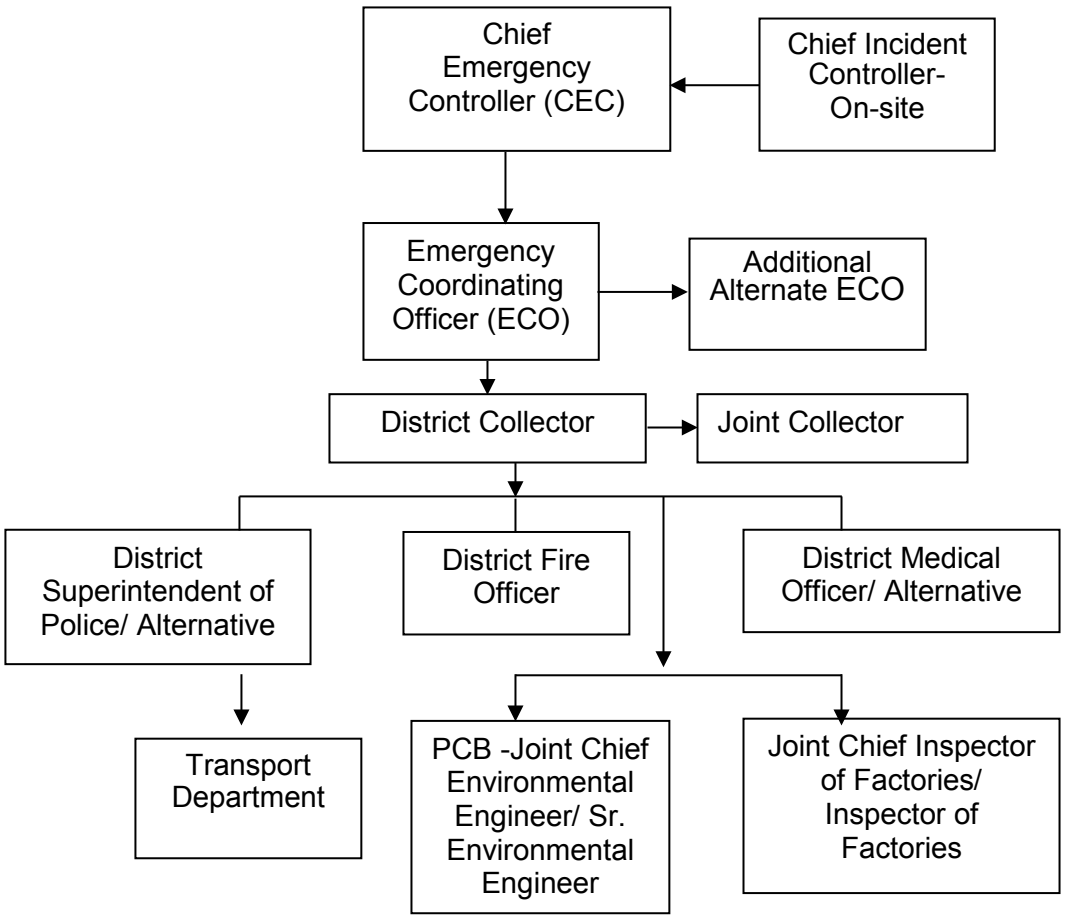


Fig. 7.4: Organization chart: Off - Site Emergency Preparedness Plan

Toxic: Toxic dispersion will effect at down distance of industrial unit, for the same people evacuated within 15–30 minutes being , people may expose to IDLH level of identified toxic gases, by giving necessary warnings and move towards crosswind side, for the same evacuation needed.

7.9.4.1 Purpose of Plan

- To save lives and injuries and to prevent or reduce property losses and to provide for quick resumption of normal situation or operation
- To make explicit inter related set of actions to be undertaken, being event of an industrial accident posing hazards to the community
- To inform people and surrounding about type of emergency and disaster if it is likely to adversely affect and to guide the people in proper way.
- To rescue and recuperation of injuries and plan for relief and rehabilitation
- To plan for prevention of harms, total loss and recurrence of disaster and It will be ensured that absolute safety and security is achieved within the shortest time

7.9.4.2 Before Emergency

Safety procedure followed before during an em ergency through posters, talks and mass media in different languages including local language. Leaflets containing dos/ don'ts before and during emergency be c irculated to educate the people in vicinity and provide information about hazardous installation, who are potentially affected in the event of an accident, be aw are of the risks of accidents. Explain concerning the installation, and understand what to do in the event of an accident. Non-governmental Organizations (NGO's) (Such as environmental, humanitarian and consumer group) motivate their constituents and others, to be involved in risk reduction and accident prevention efforts and provide technical assistance to help the public analyse and understand information that is made available.

Public authorities(at all levels) and management of hazardous installation established emergency planning activities/ program's for accidents, In this respect public health authorities, including experts from research organisation be involved in relevant aspects of off-site emergency planning.

Emergency warning alert system is in place to warn the potentially affected public and about an imminent threat of an accident. The system chosen be effective and provide timely warning. Suitable warning system includes e.g. sirens, automatic telephone message, and mobile public address system.

7.9.4.3 During Emergency

As the off-site plan is to be prepared by industrial unit by involving the government and other agencies of control committee will be formed under the chairmanship of area head the group includes officers from local units, police, fire, medical, engineering, social welfare, publicity, transport and requisite departments will be incorporated as members. Some experts will also be included for guidance.

The functions of committee will be:

- To work as main co-coordinating body constituted of necessary district heads and other authorities with overall command, coordination, guidance, supervision, policy and doing all necessary things to control disaster in shortest times
- To take advice and assistance from experts in fields to make plan more successful
- To prepare, review, to keep it document with all details
- The incident control committee, traffic control committee and pr ess publicity committee will first be informed
- **Hospital Committee** consisted of doctors for medical help to the injured persons because of disaster. Injuries are of many types. As such doctors are rarely available we have to mobilize and utilize all available doctors in the area.

- Functions and duties of the committee include:
- On receiving information to rush to spot he will immediately inform his team and will proceed with all necessary equipments to give medical help to all injured as early as possible. First aid and possible treatment will be provided at the spot or at some convenient place and patients are requested to shift to hospitals for further treatment. Continuity of the treatment will be maintained till the disaster is controlled.
- **Traffic Control and Law & Order:** Functions and duties of this committee will be:

- To control traffic towards and near disaster to maintain law and order
- To evacuate the places badly affected or likely to be affected
- To shift the evacuated people to safe assembly points and rehabilitate them after disaster is over.

However necessary vehicles, wireless sets and instruments for quick communications will be maintained and used as per requirement.

7.9.4.4 After emergency

Functions and duties of emergency (ECG/EAG) committee are:

- To find out persons in need of human help owing to disastrous effect. They may give first aid if medical team is not available
- They will serve the evacuated people kept at assembly points. They will arrange for their food, water, shelter, clothing, sanitation and guidelines to reach any needful places
- They will look for removal and disposal of dead bodies if any and for help of sick, weak, children and needy persons for their essential requirements
- The team will also work for restoration of detached people, lost articles, essential commodities etc.
- The team will also look after the restoration of government articles
- The team will also ensure that the original activities, services and systems are resumed again as they were functioning before the disaster

Police Department

- The police will assist in controlling of the accident site, organizing evacuation and removing of any seriously injured people to hospitals.
- Co-ordination with the transport authorities, civil defence and home guards
- Arrange for post mortem of dead bodies
- Establish communication centre

Fire officer / District or Divisional Fire Officer: The team will organize to put out fires and provide assistance as required.

Hospitals and doctors are ready to treat any injuries. Co-ordination with Primary Health Centres and Municipal Dispensaries ensure required quantities of drugs and equipments**.** Secure assistance of medical and paramedical personnel from nearby hospitals/ medical institutions.

Media: The media should have ready and continuous access to designated officials with relevant information, as well as to other sources in order to provide essential and accurate information to public throughout the emergency and to help avoid confusion.

Efforts should be made to check the clarity and reliability of information as it becomes available, and before it is communicated to public

Public health authorities should be consulted when issuing statements to the media concerning health aspects of chemical accidents.

Members of the media should facilitate response efforts by providing means for informing the public with credible information about accidents involving hazardous substances.

Non-governmental organizations (NGOs): NGOs could provide a valuable source of expertise and information to support emergency response efforts. Members of NGOs could assist response personnel by performing specified tasks, as planned in the emergency planning process. Such tasks could include providing humanitarian, psychological and social assistance to members of community and response person.

Duties of NGO are listed below:

- Evacuation of personnel from the affected area
- Arrangements at rallying posts and parking yards
- Rehabilitation of evacuated persons
- Co-ordination with other agencies such as police, medical, agriculture, electricity board, fire services, home guards and civil defence.
- Establishing shelters for rescue, medical, fire-fighting personnel.

7.10 Conclusion & Recommendations

- Fire/ Explosion is considered as considerable accident scenario in M/s Bhagyanagar Chlorides being several IB flammable solvents (Acetone, Acetic anhydride, Ethylene dichloride, IPA, Methanol and Toluene) has a provision of maximum of 10/ 20 KL capacity and are considered as highly flammable and are stored in tank form Area.

- Solvents being stored in tank form area with respective dykes, leak and release of material causing pool fire if spark or ignition take place, it indicates heat radiation affects few meters from edge of pool and needs of on-site emergency plan.
- In case of Fire/ explosion due to delayed ignition/ spark after vapour cloud formation causes effect of heat radiation and pressure wave crosses the industry boundary and need an off-site emergency preparedness plan and the plan also required in case of BLEVE causing fire ball.
- Specific measures to be taken to avoid or minimise accident. At storage yard fixed and movable fire-fighting system should be provided to control vapour cloud formation in case of leak/ discharge as well as to minimise exposes to external heat by storage tanks.
- Proponent is also planning to store several flammable liquid in drums in ware houses. In case of leak or rupture of drums forms unconfined pool, if ignited vapour cloud causes severe heat radiation and explosion effect on respective ware house area.
- Spill contaminant pallets/ adsorbent to be used effectively to minimise the spill over of material and control leak effectively and contaminated material disposed environmental friendly.
- Proponent is going to use several toxic liquid/gases i.e. Acetyl chloride, Chlorine, Benzyl chloride, Benzo Trichloride, Thionyl chloride, Phosphorous oxychloride and Chloroacetyl chloride including chloro acetic acid, acetic acid and Sulfuric acid. MCA analysis indicates that there is a possibility of IDLH level exposure within and outside the plant area at downwind direction.
- Specific remedial measures to be adopted to minimise the leak and control at source and simultaneously off-site emergency plan may be initiated including evacuation plan followed by medical aid with need of hour.
- In the case of leak and direct release of liquid, corresponding vapours dispersed towards downwind side of plant area even more than 1.0 km crossing plant boundary and exposed to IDLH level.
- Steps should be taken to control at source to minimise spill of chemical and spread to unconfined area by bordering inert material adsorbent, control the leak if possible. In case of uncontrolled situation delineate emergency plan including evacuation of possible exposures.
- Proponent is also using and also proposed to use more Chlorine cylinders and has a provision to store maximum of 132 cylinders, hence specific precautionary measures are suggested. Also there is a provision to store highly flammable

hydrogen gas cylinder and for the same specific measures suggested and may be taken especially during handling.

- Presence of other hazard storages and handling as per on-site plan necessary, except in few occasions of total discharge of material, however time to time emergency plan may be upgraded as and when needed as per regulations.

Safety (MSDS) data for 1,4-dioxane

General

Synonyms: dioxane, diethylene dioxide, 1,4-diethylene dioxide, diethylene ether, glycol ethylene ether, dioxane-1,4, tetrahydro-p-dioxin
Molecular formula: $C_4H_8O_2$
CAS No: 123-91-1
EINECS No: 204-661-8

Physical data

Appearance: colourless liquid
Melting point: 11.8 C
Boiling point: 100 - 120 C
Vapour density: 3
Vapour pressure: 27 mm Hg at 20 C
Density (g cm^{-3}): 1.034
Flash point: 12 C
Explosion limits: 2% - 22%
Autoignition temperature: 180 C

Stability

Stable. Incompatible with oxidizing agents, oxygen, halogens, reducing agents, moisture. **Highly flammable - note wide explosive range. May form explosive peroxides in storage** (rate of formation increased by heating, evaporation or exposure to light).

Toxicology

Probable carcinogen. Toxic. Harmful by inhalation, ingestion and through skin contact. Irritant.

oxicity data

(The meaning of any abbreviations which appear in this section is given Annexure -)
IHL-HMN LCLO 470 ppm/3d.
ORL-RAT LD50 7120 mg/kg.
IPR-MUS LD50 790 mg/kg.
ORL-CAT LD50 2000 mg kg^{-1}
ORL-RBT LD50 2000 mg kg^{-1}

Risk phrases

(The meaning of any risk phrases which appear in this section is given Annexure -)
R11 R19 R20 R21 R22 R36 R37 R40.

Transport information

(The meaning of any UN hazard codes which appear in this section is given Annexure)
UN Major hazard class: 3.0. Packing group: II. UN No 1165. EMS No 3.0-06.

Personal protection

Safety glasses, gloves, good ventilation. Treat as a carcinogen.

Safety phrases

(The meaning of any safety phrases which appear in this section is given Annexure -)

Safety (MSDS) data for Acetic acid

General

Synonyms: ethanoic acid, vinegar (a dilute solution of acetic acid - for safety data on vinegar, glacial acetic acid, ethylic acid, methanecarboxylic acid, vinegar acid
Molecular formula: $C_2H_4O_2$
CAS No: 64-19-7
EC No: 200-580-7

Physical data

Melting point: 16.7 C
Boiling point: 118 C
Specific gravity: 1.05
Vapour density 2.07
Vapour pressure 11 mm Hg at 20 C, 20 mm Hg at 30 C
Flash point: 40 C
Explosion limits: 4% - 16%
Ignition temperature 426 C

Stability

Stable. Substances to be avoided include alcohols, aldehydes, halogen-halogen compounds, oxidizing agents, metals, alkali hydroxides, anhydrides, nonmetallic halides, permanganates, peroxides, ethanolamine, carbonates. Flammable.

Toxicology

This material is strongly corrosive and causes serious burns. Very harmful if swallowed. Lachrymator.

Toxicity data

(The meaning of any abbreviations which appear in this section is given ANNEXURE.)
ORL-RAT LD50 3310 mg kg^{-1}
UNR-MAN LDLO 308 mg kg^{-1}
IHL-MUS LC50 5620 ppm/1h

Irritation data

(The meaning of any abbreviations which appear in this section is given here.)
SKN-HMN 50 mg/24h/mld
SKN-RBT open/sev
EYE-RBT open/sev

Risk phrases

(The meaning of any risk phrases which appear in this section is given ANNEXURE.)
R10 R20 R21 R22 R35.

Personal protection

Safety glasses or face mask, nitrile gloves, good ventilation.

Safety phrases

(The meaning of any safety phrases which appear in this section is given ANNEXURE.)
S23 S26 S45.

Safety (MSDS) data for Acetic anhydride

General

Synonyms: acetic acid anhydride, acetic oxide, ethanoic anhydride
Molecular formula: $(CH_3CO)_2O$
CAS No: 108-24-7
EC No:

Physical data

Appearance: colourless liquid smelling of ethanoic acid
Melting point: -73 C
Boiling point: 139 C
Vapour density: 3.5 (air = 1)
Vapour pressure: 4 mm Hg at 20 C
Density (g cm^{-3}):
Flash point: 54 C
Explosion limits:
Autoignition temperature: 2.7 - 10.1%
Water solubility: appreciable

Stability

Combustible. Incompatible with strong oxidizing agents, water, strong bases, alcohols.

Toxicology

Posion. Corrosive. Causes severe burns. Harmful if swallowed or inhaled. Causes severe respiratory irritation. Eye contact may cause serious irritation or burns. Typical TLV/TWA 5 ppm. Typical PEL 5 ppm.

Toxicity data

(The meaning of any abbreviations which appear in this section is given Annexure .)
ORL-RAT LD50 1780 mg kg^{-1}
SKN-RBT LD50 4000 mg kg^{-1}

Risk phrases

(The meaning of any risk phrases which appear in this section is given Annexure.)
R20 R22 R35 R37 R41.

Personal protection

Safety glasses, good ventilation.

Safety phrases

(The meaning of any safety phrases which appear in this section is given Annexure .)

Safety (MSDS) data for Acetone

General :

Synonyms: dimethyl ketone, methyl ketone, 2-propanone, acetone, dimethylketal, pyroacetic acid
Molecular formula: $(CH_3)_2CO$
CAS No: 67-64-1 EC No: 200-662-2

Physical data :

Appearance: colourless liquid with a fragrant, sweet odour
Melting point: -95 C
Boiling point: 56 C
Vapour density: 2.0
Vapour pressure: 181 mm Hg at 20 C
Specific gravity: 0.79
Flash point: -18 C
Explosion limits: 2.6% - 13.0%
Autoignition temperature: 538 C

Stability :

Stable. Incompatible with halogen acids and halogen compounds, strong bases, strong oxidizing agents, caustics, amines and ammonia, chlorine and chlorine compounds, strong acids, nitrosyl compounds. **Highly flammable. Readily forms explosive mixtures with air.**

Toxicology

Harmful by inhalation, ingestion or skin absorption. Irritant. Liquid may cause permanent eye damage (corneal clouding). Contact with skin may cause defatting, leading to irritation. Long-term exposure may cause liver damage. Typical TLV 750 ppm.

Ecological information

Biological degradability: good. Aquatic toxicity: low. Bioaccumulation potential: low. Fish toxicity LC50 (*L. macrochirus*) 8300 mg/l/96h.

Personal protection

Safety glasses. Effective ventilation. Remove sources of ignition from the working area. Nitrile gloves.

Safety data for acetyl chloride

General

Synonyms: acetic chloride, ethanoyl chloride, acetic acid chloride
Molecular formula: CH_3COCl
CAS No: 75-36-5
EINECS No: 200-865-6
Annex I Index No: 607-011-00-5

Physical data

Appearance: colourless to light yellow liquid with a pungent and choking odour
Melting point: -112 C
Boiling point: 51 C
Vapour density: 2.7
Vapour pressure: 315 mbar at 20 C
Density (g cm^{-3}): 1.104
Flash point: 4 C (closed cup)
Explosion limits: 7.3% - 19%
Autoignition temperature: 390 C
Water solubility: decomposes

Stability

Highly flammable. Reacts violently with DMSO, water, lower alcohols, and amines to generate toxic fumes. May form an explosive mixture with air. Note low flash point. Incompatible with water, alcohols, amines, strong bases, strong oxidizing agents, most common metals.

Toxicology

Corrosive - causes severe burns. Harmful if inhaled or swallowed, and in contact with skin. Contact with water generates phosgene - very toxic! May cause permanent eye damage if splashed in the eyes. Ingestion may cause serious burns to mouth and stomach.

Toxicity data

(The meaning of any abbreviations which appear in this section is given here.)
ORL-RAT LD50 910 mg kg^{-1}

Irritation data

(The meaning of any abbreviations which appear in this section is given here.)
IHL-HMN TCLO 1 ppm/1m

Risk phrases

(The meaning of any risk phrases which appear in this section is given here.)
R11 R14 R34. (Annex I does not give hazard codes R20 R21 and R22 but these should be assumed in handling this material.)

Transport information

(The meaning of any UN hazard codes which appear in this section is given here.)
UN No 1717. Major hazard class 3. Subsidiary risk 8. Packing group II.

Personal protection

Safety glasses, gloves, good ventilation. Remove sources of ignition.

Safety phrases

(The meaning of any safety phrases which appear in this section is given here.)
S9 S16 S26 S45.

Safety (MSDS) data for Aluminium Chloride, Anhydrous

General

Synonyms: aluminium chloride, aluminium trichloride, aluminum chloride, aluminum chloride anhydrous, trichloroaluminium, trichloroaluminum
Molecular formula: $AlCl_3$
CAS No: 7446-70-0
EC No: 231-208-1

Physical data

Appearance: yellow to grey solid
Melting point: ca. 190 C (sublimes)
Boiling point:
Vapour density: 4.5 (air = 1)
Vapour pressure: 1.3 mbar at 100 C
Specific gravity: 2.44
Flash point:
Explosion limits:
Autoignition temperature:

Stability

Stable, but reacts violently with water. Prolonged storage may lead to pressure build-up - vent container periodically. Incompatible with alcohols and a variety of other materials (see complete MSDS sheet for full list).

Toxicology

Corrosive - causes burns. Extremely destructive of mucous membranes. May cause allergic reactions. Harmful if swallowed or inhaled and in contact with the skin.

Toxicity data

(The meaning of any abbreviations which appear in this section is given Annexure .)
ORL-RAT LD50 3450 mg kg^{-1}
ORL-MUS LD50 1130 mg kg^{-1}
SKN-RBT LD50 > 2000 mg kg^{-1}

Risk phrases

(The meaning of any risk phrases which appear in this section is given Annexure)
R14 R20 R21 R22 R34.

Personal protection

Safety glasses, rubber gloves. Adequate ventilation.

Safety phrases

(The meaning of any safety phrases which appear in this section is given Annexure)
S7 S8 S28 S45.

Safety (MSDS) data for ammonia (anhydrous)

General Note: This data sheet is for anhydrous ammonia, in other words, ammonia gas. If you want data for ammonium hydroxide (commonly called "ammonia solution"), click on this link.
Synonyms: ammonia gas, nitro-sil, ammonia, R 717, spirit of hartshorn, STCC 4904210, OHS01050
Molecular formula: NH_3
CAS No: 7664-41-7
EC No: 231-635-3

Physical data

Appearance: colourless gas with a penetrating, suffocating odour
Melting point: -77.7 C
Boiling point: -33.3 C
Vapour density: 0.89 g/l
Vapour pressure: 0.597
Specific gravity: 0.77
Flash point: 11
Explosion limits: 16% - 25%
Autoignition temperature:
Water solubility: High

Stability

Stable. Hygroscopic. Flammable. Incompatible with acids, strong oxidizing agents. **May react violently with acids, aldehydes, alkylene oxides, amides, boron, boron halides, calcium, chlorine azide, chloric acid, chlorine monoxide, chlorites, halogens, heavy metals and many other materials - check the complete data sheet before use!**

Toxicology

Toxic by inhalation or skin contact **- may be fatal if inhaled. 500 ppm is immediately dangerous to life or health.** Corrosive - may cause serious burns. **This material is extremely harmful to the eyes.** Respiratory irritant. Typical OEL 25 ppm. ATSDR Minimal risk levels: Inhalation acute 0.5 ppm, chronic 0.3 ppm, oral 0.3mg/kg/day.

Toxicity data

(The meaning of any toxicological abbreviations which appear in this section is given here.)
IHL-HMN TCLO 5000 ppm/5m
IHL-RAT LC50 1000 ppm/4h
IHL-MUS LC50 4230 ppm/1h

Risk phrases

(The meaning of any risk phrases which appear in this section is given here.)
R10 R23.

Personal protection

Safety glasses and gloves. Good ventilation.
[Return to Physical & Theoretical Chemistry Lab. Safety home page.]

Safety (MSDS) data for ammonium hydroxide

General
Synonyms: ammonia solution (typically contains between 12% and 44% ammonia before dilution), dilute ammonia, concentrated ammonia. [Data for ammonia gas, NH_3, is available Annexure.]
Molecular formula: NH_4OH
CAS No: 1336-21-6
EC No: 215-647-6
Physical data
Appearance: colourless liquid
Melting point:
Boiling point:
Vapour density: 1.2
Vapour pressure: 115 mm at 20 C (depends on solution strength)
Specific gravity: typically 0.9 (depends on solution strength)
Flash point: none
Explosion limits: 16 - 27%
Autoignition temperature: 651 C
Stability
Stable. Incompatible with copper, copper alloys, acids, galvanised iron, zinc, aluminium, bronze, dimethyl sulphate, mercury, alkali metals..
Toxicology
Concentrated solution is extremely damaging to eyes. Even contact with dilute ammonia solution can lead to serious eye damage. Harmful if swallowed or inhaled and in contact with skin. Very destructive of mucous membranes. Corrosive - causes burns. Typical TLV 25 ppm. Typical STEL 35 ppm. Typical PEL 50 ppm.
Toxicity data
(The meaning of any toxicological abbreviations which appear in this section is given Annexure .)
ORL-RAT LD50 350 mg kg^{-1}
Risk phrases
(The meaning of any risk phrases which appear in this section is given Annexure .)
R34 R37.
Personal protection
Good quality safety glasses with side protection against splashes. Good ventilation. Do not work in the open laboratory with concentrated ammonium hydroxide solution.
Safety phrases
(The meaning of any safety phrases which appear in this section is given Annexure .)
S7 S26 S45.

Safety data for Chlorine

General

Synonyms: bertholite, molecular chlorine
Molecular formula: Cl_2
CAS No: 7782-50-5
EC No: 231-959-5

Physical data

Appearance: light greenish-yellow gas with an irritating odour
Melting point: -101 C
Boiling point: -34 C
Vapour density: 2.98 g/l
Vapour pressure: 5.8 bar at 20 C
Specific gravity: 1.47 g/ml at 0C
Critical temperature: 144 C
Flash point:
Explosion limits:
Autoignition temperature: n/a

Stability

Stable. Incompatible with reducing agents, alcohols.

Toxicology

Toxic by inhalation, ingestion and through skin contact. Inhalation can cause serious lung damage and may be fatal. 1000ppm (0.1%) is likely to be fatal after a few deep breaths, and half that concentration fatal after a few minutes. May irritate or burn skin. OEL (8hr TWA) 1 ppm.

Toxicity data

(The meaning of any abbreviations which appear in this section is given Annexure)
IHL-HMN LCLO 2530 mg/m3/30m
IHL-HMN LCLO 500 ppm/5m
IHL-RAT LC50 293 ppm/1h
IHL-MUS LC50 137 ppm/1h

Risk phrases

(The meaning of any risk phrases which appear in this section is given Annexure)
R23 R36 R37 R38 R50.

Transport information

(The meaning of any UN hazard codes which appear in this section is given Annexure)
Un No 1017. Hazard class 8.0. Transport category 1.

Environmental information

Very toxic to aquatic organisms.

Personal protection

Safety glasses, gloves and good ventilation.

Safety phrases

(The meaning of any safety phrases which appear in this section is given Annexure)
S7 S9 S44 S45 S61.

Safety (MSDS) data for Chloroacetyl chloride

General

Synonyms: monochloroacetyl chloride, chloracetic chloride
Molecular formula: $C_2H_2Cl_2O$
CAS No: 79-04-9
EC No: 201-171-6

Physical data

Appearance: colourless liquid with a pungent odour
Melting point: -22 C
Boiling point: 105 - 106 C
Vapour density: 3.9
Vapour pressure:
Specific gravity: 1.418
Flash point: 41 C at 60 mm Hg
Explosion limits:
Autoignition temperature:

Stability

Stable. Incompatible with strong bases, alcohols, strong oxidizing agents. May decompose on exposure to water or moisture.

Toxicology

Harmful by inhalation, ingestion or through skin absorption. Corrosive - causes burns. Very destructive of mucous membranes. Lachrymator. Inhalation may result in spasm. Typical OEL 0.2 mg/m3.

Toxicity data

(The meaning of any toxicological abbreviations which appear in this section is given Annexure)
ORL-RAT LD50 208 mg kg^{-1}
IHL-RAT LC50 1000 ppm/4h.
IVN-MUS LD50 32 mg kg^{-1}

Risk phrases

(The meaning of any risk phrases which appear in this section is given Annexure)
R20 R21 R22 R34 R37.

Transport information

(The meaning of any UN hazard codes which appear in this section is given Annexure)
UN Major hazard class: 6.1 Packing group: I

Personal protection

Safety glasses, gloves, adequate ventilation.

Safety phrases

(The meaning of any safety phrases which appear in this section is given Annexure)
S9 S26 S45.

Safety (MSDS) data for Diethylamine

General

Synonyms: diethamine, N-ethylethanamine, DEN, N,N-diethylamine, N-ethylethanamine
Molecular formula: $C_4H_{11}N$ Structural: $(C_2H_5)_2NH$
CAS No: 109-89-7
EC No: 203-716-3

Physical data

Appearance: liquid
Melting point: -50 C
Boiling point: 56.3 C
Vapour density: 2.53
Vapour pressure: 195 mm Hg at 20 C
Specific gravity: 0.7074
Flash point: -39 C
Explosion limits: 1.8% - 10.1 %
Autoignition temperature: 313 C
Critical pressure: 37.1 atm
Critical temperature: 223 C

Stability

Stable. **Highly flammable.** Incompatible with strong oxidizing agents.

Toxicology

Corrosive - causes burns. Skin and eye irritant. Severe respiratory tract irritant. Harmful by inhalation, ingestion or skin absorption. May act as a sensitizer. Lachrymator. Typical TLV 10 ppm. Odour detection limit 0.13 ppm.

Toxicity data

(The meaning of any abbreviations which appear in this section is given Annexure .)
ORL-RAT LD50 540 mg kg^{-1}
IHL-RAT LC50 4000 ppm/4h
ORL-MUS LD50 500 mg kg^{-1}

Risk phrases

(The meaning of any risk phrases which appear in this section is given Annexure .)
R11 R20 R21 R22 R35.

Transport information

(The meaning of any UN hazard codes which appear in this section is given Annexure
UN No 1154. Packing group II. Major hazard class 3.0.

Personal protection

Safety glasses. Effective ventilation. Remove sources of ignition from the working area.

Safety phrases

(The meaning of any safety phrases which appear in this section is given Annexure .)
S16 S26 S29 S36 S37 S39 S45.

Safety (MSDS) data for Dimethyl Sulfate

General

Synonyms: dimethyl sulphate, sulphuric acid dimethyl ester, sulfuric acid dimethyl ester, dimethylsulfate, dimethyl monosulfate

Use:

Molecular formula: $C_2H_6SO_4$

CAS No: 77-78-1

EINECS No: 201-058-1

EC Index No: 016-023-00-4

Physical data

Appearance: colourless liquid

Melting point: -32 C

Boiling point: 188 C

Vapour density: 4.3

Vapour pressure: 0.7 mm Hg at 25 °C

Density (g cm^{-3}):

Flash point: 182 F

Explosion limits:

Autoignition temperature:

Water solubility:

Stability

Stable; combustible. Incompatible with strong oxidizing agents, strong bases including ammonia. Moisture-sensitive.

Toxicology

Very toxic, and may be fatal, if inhaled. Toxic if swallowed. Lachrymator. May act as a human carcinogen. Readily absorbed through the skin. Very destructive of mucous membranes. May act as a sensitizer. May cause reproductive damage.

Toxicity data

(The meaning of any toxicological abbreviations which appear in this section is given Annexure)

IHL-HMN LCLO 97 ppm/10m

ORL-RAT LD50 205 mg kg^{-1}

IHL-RAT LC50 45 mg/m3/4h

SCU-RAT LD50 100 mg kg^{-1}

Risk phrases

(The meaning of any risk phrases which appear in this section is given Annexure)

R25 R26 R34 R43 R45.

Transport information

(The meaning of any UN hazard codes which appear in this section is given Annexure)

Personal protection

Handle as a possible carcinogen. Safety glasses, rubber gloves, good ventilation.

Safety phrases

(The meaning of any safety phrases which appear in this section is given Annexure)

Safety (MSDS) data for Ethylene Dichloride

General

Synonyms: 1,2-bichloroethane, dichloroethylene, ethylene chloride, ethane dichloride, ethylene dichloride, 1,2-ethylene dichloride, glycol dichloride, EDC, NCI-C00511, sym-dichloroethane, alpha, beta-dichloroethane, borer sol, brocide, destruxol, dichloremulsion, dutch oil, di-chlor-mulsion, dutch liquid, freon 150, NU-G00511
Molecular formula: $C_2H_4Cl_2$
CAS No: 107-06-2
EC No: 203-458-1
EC Index No 602-012-00-7

Physical data

Appearance: colourless liquid
Melting point: -35 C
Boiling point: 83 C
Specific gravity: 1.256
Vapour pressure: 387 mm Hg at 25 C
Vapour density: 3.4 (air = 1)
Flash point: 15 C
Explosion limits: 6.2% - 15.6%
Autoignition temperature: 775 F
Water solubility: slight

Stability

Stable. Substances to be avoided include oxidising agents, strong alkalies, strong caustics, magnesium, sodium, potassium, active amines, ammonia, iron, zinc, nitric acid and aluminium. Air and light sensitive. Highly flammable.

Toxicology

Probable human carcinogen. Causes liver damage. Mutagen, toxic. Experimental transplacental carcinogen. May cause systemic effects. Narcotic. Regarded as a priority pollutant in many countries. Skin irritant. A long-term MEL of 20 mg per cubic metre (8-hour TWA reference period) applies to this chemical in the UK.

Toxicity data

(The meaning of any abbreviations which appear in this section is given Annexure- .)
ORL-RAT LD50 670 mg kg^{-1}
SKN-RBT LD50 2800 mg kg^{-1}
IHL-RAT LD50 1000 ppm/7h

Risk phrases

(The meaning of any risk phrases which appear in this section is given Annexure- .)
R11 R22 R36 R37 R38 R45.

Personal protection

Safety glasses. Good ventilation. Use precautions appropriate to a carcinogen.

Safety phrases

(The meaning of any safety phrases which appear in this section is given Annexure- .)
S45 S53.

Safety (MSDS) data for Hydrochloric acid (concentrated)

General

Synonyms: muriatic acid, chlorohydric acid. [Data for dilute Hydrochloric acid can be found Annexure .]
Molecular formula: HCl
CAS No: 7647-01-0
EC No: 231-595-7
Annex I Index No: 017-002-01-X

Physical data

Appearance: clear colourless or slightly yellow liquid with pungent odour. Concentrated acid is fuming.
Melting point: -25 C
Boiling point: 109 C
Specific gravity: 1.19
Vapour pressure:
Flash point:
Explosion limits:
Autoignition temperature:

Stability

Stable. Avoid heat, flames. Incompatible with most common metals, amines, metal oxides, acetic anhydride, propiolactone, vinyl acetate, mercuric sulphate, calcium phosphide, formaldehyde, alkalies, carbonates, strong bases, sulphuric acid, chlorosulphonic acid.

Toxicology

Extremely corrosive. Inhalation of vapour can cause serious injury. Ingestion may be fatal. Liquid can cause severe damage to skin and eyes. TLV 5 ppm.

Toxicity data

(The meaning of any abbreviations which appear in this section is given Annexure .)
ORL-RBT LD50 900 mg kg^{-1}
IPR-MUS LD50 40 mg kg^{-1}
IHL-RAT LC50 3124 ppm/1h.
IHL-HMN LCLO 1300 ppm 30min

Risk phrases

(The meaning of any risk phrases which appear in this section is given Annexure .)
R23 R24 R25 R34 R36 R37 R38. Transport information (The meaning of any UN hazard codes which appear in this section is given Annexure .) UN No 1789. Packing group II. Major hazard class 8.0. Transport category 2.

Environmental information

Lethal to fish from 25 mg/l up. Toxic for aquatic organisms due to pH shift.

Personal protection

Safety glasses or face mask, gloves. Effective ventilation.

Safety phrases

(The meaning of any safety phrases which appear in this section is given Annexure .)
S26 S36 S37 S39 S45.

Safety (MSDS) data for hydrogen peroxide, 50% solution

General

Synonyms: albone 30, albone 35, albone 50, albone 70, albone 35cg, albone 50cg, albone 70cg, interox, kastone, perone 30, perone 35, perone 50. Data also applies to solutions of similar strength.
Note: Typical concentrations lie in the range 3%-35%. Solutions of much higher concentration (e.g. 60% and above) present significantly increased risks, and should not be used unless such strength is absolutely essential.
Molecular formula: H_2 O_2
CAS No: 7722-84-1
EC No: 231-765-0

Physical data

Appearance: colourless liquid
Melting point: ca. -28 C
Boiling point: ca. 114 C
Specific gravity: typically near 1.19
Vapour pressure: 23.3 at 30 C
Flash point:
Explosion limits:
Autoignition temperature:

Stability

Unstable - readily decomposes to water and oxygen. Light sensitive. May develop pressure in the bottle - take care when opening. Forms potentially explosive compounds with ketones, ethers, alcohols, hydrazine, glycerine, aniline, sodium borate, urea, sodium carbonate, triethylamine, sodium fluoride, sodium pyrophosphate and carboxylic acid anhydrides. Materials to avoid include combustibles, strong reducing agents, most common metals, organic materials, metallic salts, alkali, porous materials, especially wood, asbestos, soil, rust, strong oxidizing agents.

Toxicology

Toxic. Corrosive - can causes serious burns. Eye contact can cause serious injury, possibly blindness. Harmful by inhalation, ingestion and skin contact. Typical OEL 1 ppm.

Transport information

(The meaning of any UN hazard codes which appear in this section is given ANNEXURE- .) UN Major hazard class 5.1. Packing group II. UN No 2014. EMS No 5.1-02.

Personal protection

Safety glasses are essential; acid-resistant gloves are suggested. Suitable ventilation.

Safety phrases

(The meaning of any safety phrases which appear in this section is given ANNEXURE- .)
S3 S28 S37 S39 S45

Safety (MSDS) data for Hydrogen

General

Synonyms:
Molecular formula: H_2
CAS No: 1333-74-0
EINECS No: 215-605-7

Physical data

Appearance: colourless gas
Melting point: -259 C
Boiling point: -253 C
Critical temperature -240 C
Vapour density: 0.07 (air = 1)
Vapour pressure: (n/a at 20 C)
Density (g cm^{-3}):
Flash point:
Flammability range in air: 4 - 75%
Autoignition temperature: 560 C

Stability

Stable. Highly flammable. Readily forms explosive mixtures with air. Upper (U.K.) composition limit for use of a nitrogen/hydrogen mixture in the open lab is 5.7% hydrogen.

Toxicology

Generally considered as safe, apart from the physical risks which arise from flammability. [Safety note: Annexure- are reputed to have been cases in which, as part of a chemistry show, hydrogen has been inhaled instead of helium in a demonstration of the "Mickey Mouse voice" effect. Inhalation of hydrogen is a dangerous practice in view of the possibility of explosive reaction of the hydrogen-air mixture either outside or within the body, caused by static electricity discharge. Reports of accidents during the inhalation of hydrogen may be cases of "urban myths", but tAnnexure-XI is clear potential for a serious or fatal accident, and hydrogen should not be used for this. Note also that some sources of helium, which is more commonly associated with the "Mickey Mouse voice" demonstration, may contain small amounts of arsenic, a serious poison.]

Risk phrases

(The meaning of any risk phrases which appear in this section is given Annexure-.) R12.

Transport information

Personal protection

Safety glasses; maintain good ventilation at all times.

Safety phrases

(The meaning of any safety phrases which appear in this section is given Annexure- .)
S9 S16 S33.

Safety (MSDS) data for 2-propanol

General

Synonyms: 2-hydroxypropane, isopropanol, isopropyl alcohol, iso-propanol, iso-propyl alcohol, IPA, sec-propanol, sec-propyl alcohol, dimethylcarbinol, propan-2-ol, avantin, avantine, combi-schutz, rubbing alcohol, spectrar, sterisol, takineocol, virahol
Molecular formula: $CH_3CHOHCH_3$
CAS No: 67-63-0
EC No: 200-661-7
Annex I Index No: 603-117-00-0

Physical data

Appearance: colourless liquid with slight alcohol odour
Melting point: -89 C
Boiling point: 82 C
Vapour density: 2.1
Vapour pressure: 33 mm at 20 C
Specific gravity: 0.79
Flash point: 12 C
Explosion limits: 2.0 % - 12 %
Autoignition temperature: 425 C

Stability

Stable. Incompatible with strong acids, strong oxidizing agents, halogens, aluminium, active halogen compounds. Regulated in UK under Highly Flammable Liquids and Liquefied Petroleum Gases Regulations 1972. Highly flammable. Vapour-air mixtures may be explosive.

Toxicology

May be harmful by inhalation, ingestion or skin absorption. May act as an irritant. UK OES Long-term 980 mg/m3.

Transport information

(The meaning of any UN hazard codes which appear in this section is given here.)
UN No 1219. Hazard class 3. Packing group II.

Personal protection

Safety glasses. Effective ventilation.

Safety (MSDS) data for Hexane

General

Synonyms: n-hexane, normal hexane, hexyl hydride
Molecular formula: C_6H_{14}
CAS No: 110-54-3
EC No: 203-777-6
EC Index No: 601-037-00-0

Physical data

Appearance: colourless liquid
Melting point: -95 C
Boiling point: 69 C
Vapour density: 3 (air = 1)
Vapour pressure: 132 mm Hg at 20 C
Specific gravity: 0.659
Flash point: -10 F
Explosion limits: 1.2% - 7.7%
Autoignition temperature: 453 F

Stability

Stable. Incompatible with oxidising agents, chlorine, fluorine, magnesium perchlorate. Highly flammable. Readily forms explosive mixtures with air. Note low flash point.

Toxicology

May cause impaired fertility. Harmful by inhalation, ingestion or skin absorption. Irritant. May cause CNS depression. Prolonged exposure may cause serious health damage.

Toxicity data

(The meaning of any abbreviations which appear in this section is given Annexure .)
ORL-RAT LD50 28700 mg kg^{-1}
IHL-RAT LC50 48000 ppm/4h

Risk phrases

(The meaning of any risk phrases which appear in this section is given Annexure .)
R11 R20 R21 R22 R36 R37 R38 R48 R62.

Personal protection

Safety glasses. Effective ventilation. Remove sources of ignition from the working area.

Safety phrases

(The meaning of any safety phrases which appear in this section is given Annexure .)
S16 S36 S37 S39 S45 S53.

Safety (MSDS) data for Phosphorus Oxychloride

General

Synonyms: phosphoryl trichloride, trichlorophosphine oxide, phosphorus oxytrichloride, phosphoryl chloride
Molecular formula: $POCl_3$
CAS No: 10025-87-3
EINECS No: 233-046-7

Physical data

Appearance: colourless liquid
Melting point: 1.25 C
Boiling point: 105.8 C
Vapour density: 5.3 (air = 1)
Vapour pressure: 28 mm Hg at 20 C
Density (g cm^{-3}): 1.645
Flash point:
Explosion limits:
Autoignition temperature:
Water solubility:

Stability

Stable. **Reacts violently with water.** Incompatible with many metals, alcohols, amines, phenol, DMSO, strong bases.

Toxicology

May be fatal if inhaled, swallowed or absorbed through the skin. May cause serious and permanent eye damage, including blindness. Causes burns; very destructive of mucous membranes. Corrosive. Lachrymator. If inhaled may cause delayed lung injury. Typical STEL 0.5 ppm.

Toxicity data

(The meaning of any toxicological abbreviations which appear in this section is given ANNEXURE-XI.)
ORL-RAT LD50 36 mg kg^{-1}
IHL-RAT LC50 32 ppm/4h
IHL-GPG LC50 53 ppm/4h

Risk phrases

R23 R24 R25 R34 R37 R41.

Transport information

Personal protection

Safety glasses, gloves, good ventilation.

Safety phrases

(The meaning of any safety phrases which appear in this section is given ANNEXURE XI.)
S7 S8 S26 S45.

Safety (MSDS) data for Sulfuric acid (concentrated)

General

Synonyms: oil of vitriol, mattling acid, vitriol, battery acid, dipping acid, electrolyte acid, vitriol brown oil, sulphuric acid
Molecular formula: H_2SO_4
CAS No: 7664-93-9
EC No: 231-639-5
EC index No: 016-020-00-8

Physical data

Appearance: Colourless oily liquid
Melting point: -2 C
Boiling point: 327 C
Specific gravity: 1.84
Vapour pressure: <0.3 mm Hg at 20 C (vapour density 3.4)
Flash point:
Explosion limits:
Autoignition temperature:
Water solubility: miscible in all proportions

Stability

Stable, but reacts with moisture very exothermically, which may enhance its ability to act as an oxidizing agent. Substances to be avoided include water, most common metals, organic materials, strong reducing agents, combustible materials, bases, oxidising agents. Reacts violently with water - when diluting concentrated acid, carefully and slowly add acid to water, not the reverse. Reaction with many metals is rapid or violent, and generates hydrogen (flammable, explosion hazard).

Toxicology

Extremely corrosive, causes serious burns. Highly toxic. Harmful by inhalation, ingestion and through skin contact. Ingestion may be fatal. Skin contact can lead to extensive and severe burns. Chronic exposure may result in lung damage and possibly cancer.

Toxicity data

(The meaning of any abbreviations which appear in this section is given ANNEXURE .)
IHL-RAT LC50 0.51 mg/l
UNR-MAN LDLO 135 mg kg^{-1}
ORL-RAT LD50 2140 mg kg^{-1} (25% solution)
IHL-MUS LC50 320 mg m^{-3} / 2h
IHL-GPG LC50 18 mg m^{-3}

Risk phrases

(The meaning of any risk phrases which appear in this section is given ANNEXURE .)
R35 R36 R37 R38 R49.

Transport information

(The meaning of any UN hazard codes which appear in this section is given ANNEXURE .)
UN No 1830. IMDG class 8. Packing group II. IATA 1830. UK transport category 2.

Personal protection

Safety glasses or face mask; acid-resistant gloves. Suitable ventilation. In the UK use of this material must be assessed under the COSHH regulations.

Safety phrases

(The meaning of any safety phrases which appear in this section is given ANNEXURE .)
S23 S30 S36 S37 S39 S45.

Safety (MSDS) data for Thionyl chloride

General

Synonyms: sulfur chloride oxide, sulfurous oxychloride, sulfinyl chloride, sulfurous dichloride, thionyl dichloride
Molecular formula: $SOCl_2$
CAS No: 7719-09-7
EINECS No: 231-748-8
EU number 016-015-00-0

Physical data

Appearance: colourless, pale yellow or reddish liquid with a suffocating odour
Melting point: -104 C
Boiling point: 76 C
Vapour density: 4.6 (air = 1)
Vapour pressure: 97 mm Hg at 20 C
Density (g cm^{-3}): 1.64
Water solubility: decomposes

Stability

Reacts violently with water. Incompatible with most common metals, strong reducing agents, strong bases, alcohols, amines.

Toxicology

Poison. May be fatal if inhaled. Causes severe burns. May cause serious eye damage. Typical TLV 1 ppm STEL.

Toxicity data

(The meaning of any abbreviations which appear in this section is given ANNEXURE.)
IHL-RAT LD50 500 ppm/1h

Risk phrases

(The meaning of any risk phrases which appear in this section is given ANNEXURE)
R14 R20 R22 R29 R34 R35 R37.

Personal protection

Safety glasses, gloves, good ventilation.

Safety phrases

(The meaning of any safety phrases which appear in this section is given ANNEXURE)
S26 S36 S37 S39 S45.

Safety (MSDS) data for Toluene

General

Synonyms: methylbenzene, phenylmethane, toluol, antisal 1A, CP 25, methacide, methylbenzol, NCI-C07272, RCRA waste number U220, tolu-sol
Uses: Solvent
Molecular formula: C_7H_8
CAS No: 108-88-3
EC No: 203-625-9
Annex I Index No: 601-021-00-3

Physical data

Appearance: Colourless liquid with a benzene-like odour (odour threshold 0.17 ppm)
Melting point: -93 C
Boiling point: 110.6 C
Specific gravity: 0.865
Vapour pressure: 22 mm Hg at 20 C (vapour density 3.2)
Flash point: 4 C
Explosion limits: 1% - 7%
Autoignition temperature: 536 C

Stability

Stable. Substances to be avoided: oxidising agents, oxygen, moisture. Highly flammable. Hygroscopic.

Toxicology

Toxic by inhalation, ingestion or by absorption through skin. Serious irritant. Experimental teratogen.

Toxicity data

(The meaning of any abbreviations which appear in this section is given ANNEXURE- **)**
ORL-RAT LD50 636 mg kg^{-1}
IPR-RAT LD50 1332 mg kg^{-1}
ORL-HMN LDLO 50 mg kg^{-1}
IPR-MUS LD50 59 mg kg^{-1}
IHL-MAM LC50 30 g m^{-3}

Irritation data

(The meaning of any abbreviations which appear in this section is given ANNEXURE- **)**
EYE-HMN 300 ppm.
SKN-RBT 435 mg mild.

Risk phrases

(The meaning of any risk phrases which appear in this section is given ANNEXURE-) **R11 R20**

Personal protection

Safety glasses. Good ventilation.

Safety phrases

(The meaning of any safety phrases which appear in this section is given ANNEXURE-)
S16 S25 S29 S33.

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: 63.5° C
Vapor Pressure at Ambient Temperature: 0.17 atm
Ambient Saturation Concentration: 173,122 ppm or 17.3%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)

Wind: 2 meters/second from 120° true at 3 meters
Ground Roughness: open country Cloud Cover: 5 tenths
Air Temperature: 25° C
Stability Class: D (user override)
No Inversion Height Relative Humidity: 50%

1. SOURCE STRENGTH:

Burning Puddle / Pool Fire
Puddle Area: 16 square meters Puddle Volume: 20 cubic meters
Initial Puddle Temperature: Air temperature
Flame Length: 4 meters
Burn Duration: ALOHA limited the duration to 1 hour
Burn Rate: 15.9 kilograms/min
Total Amount Burned: 956 kilograms

THREAT ZONE:

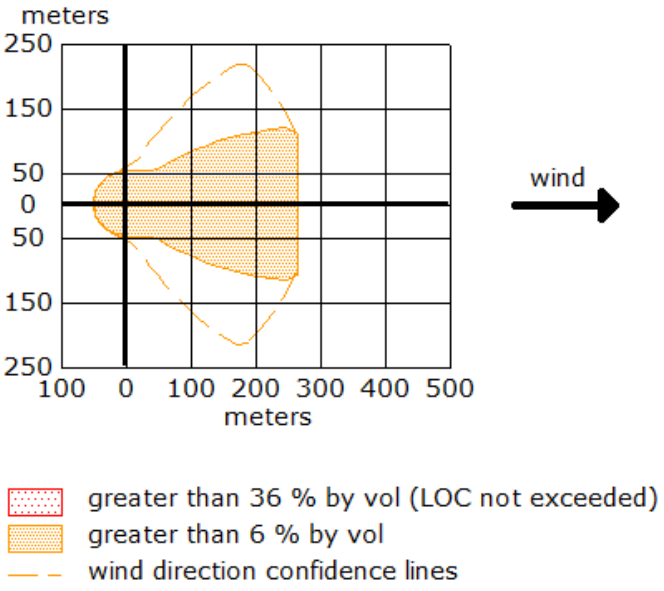
Threat Modeled: Thermal radiation from pool fire
Red : less than 10 meters(10.9 yards) --- (37.5 kW/(sq m))
Orange: less than 10 meters(10.9 yards) --- (12.5 kW/(sq m))
Yellow: less than 10 meters(10.9 yards) --- (4.5 kW/(sq m))

2.SOURCE STRENGTH:

Direct Source: 20 cubic meters Source Height: 0
Source State: Liquid
Source Temperature: equal to ambient
Release Duration: 1 minute
Release Rate: 263 kilograms/sec
Total Amount Released: 15,792 kilograms

THREAT ZONE:

Threat Modeled: Flammable Area of Vapor Cloud
Model Run: Heavy Gas
Red : LOC was never exceeded --- (36 % by vol)
Orange: 264 meters --- (6 % by vol)

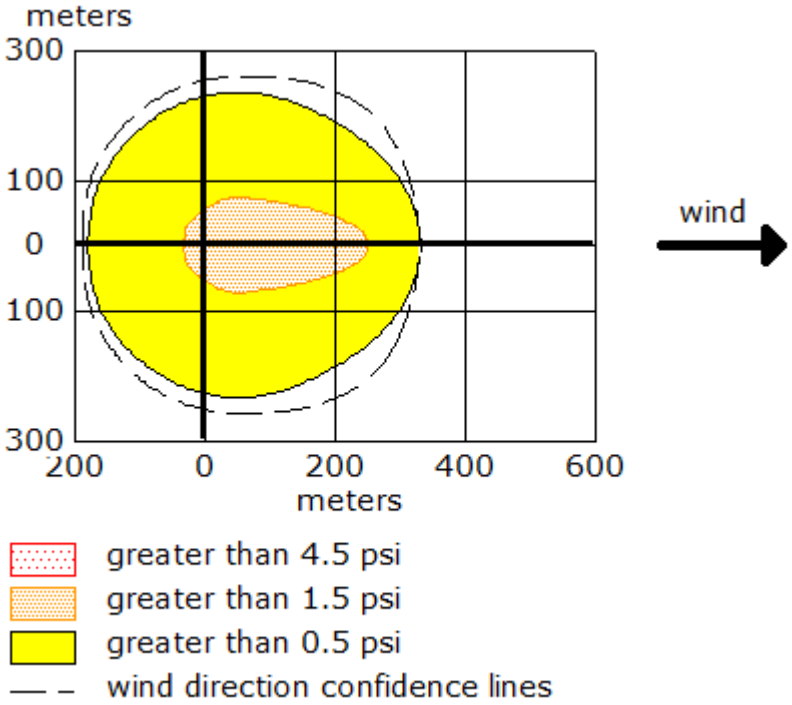


3.SOURCE STRENGTH:

Direct Source: 20 cubic meters Source Height: 0
Source State: Liquid
Source Temperature: equal to ambient
Release Duration: 1 minute
Release Rate: 263 kilograms/sec
Total Amount Released: 15,792 kilograms

THREAT ZONE:

Threat Modeled: 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 --- (4.5 psi)
Orange: 253 meters --- (1.5 psi)
Yellow: 334 meters --- (0.5 psi)

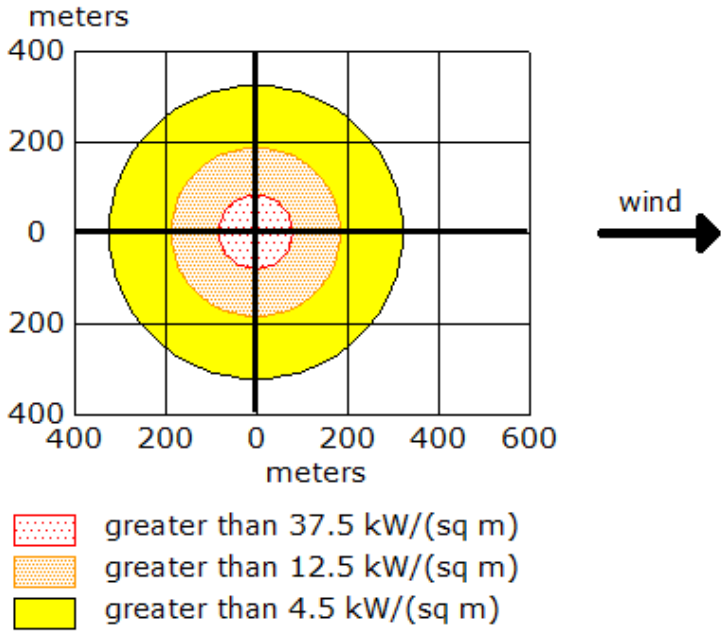


4. SOURCE STRENGTH:

BLEVE of flammable liquid in horizontal cylindrical tank
Tank Diameter: 2 meters Tank Length: 6.37 meters
Tank Volume: 20 cubic meters
Tank contains liquid
Internal Storage Temperature: 25° C
Chemical Mass in Tank: 17.4 tons Tank is 100% full
Percentage of Tank Mass in Fireball: 100%
Fireball Diameter: 145 meters Burn Duration: 10 seconds

THREAT ZONE:

Threat Modeled: Thermal radiation from fireball
Red : 81 meters --- (37.5 kW/(sq m))
Orange: 186 meters --- (12.5 kW/(sq m))
Yellow: 322 meters --- (4.5 kW/(sq m))



5.SOURCE STRENGTH:

Leak from hole in horizontal cylindrical tank
Flammable chemical is burning as it escapes from tank
Tank Diameter: 2.0 meters Tank Length: 6.37 meters
Tank Volume: 20 cubic meters
Tank contains liquid Internal Temperature: 25° C
Chemical Mass in Tank: 17.4 tons Tank is 100% full
Circular Opening Diameter: 3 inches
Opening is 4 inches from tank bottom
Max Flame Length: 4 meters
Burn Duration: ALOHA limited the duration to 1 hour
Max Burn Rate: 15.9 kilograms/min
Total Amount Burned: 955 kilograms
Note: The chemical escaped as a liquid and formed a burning puddle.
The puddle spread to a diameter of 4.5 meters.

THREAT ZONE:

Threat Modeled: Thermal radiation from pool fire
Red : less than 10 meters(10.9 yards) --- (37.5 kW/(sq m))
Orange: less than 10 meters(10.9 yards) --- (12.5 kW/(sq m))
Yellow: less than 10 meters(10.9 yards) --- (4.5 kW/(sq m))

ANNEXURE -II

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: 109.2° C
Vapor Pressure at Ambient Temperature: 0.038 atm
Ambient Saturation Concentration: 39,139 ppm or 3.91%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)

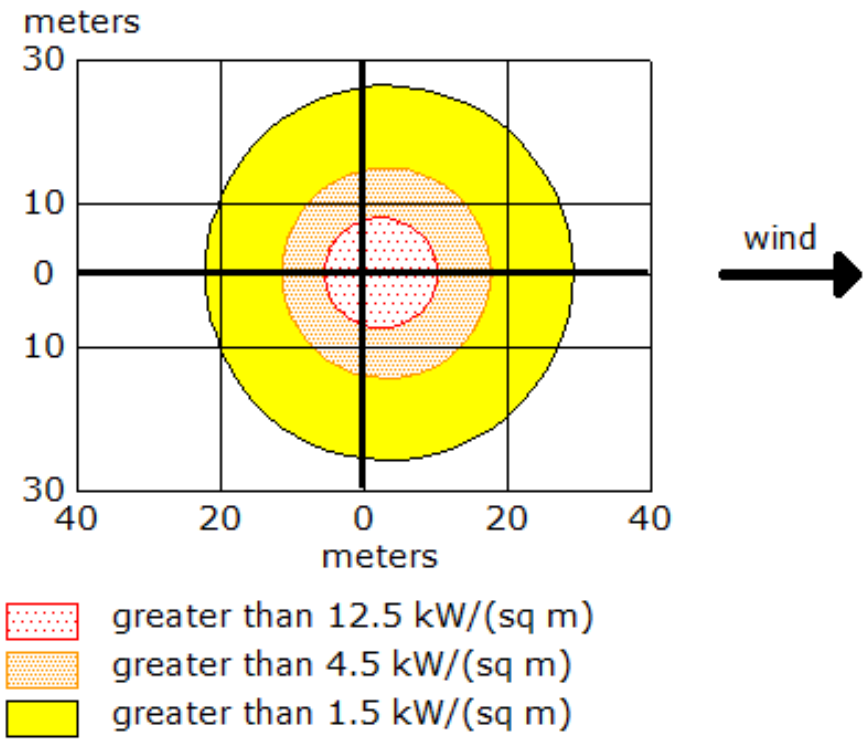
Wind: 2 meters/second from 120° true at 3 meters
Ground Roughness: open country Cloud Cover: 5 tenths
Air Temperature: 25° C
Stability Class: D (user override)
No Inversion Height Relative Humidity: 50%

1. SOURCE STRENGTH:

Burning Puddle / Pool Fire
Puddle Area: 16 square meters Puddle Volume: 20 cubic meters
Initial Puddle Temperature: Air temperature
Flame Length: 11 meters
Burn Duration: ALOHA limited the duration to 1 hour
Burn Rate: 77 kilograms/min
Total Amount Burned: 4,621 kilograms

THREAT ZONE:

Threat Modeled: Thermal radiation from pool fire
Red : 10 meters --- (12.5 kW/(sq m))
Orange: 18 meters --- (4.5 kW/(sq m))
Yellow: 29 meters --- (1.5 kW/(sq m))

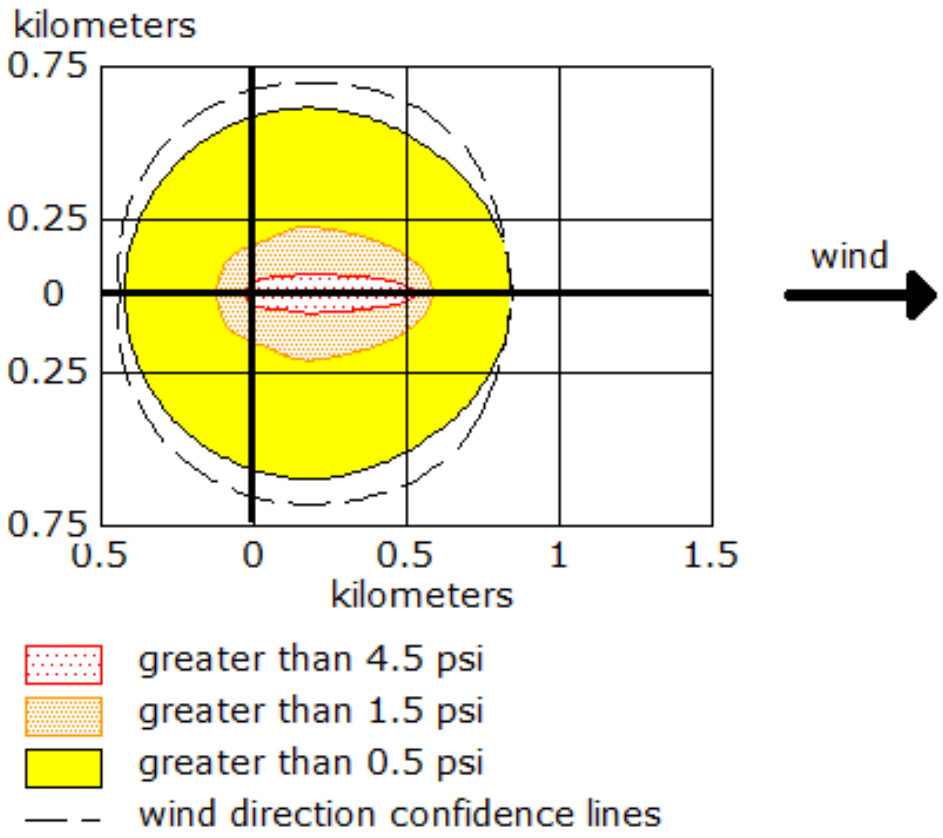


2.SOURCE STRENGTH:

Direct Source: 20 cubic meters Source Height: 0
Source State: Liquid
Source Temperature: equal to ambient
Release Duration: 1 minute
Release Rate: 288 kilograms/sec
Total Amount Released: 17,278 kilograms

THREAT ZONE:

Threat Modeled: Overpressure (blast force) from vapor cloud explosion
Type of Ignition: ignited by spark or flame
Level of Congestion: congested
Model Run: Heavy Gas
Red : 529 meters --- (4.5 psi)
Orange: 585 meters --- (1.5 psi)
Yellow: 849 meters --- (0.5 psi)

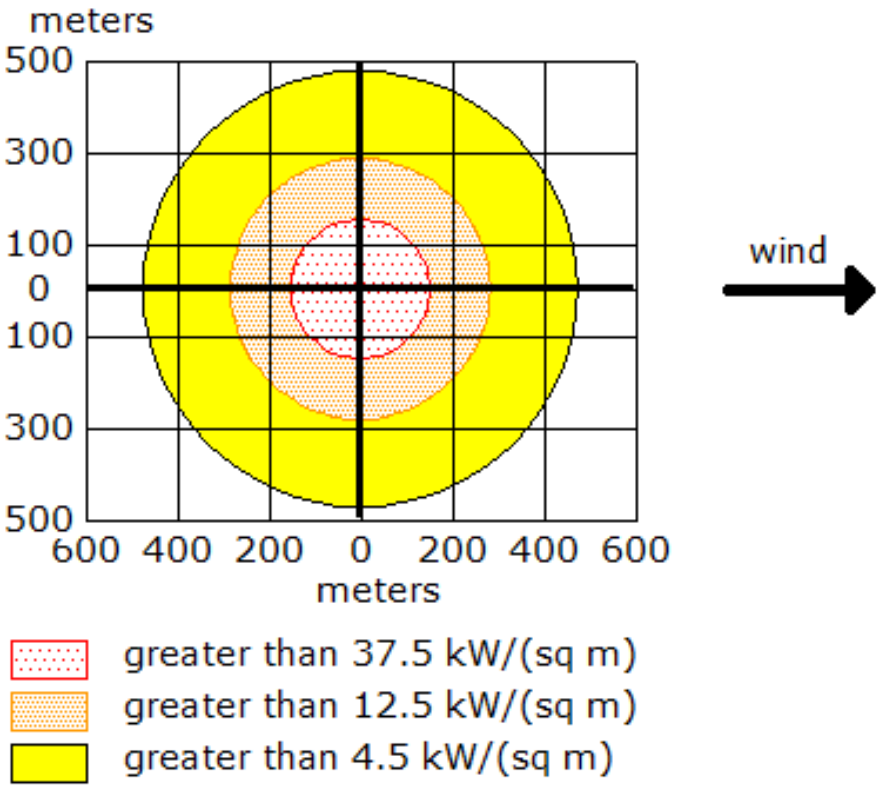


3.SOURCE STRENGTH:

BLEVE of flammable liquid in horizontal cylindrical tank
Tank Diameter: 2 meters Tank Length: 6.37 meters
Tank Volume: 20 cubic meters
Tank contains liquid
Internal Storage Temperature: 25° C
Chemical Mass in Tank: 19.0 tons Tank is 100% full
Percentage of Tank Mass in Fireball: 100%
Fireball Diameter: 150 meters Burn Duration: 10 seconds

THREAT ZONE:

Threat Modeled: Thermal radiation from fireball
Red : 151 meters --- (37.5 kW/(sq m))
Orange: 282 meters --- (12.5 kW/(sq m))
Yellow: 472 meters --- (4.5 kW/(sq m))

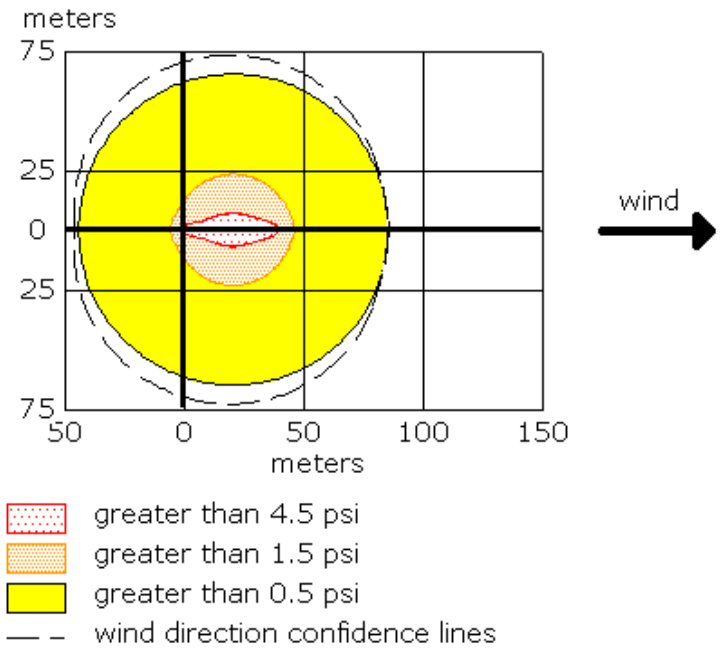


Chemical Name: N-HEXANE Molecular Weight: 86.18 g/mol
AEGL-1 (60 min): N/A AEGL-2 (60 min): 2900 ppm AEGL-3 (60 min): 8600 ppm
IDLH: 1100 ppm LEL: 12000 ppm UEL: 72000 ppm
Ambient Boiling Point: 68.0° C
Vapor Pressure at Ambient Temperature: 0.20 atm
Ambient Saturation Concentration: 204,820 ppm or 20.5%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
Wind: 2.6 meters/second from 120° true at 3 meters
Ground Roughness: open country Cloud Cover: 5 tenths
Air Temperature: 25° C Stability Class: C
No Inversion Height Relative Humidity: 50%

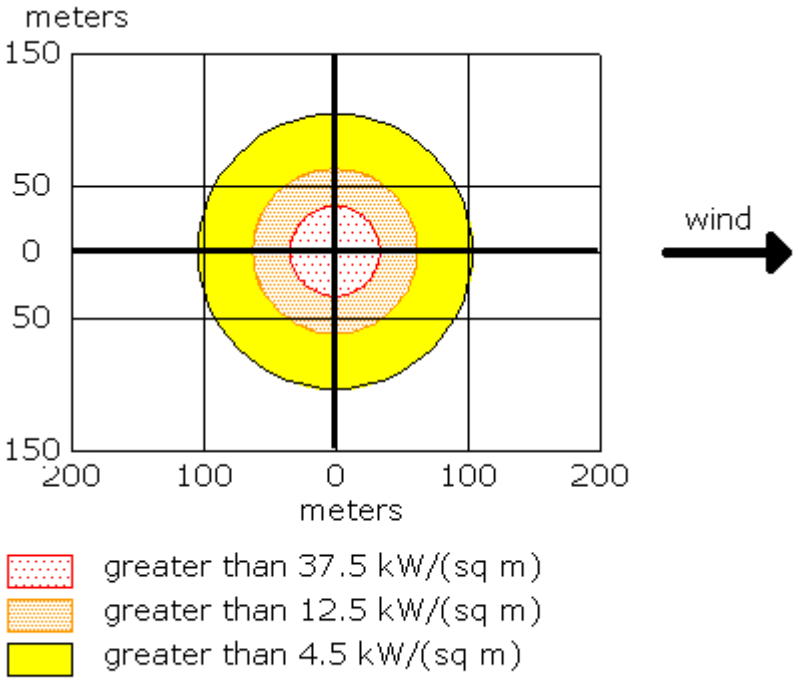
SOURCE STRENGTH:
Direct Source: 200 liters Source Height: 0
Source State: Liquid
Source Temperature: equal to ambient
Release Duration: 1 minute
Release Rate: 2.19 kilograms/sec
Total Amount Released: 131 kilograms

THREAT ZONE: (GAUSSIAN SELECTED)
Threat Modeled: Overpressure (blast force) from vapor cloud explosion
Type of Ignition: ignited by spark or flame
Level of Congestion: congested
Model Run: Gaussian
Red : 39 meters --- (4.5 psi)
Orange: 46 meters --- (1.5 psi)
Yellow: 86 meters --- (0.5 psi)



SOURCE STRENGTH:
BLEVE of flammable liquid in vertical cylindrical tank
Tank Diameter: 0.45 meters Tank Length: 1.35 meters
Tank Volume: 215 liters
Tank contains liquid
Internal Storage Temperature: 25° C
Chemical Mass in Tank: 0.14 tons Tank is 93% full
Percentage of Tank Mass in Fireball: 100%
Fireball Diameter: 29 meters Burn Duration: 3 seconds

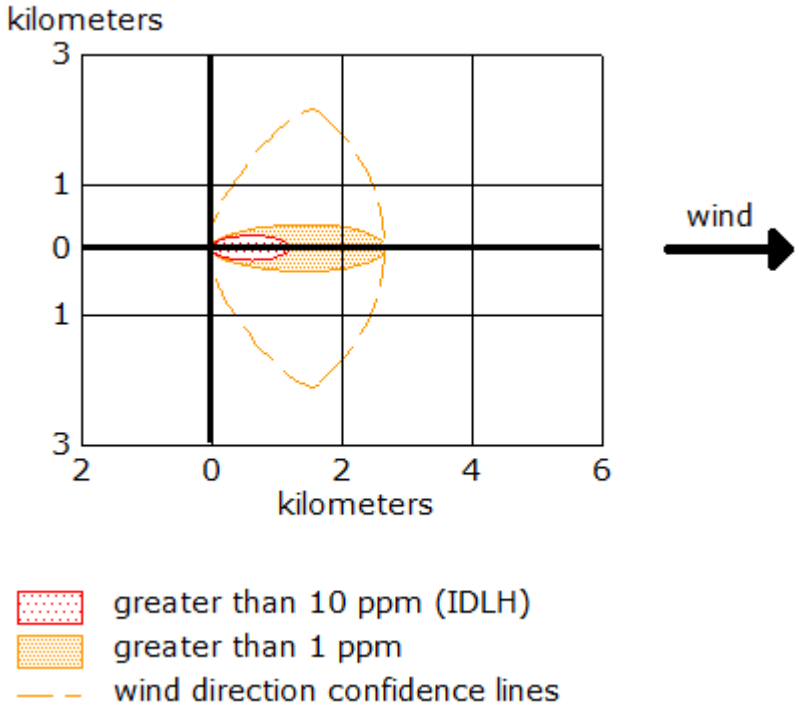
THREAT ZONE:
Threat Modeled: Thermal radiation from fireball
Red : 34 meters --- (37.5 kW/(sq m))
Orange: 62 meters --- (12.5 kW/(sq m))
Yellow: 104 meters --- (4.5 kW/(sq m))



CHEMICAL DATA:
Chemical Name: BENZYL CHLORIDE
CAS Number: 100-44-7 Molecular Weight: 126.58 g/mol
ERPG-1: 1 ppm ERPG-2: 10 ppm ERPG-3: 50 ppm
IDLH: 10 ppm LEL: 11000 ppm UEL: 71000 ppm
Carcinogenic risk - see CAMEO Chemicals
Ambient Boiling Point: 179.4° C
Vapor Pressure at Ambient Temperature: 0.0017 atm
Ambient Saturation Concentration: 1,737 ppm or 0.17%

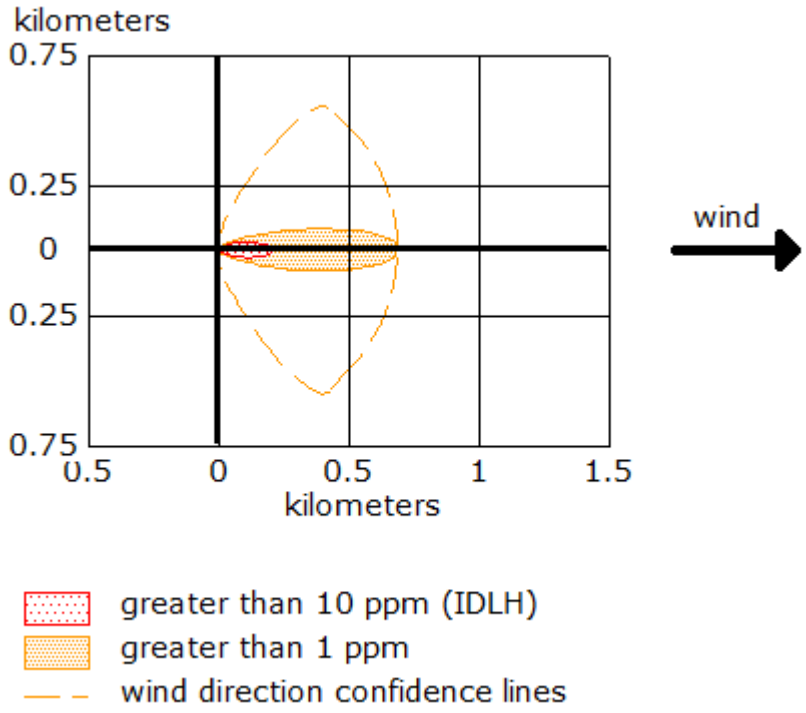
ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
Wind: 2 meters/second from 120° true at 3 meters
Ground Roughness: open country Cloud Cover: 5 tenths
Air Temperature: 25° C
Stability Class: B (user override)
No Inversion Height Relative Humidity: 50%

SOURCE STRENGTH:
Direct Source: 200 liters Source Height: 0
Source State: Liquid
Source Temperature: equal to ambient
Release Duration: 1 minute
Release Rate: 3.66 kilograms/sec
Total Amount Released: 219 kilograms



SOURCE STRENGTH:
Direct Source: 200 liters/hr Source Height: 0
Source State: Liquid
Source Temperature: equal to ambient
Release Duration: 60 minutes
Release Rate: 3.66 kilograms/min
Total Amount Released: 219 kilograms

THREAT ZONE:
Model Run: Heavy Gas
Red : 208 meters --- (10 ppm = IDLH)
Orange: 695 meters --- (1 ppm)

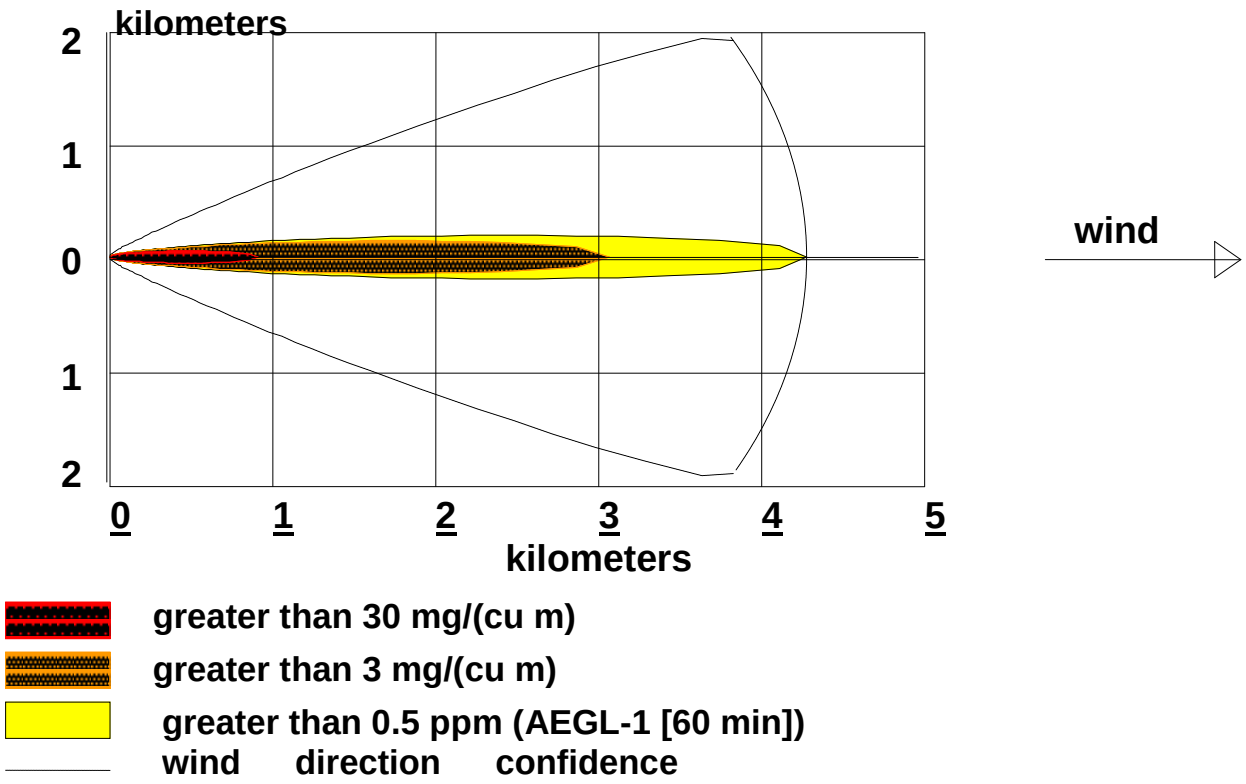


Chemical Name: CHLORINE Molecular Weight: 70.91 g/mol
AEGL-1 (60 min): 0.5 ppm AEGL-2 (60 min): 2 ppm AEGL-3 (60 min): 20 ppm
IDLH: 10 ppm
Ambient Boiling Point: -34.9° C
Vapor Pressure at Ambient Temperature: greater than 1 atm
Ambient Saturation Concentration: 1,000,000 ppm or 100.0%
ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
Wind: 2 meters/second from 120° true at 3 meters Ground Roughness: open country
Cloud Cover: 5 tenths
Air Temperature: 30° C
Stability Class: D (user override)
No Inversion Height Relative Humidity: 50%

1.SOURCE STRENGTH:

Direct Source: 0.25 kilograms/sec Source Height: 0
Release Duration: 60 minutes, Release Rate: 15 kilograms/min
Total Amount Released: 900 kilograms
Note: This chemical may flash boil and/or result in two phase flow.

THREAT ZONE:
Model Run: Heavy Gas
Red : 908 meters --- (30 mg/(cu m)), Orange: 3.1 kilometers --- (3 mg/(cu m))
Yellow: 4.3 kilometers --- (0.5 ppm = AEGL-1 [60 min])



2. SOURCE STRENGTH:

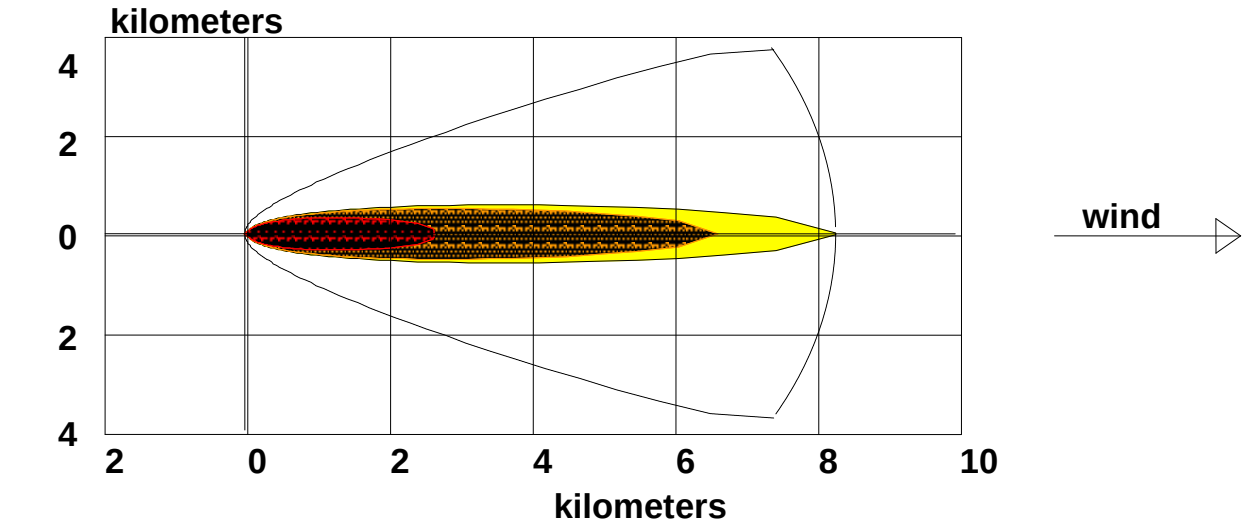
Direct Source: 900 kilograms Source Height: 0

Release Duration: 1 minute

Release Rate: 15 kilograms/sec

Total Amount Released: 900 kilograms

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



THREAT ZONE:

Model Run: Heavy Gas

Red : 2.6 kilometers --- (30 mg/(cu m))

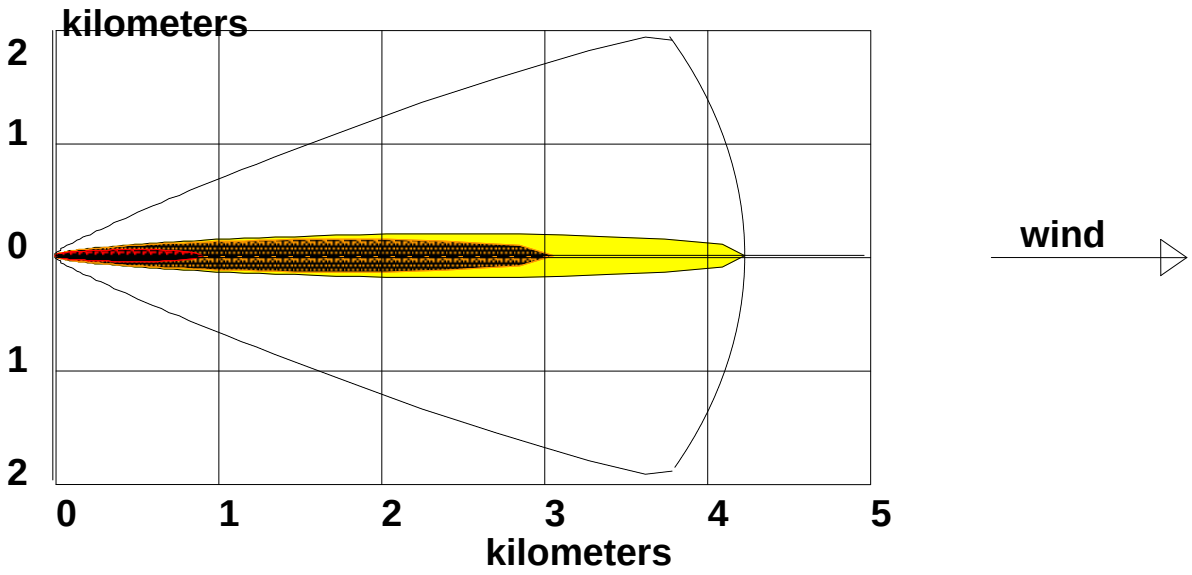
Orange: 6.6 kilometers --- (3 mg/(cu m))

3. SOURCE STRENGTH:

Direct Source: 0.25 kilograms/sec Source Height: 0
Release Duration: 15 minutes
Release Rate: 15 kilograms/min
Total Amount Released: 225 kilograms
Note: This chemical may flash boil and/or result in two phase flow.

THREAT ZONE:

Model Run: Heavy Gas
Red : 908 meters --- (30 mg/(cu m))
Orange: 3.1 kilometers --- (3 mg/(cu m))
Yellow: 4.2 kilometers --- (0.5 ppm = AEGL-1 [60 min])



greater than 30 mg/(cu m)
greater than 3 mg/(cu m)
greater than 0.5 ppm (AEGL-1 [60 min])
wind direction confidence

CHEMICAL DATA:
Chemical Name: SULFURIC ACID Molecular Weight: 82.08 g/mol
PAC-1: 0.0099 mg/(cu m) PAC-2: 0.11 mg/(cu m) PAC-3: 0.66 mg/(cu m)
Normal Boiling Point: -unavail-
Note: Not enough chemical data to use Heavy Gas option

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
Wind: 2.0 meters/second from 120° true at 3 meters
Ground Roughness: open country Cloud Cover: 5 tenths
Air Temperature: 25° C Stability Class: C
No Inversion Height Relative Humidity: 50%

SOURCE STRENGTH:
Direct Source: .0141 kilograms/sec Source Height: 0
Release Duration: 60 minutes
Release Rate: 846 grams/min
Total Amount Released: 50.8 kilograms
THREAT ZONE:
Model Run: Gaussian
Red : 115 meters --- (15 mg/(cu m))
Orange: 458 meters --- (1 mg/(cu m))