7 ADDITIONAL STUDIES – RISK ASSESSMENT AND EMERGENCY RESPONSE PLAN

7.1 PUBLIC CONSULTATION

UPL Unit 2), Plot No # 3405/3406/3460 A is located within Notified GIDC Ankleshwar Industrial Estatein the revenue survey nos.# 122/5/P, 124/3/P, 125/P, 126/P & 182/P of village Gadkhol and revenue survey nos. 161/P, 162/P, 182/P of village Sarangpur within the village limits Sarangpur and Gadkhol Taluka, Ankleshwar, District, Bharuch having area of 6.56 ha (65,625 m^2). The land was allotted to UPL by GIDC Ankleshwar in 1992 i.e., prior to 14th September 2006 i.e., before the EIA Notification 2006 coming into force. The said plot is a part of GIDC Notification dated 1st February 1978 allotted to UPL in 1992.

Therefore, in view of Office Memorandum (OM) vide J-11013/36/2014-IA.II (I) dated 4th April, 2016, para 3, and OM vide J-11011/321/2016-IA.II (I) dated 27th April, 2018, sub para (iii), Public Consultation is not applicable for the proposed Project. Refer to ToR compliance in the beginning of this report (i.e. before *Section 1)* for details.

7.2 RISK ASSESSMENT

This section on Risk Assessment (RA) aims to provide a systematic analysis of the major risks that may arise from the expansion of UPL's proposal on expansion for manufacturing of technical pesticides and intermediate products within UPL's Unit 2 at Plot no 3405/3406/3460A, Notified GIDC Industrial Estate, Ankleshwar-393002, Bharuch District, Gujarat, India.

The RA process outlines rational evaluations of the identified risks based on their significance and provides the outline for appropriate preventive and risk mitigation measures. The output of the RA will contribute towards strengthening of the Emergency Response Plan (ERP) in order to prevent damage to personnel, infrastructure and receptors in the immediate vicinity of the plant. Additionally, the results of the RA can also provide valuable inputs for keeping risk at As Low As Reasonably Practicable (ALARP) and arriving at decisions for mitigation of high risk events.

The following section describes the objectives, methodology of the risk assessment study and assessment for each of the potential risk separately. This includes identification of major hazards, hazard screening and ranking, frequency and consequence analysis for major hazards. The hazards have been quantitatively evaluated through a criteria base risk evaluation matrix. Risk mitigation measures to reduce significant risks to acceptable levels have also been recommended as a part of the risk assessment study.

7.3 *RA STUDY OBJECTIVE*

The overall objective of this RA with respect to the proposed project involves identification and evaluation of major risks, prioritizing risks identified based on their hazard consequences and using the outcome to guide and strengthen both onsite and offsite ERP. Hence in order to ensure effective management of any emergency situations that may arise from failure of isolated storages of flammable and toxic chemical storages with respect to the proposed expansion operations, the following specific objectives need to be achieved.

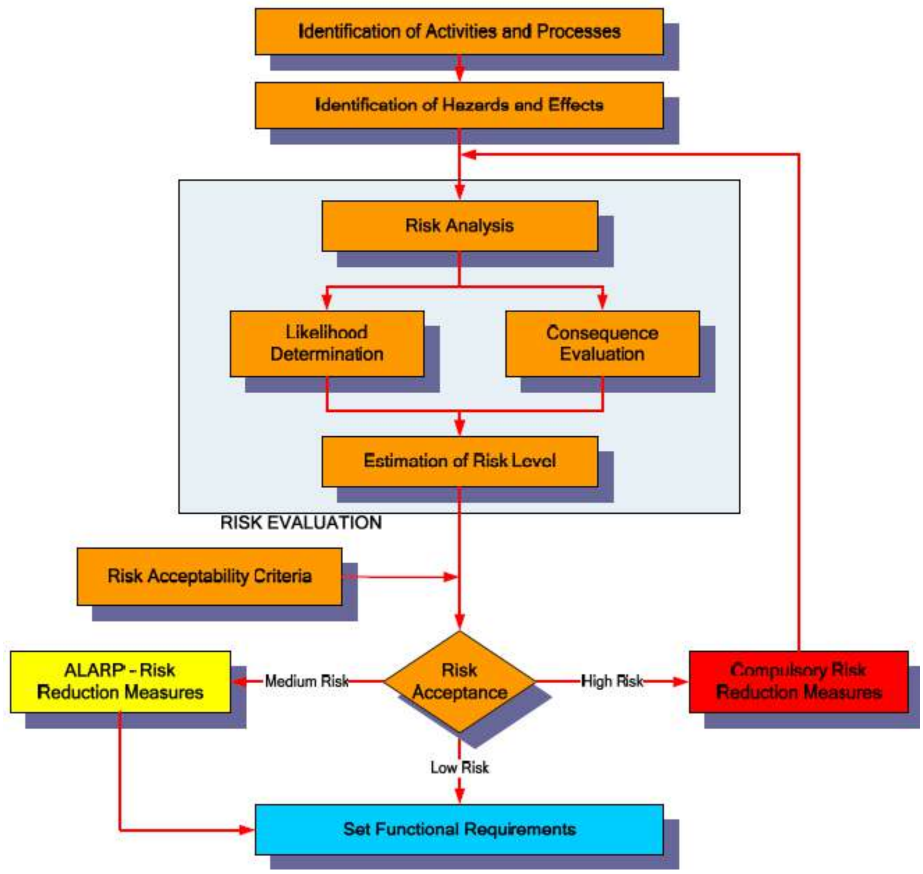
- Identify potential risk scenarios that may arise from storage and handling of hazardous chemicals;
- Review existing information and historical databases to arrive at possible likelihood of such risk scenarios;
- Predict the consequences of such potential risk scenarios and if consequences are observed to be high, establish the same through application of quantitative simulations; and
- Recommend feasible preventive and risk mitigation measures as well as provide inputs for strengthening of the Project's onsite Emergency Response Plan (ERP) and Disaster Management Plan (DMP).

7.4 *RA METHODOLOGY*

The risk assessment process is primarily based on likelihood of occurrence of the risks identified and their possible hazard consequences particularly being evaluated through hypothetical accident scenarios. With respect to the proposed project, major risks viz. leaks and rupture of storage tanks and containers evaluated through a risk matrix generated to combine the risk severity and likelihood factor. Risk associated with the chemical storages have been determined semi-quantitatively as the product of likelihood/probability and severity/consequence by using order of magnitude data (*risk ranking = severity/consequence factor X likelihood/probability factor*). Significance of such project related risks was then established through their classification as high, medium, low, very low depending upon risk ranking.

The risk matrix is widely accepted as standardized method of risk assessment and is preferred over purely quantitative methods, given that it's inherent limitations to define a risk event is certain. Application of this tool has resulted in the prioritization of the potential risks events for the existing operations and proposed expansion thus providing the basis for drawing up risk mitigation measures and leading to formulation of plans for risk and emergency management. The overall approach is summarized below in ***Figure 7.1*.**

Figure 7.1 Risk Assessment Methodology



7.5 *PROJECT – FLAMMABLE AND TOXIC MATERIAL STORAGE DETAILS*

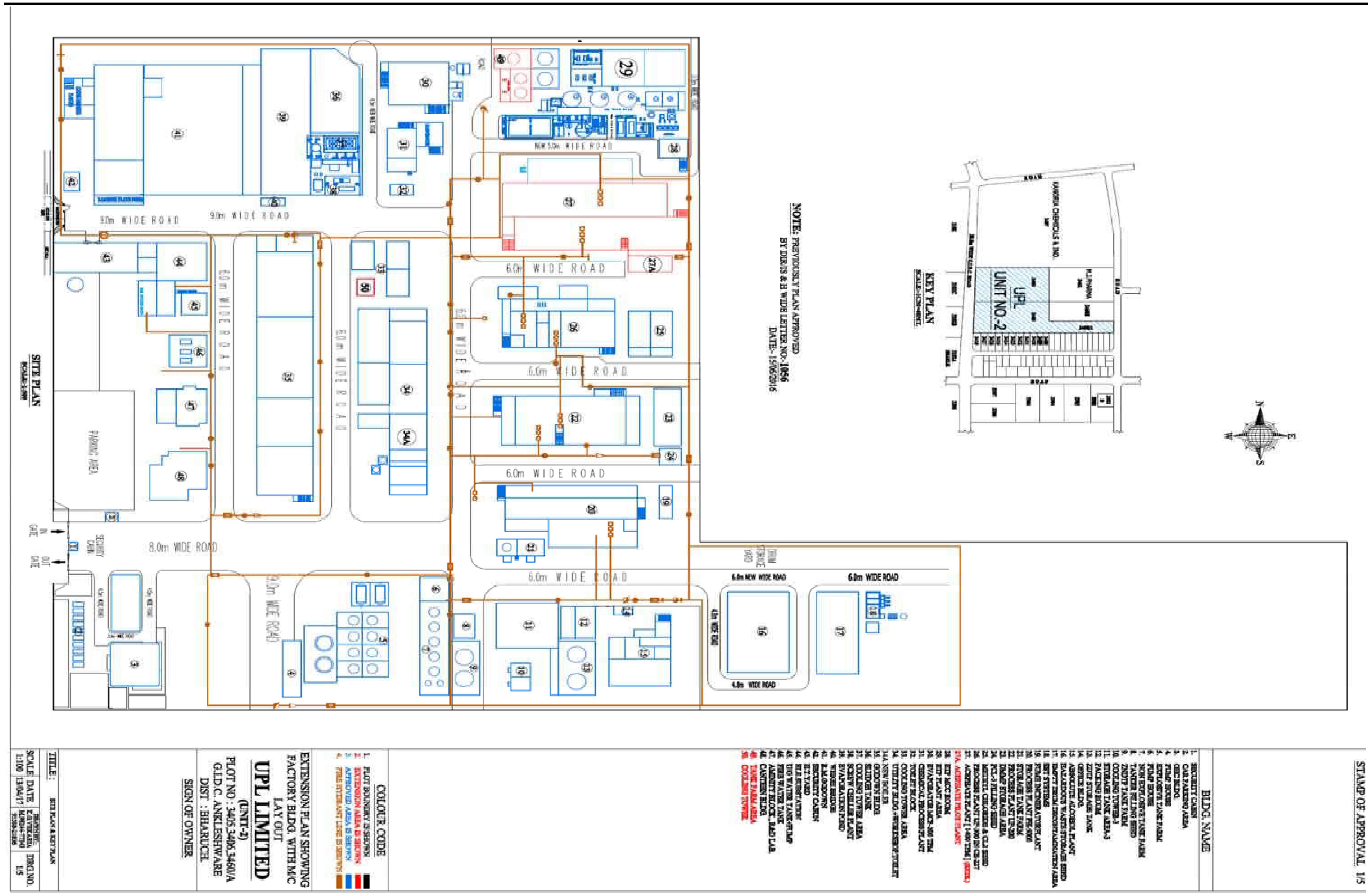
The list of chemicals stored or likely to be stored in the UPL Unit 2 facility as part of the proposed expansion Project has been provided below in *Table 7.1*.

Table 7.1 Flammable and Toxic Chemical Storage Details –Existing and Proposed

S.N.	Chemical Name	Tank Type	Diameter (m)	Height (m)	Existing Storage (KL)	Proposed Storage (KL)	Pressure (kg/cm^2g)	Temperature (°C)
1	Thionyl Chloride	Drums: MS/GL – 0.237KL	0.58	0.9	15	50	Ambient pressure	Ambient temperature
2	Methanol	Tank: CS Underground-ST5007	3.6 ID	5	50	70	Ambient pressure	Ambient temperature
3	Sulphuric Acid (98%)	CS Tank	2.4 OD	3.5	15	180	Ambient pressure	Ambient temperature
4	Bromine	Glass line tank	0.65	1.5	Nil	5	Ambient pressure	Ambient temperature
5	Triethyl Amine (TEA)	MS Drums	0.576	0.9	Nil	1	Ambient pressure	Ambient temperature
6	Hydrogen Peroxide	Tank	4.25	3.5	Nil	30	Ambient pressure	Ambient temperature
7	Ammonia (30%)	CS Dishedend tanks	i) 3.4 ii)4.6	i) 4.5 ii)6	i)40	260	Ambient pressure	Ambient temperature
8	Acetic Anhydride	SS316 Flat bottom tank	4.5	6.7	100	370	Ambient pressure	Ambient temperature
9	Ethyl Acetate	CS flat bottom tank	3.4	4.5	20	40	Ambient pressure	Ambient temperature
10	Chlorine	Tonner	0.8	2.0	Nil	5	Ambient pressure	Ambient temperature
11	Phosphorous Oxy chloride ($POCl_3$)	Tank	3.0	1.5	Nil	10	Ambient pressure	Ambient temperature
12	Acetone	Drums	0.576	0.9	0	2	Ambient pressure	Ambient temperature
13	Acetone Cyanohydrin	Carbuoys	1.0	1.0	0	1	Ambient pressure	Ambient temperature
14	Ethanol	Tank: CS Underground- ST5008	3.6 ID	5	50	200	Ambient pressure	Ambient temperature
15	O-Cresol	Drums	0.576	0.9	0	10	Ambient pressure	Ambient temperature
16	Phosphorus Trichloride	MS Tank	2.1	2.55	8	110	Connected scrubber with negative draft	Connected scrubber with negative draft
17	Methyl Chloride	Tonner	0.8	2.0	Nil	24 Tonner	Pressurised	Ambient temperature
18	Monocrotophos	Drums	0.576	0.9	10	40	Ambient pressure	Ambient temperature
19	Furnace oil	Tank	3.66	4.0	40	20	Ambient pressure	Ambient temperature
20	Formaldehyde	Tank	3.66	4.0	40	10	Ambient pressure	Ambient temperature
21	Caustic (48%)-Devrinol	Tank	2.5 OD	4	50	250	Ambient pressure	Ambient temperature
22	Caustic (32%)-Clomazone	Tank	3.2 OD	4.92	40	50	Ambient pressure	Ambient temperature
23	Sodium Cyanide	Drums	0.576	0.9	0	4	Ambient pressure	Ambient temperature

Source: UPL

Figure 7.2 Map showing Existing and Proposed Tanks in UPL Plant



Source: UPL

7.6 *HAZARD IDENTIFICATION*

The first stage in any risk assessment is to identify the potential incidents that could lead to the release of a hazardous material from its normal containment and result in a major accident. This is achieved by a systematic review of the facilities to determine where a release of a hazardous material could occur from various parts of the installation.

The major hazards are generally one of three types: flammable, reactive and/or toxic. For the present project, flammable and toxic releases have been identified as the predominant scenarios resulting from chemical storage and transfer pipeline failure in the form of leaks, ruptures etc.

Based on the result of this exercise, potential hazards that may arise due to proposed project were identified and a qualitative understanding of their probability and significance were obtained. Taking into account the applicability of different risk aspects the following hazard has been identified with respect to the proposed Project, which has been dealt in detail in the subsequent sections.

- Release of flammable liquids and gases from failure of loading/unloading line or hose and from storage tank/container leaks that may lead to jet fire (from immediate ignition), pool fire and VCE (from delayed ignition); and
- Toxic vapour cloud formation from leakage of toxic chemical storage containers, pumps, valves and flanges.

7.6.1 *Hazards from Flammable Chemical Storages*

With respect to flammable chemicals, this study is concerned with 'major hazards' which may result from the storage and handling of chemicals viz. methanol, triethyl amine, acetic anhydride, acetone, acetone cyanohydrin, ethanol, o-cresol, methyl chloride and furnace oil. These are as follows:

- Jet fires;
- Pool fires and
- Vapour cloud explosions (VCE);

Each of these hazards has been described below.

Jet Fire

Jet fires result from ignited releases of pressurized flammable gas or superheated/pressurized liquid. The momentum of the release carries the material forward in a long plume entraining air to give a flammable mixture. Jet fires only occur flammable gas is being handled under pressure or when handled in gas phase and the release are unobstructed.

Pool Fires

One of the type of chemical fire of interest in this study is a pool fire. If a liquid release has time to form a pool and is then ignited before the pool evaporates or drains away, then a pool fire results. Because they are less well aerated, pool fires tend to have lower flame temperatures and produce lower levels of thermal radiation than some other types of fire (such as jet fires); however, this means that they will produce more smoke. Although a pool fire can still lead to structural failure of items within the flame, this will take several times longer than in a jet fire. A burning liquid pool can spread along a horizontal surface or run down a vertical surface to give a running fire. Due to the presence of kerbs, slopes, drains and other obstacles; pool fire areas and directions can be unpredictable.

Vapour Cloud Explosion
When a flammable chemical is released into the atmosphere, it forms a vapor cloud that will disperse as it travels downwind. If the cloud encounters an ignition source, the parts of the cloud where the concentration is within the flammable range will burn. In some situations, the cloud will burn so fast that it creates an explosive force (blast wave). The effects of an explosion, defined by blast overpressure, can be significant.As such, if the vapour cloud is ignited in a confined or congested space, an explosion could also occur.

7.6.1 Hazards from Toxic Chemical Storages

For the toxic chemicals presently and likely to be stored and handled for the proposed project, the following hazards have been identified and presented in *Table 7.2* along with their existing control measures. For the hazard rating of the toxic chemicals to be used for the proposed project, the National Fire Protection Agency (NFPA) 704 rating system has been used. Chemical substances are rated for degree of HEALTH RISK, FLAMMABILITY and REACTIVITY, on a scale of 0 to 4 as described below.

Health Risk
- Level 4 – Can affect health or cause serious injury, during periods of very short exposure, even though prompt medical treatment is given.
- Level 3 – Can affect health or cause serious injury, during periods of short exposure, even though prompt medical treatment is given.
- Level 2 – Can cause incapacitation or residual injury, during intense or continued exposure, unless prompt medical treatment is provided.
- Level 1 – Cause irritation upon exposure, but only minor injury is sustained even if no medical treatment is provided.
- Level 0 – Offer no unusual hazards upon exposure to fire conditions.

Flammability
- Level 4 – Completely vaporize at normal pressure and temperature and burn readily.
- Level 3 – Liquids and solids that can be ignited under the most ambient conditions.
- Level 2 – Must be moderately heated before ignition can occur.
- Level 1 – Must be strongly heated before ignition will occur.
- Level 0 – Will not burn.

Reactivity

- Level 4 – Capable of explosive decomposition at normal temperatures and pressure.
- Level 3 – Easily capable of explosive decomposition, but require an ignition source or will react explosively with water.
- Level 2 – Easily undergo a violent reaction, but do not explosively decompose.
- Level 1 – Normally stable, but become explosive at elevated temperatures and pressure.
- Level 0 – Stable even under exposure to fire.

The fire and health hazards of the chemicals being and/or likely to be used for the proposed expansion project is presented in ***Table 7.2***.

Table 7.2 Hazard Summary of Toxic Chemicals

S.No	Chemical Name	NFPA Hazard Rating			Toxicity	Control Measure
		Health	Flammability	Reactivity		
1	Thionyl Chloride	4	0	2	Identified as a corrosive and toxic chemical with life threatening health effects likely to be experienced at a concentration of 14ppm and above for an hour of exposure (AEGL-3).	Level trans meter with interlocks on LL and DCS operation, vent to scrubber, sand pit for leakage spillage. MSDS
2	Sulphuric Acid (98%)	3	0	2	Identified as a corrosive chemical with life threatening health effects likely to be experienced at a concentration of 160 mg/m3 and above for an hour of exposure (AEGL-3).	Flange guard, dyke wall, trained Operator, DCS operation, safety shower.
3	Bromine	3	0	0	Identified as a toxic chemical with life threatening health effects likely to be experienced at a concentration of 8.5ppm and above for an hour of exposure (AEGL-3).	• **Preventing and controlling exposure** by o Engineering controls Such as chlorine enclosure, ventilation with automatic or remote shut-down device o Administrative controls with alarm systems, multi-gas instruments, detector tubes • **Personal protective equipment** - Eye protection, skin protection, respiratory protection **First AID:** First aid kit and knowledge on first aid to all workers working in hazardous chemicals handling /storage area.
4	Hydrogen Peroxide	3	0	3	Life threatening health effects likely to be experienced at a concentration of 100ppm and above (EPRG-3).	-
5	Ammonia	3	1	0	Identified as a toxic chemical with TOXIC; with inhalation, ingestion or skin contact may cause severe injury or death. Life threatening health effects	• **Preventing and controlling exposure by**

S.No	Chemical Name	NFPA Hazard Rating			Toxicity	Control Measure
		Health	Flammability	Reactivity		
					likely to be experienced at a concentration of 1100ppm and above for an hour of exposure (AEGL-3).	o Engineering controls such as chlorine enclosure, ventilation with automatic or remote shut-down device o Administrative controls with alarm systems, multi-gas instruments, detector tubes • **Personal protective equipment** - Eye protection, skin protection, respiratory protection **First AID:** First aid kit and knowledge on first aid to all workers working in hazardous chemicals handling /storage area.
6	Chlorine	4	0	0	High toxic chemical with life threatening health effects likely to be experienced at a concentration of 20ppm and above for an hour of exposure (AEGL-3).	Written safe work procedures A Workplace Hazardous Materials Information System (WHMIS) program
7	Phosphorous Oxychloride	4	0	2	The chemical is highly toxic by inhalation and ingestion and is strongly irritating to skin and tissues. Life threatening health effects likely to be experienced at a concentration of 0.85ppm and above for an hour of exposure (AEGL-3).	Exposure control plan Respiratory protection program (personal protective equipment) Written emergency procedures
8	Phosphorus Trichloride	4	0	2	This material is highly toxic; it may cause death or permanent injury. Life threatening health effects likely to be experienced at a concentration of 5.6ppm and above for an hour of exposure (AEGL-3).	Vent to scrubber system, Sprinkler for cooling. All flanges covered flange guard, Dyke wall safety shower.

Source: https://cameochemicals.noaa.gov/ and **https://www.epa.gov/aegl/access-acute-exposure-guideline-levels-aegls-values#chemicals**; file:///C:/Users/20007398/Downloads/chlorine-pdf-en.pdf

7.7 FREQUENCY ANALYSIS

The frequency analysis of the hazards identified with respect to the proposed project was undertaken to estimate the likelihood of their occurrences during the project life cycle. Hazard frequencies in relation to the proposed project were estimated based on the analysis of historical accident frequency data and professional judgment. Based on the range of probabilities arrived at for different potential hazards that may be encountered with respect to the storage and handling of flammable and toxic chemicals including fuel with respect to the expansion project, the following frequency categories and criteria have been defined (Refer*Table 7.3*).

Table 7.3 Frequency Categories and Criteria

Likelihood Ranking	Criteria Ranking (cases/year)	Frequency Class
5	Likely to occur often in the life of the project, with a probability greater than 10^{-1}	Frequent
4	Will occur several times in the life of project, with a probability of occurrence less than 10^{-1}, but greater than 10^{-2}	Probable
3	Likely to occur sometime in the life of a project, with a probability of occurrence less than 10^{-2}, but greater than 10^{-3}	Occasional/Rare
2	Unlikely but possible to occur in the life of a project, with a probability of occurrence less than 10^{-3}, but greater than 10^{-6}	Remote
1	So unlikely it can be assumed that occurrence may not be experienced, with a probability of occurrence less than 10^{-6}	Improbable

Source: Guidelines for Developing Quantitative Safety Risk Criteria – Centre for Chemical Process and Safety

7.7.1 *Frequency Analysis – Flammable Fuel & Chemical Storage Tankages*

The most credible scenario of a flammable and toxic liquid tankages will be pool fire, VCE and toxic vapour cloud. In order to determine the probability of a toxic vapour cloud/VCE/pool fire occurring, the failure rate needs to be modified by the probability of the material finding an ignition source. The probability of any of the aforesaid incident occurring in the event of a release is therefore equal to the product of the failure rate and the probability of ignition. The frequency of the possible release scenarios has been presented in *Table 7.4* below. The ignition probability is dependent on a number of factors including the type of site, the release rate and the type of material released.

Table 7.4 Tank Failure Frequency – Flammable and Toxic Chemicals

S.N	Type of Release	Failure Rate (per vessel per year)	Frequency
A	**Ambient Temperature & Pressure Vessels**		
1	Catastrophic tanks failure	5.0×10^{-6}	Remote
2	Major failure	1.0×10^{-4}	Remote
3	Minor failure	2.5×10^{-3}	Occasional/Rare
4	Roof top release	2.0×10^{-3}	Occasional/Rare

Source: Failure Rate and Event Data for use within Risk Assessments (28/06/2012) - UK HSE

Based on the chemical inventory made available, majority of flammable chemicals viz. methanol, acetone, o-cresol, tri-ethyl amine etc. are being or to be stored under ambient conditions. In all such cases, the catastrophic failure frequency rate is found to be **~5.0 X 10^{-6} per vessel per year**.

Roof failures being considered for atmospheric tanks include all failures of the roof and do not include liquid pooling on the ground. For vessels that are storing flammable liquids, this could lead to a flammable atmosphere being formed and possible ignition and escalation.

Event Tree Analysis

Event tree analysis (ETA) is used to model the evolution of an event from the initial release through to the final outcome such as jet fire, fireball, flash fire etc. This may depend on factors such as whether immediate or delayed ignition occurs, or whether there is sufficient congestion to cause a vapour cloud explosion.

Ignition Probability

Immediate ignition for gas storage vessels is assigned a probability of 0.3 for large releases following Cox, Lees and Ang (Lees, 1996). For massive liquid releases the ignition probability is found to be comparatively lower i.e. 0.08 given higher flash points (see *Table 7.5*).

Table 7.5 Ignition Probabilities from Cox, Lees and Ang

Sl. No	Leak Rate	Probability of Ignition	
		Gas Release	**Liquid Release**
1	Minor (< 1kg/s)	0.01	0.01
2	Major (1-50 kg/s)	0.07	0.03
3	Massive (>50 kg/s)	0.3	0.08

Delayed ignition is assigned a probability of 0.5 (ENSR, 2008).

Delayed ignition of flammable gas cloud may produce a flash fire or vapour cloud explosion (VCE). Given the fairly open nature of the surroundings, an explosion probability of 0.2 has been assumed.

7.8 CONSEQUENCE ANALYSIS

In parallel with the frequency analysis, hazard prediction / consequence analysis exercises were undertaken to assess the likely impact of project related risks on onsite personnel, infrastructure and environment. In relation to the proposed project as well as the existing activities have been considered, the estimation of the consequences for each possible event has been based either on accident frequency, consequence modeling or professional judgment, as appropriate. Overall, the consequence analysis takes into account the following aspects:

- Nature of impact on environment and community;
- Occupational health and safety;
- Asset and property damage;
- Corporate image; and
- Timeline for restoration of property damage.

The following criteria for consequence rankings (Refer *Table 7.6)* have been drawn up in context of the possible consequences of the risk events that may occur during the proposed project operations:

Table 7.6 Severity Categories and Criteria

Consequence	Ranking	Criteria Definition
Catastrophic	5	• Multiple fatalities/permanent total disability to more than 50 persons. • Net negative financial impact of >10 crores • International media coverage • Loss of corporate image and reputation
Major	4	• Single fatality/permanent total disability to one or more persons • Net negative financial impact of 5 -10 crores • National stakeholder concern and media coverage.
Moderate	3	• Short term hospitalization & rehabilitation leading to recovery • Net negative financial impact of 1-5 crores • State wide media coverage
Minor	2	• Medical treatment injuries • Net negative financial impact of 0.5 – 1 crore • Local stakeholder concern and public attention
Insignificant	1	• First Aid treatment • Net negative financial impact of <0.5 crores. • No media coverage

Risk Evaluation

Based on ranking of likelihood and frequencies, each identified hazard has been evaluated based on the likelihood of occurrence and the magnitude of consequences. The significance of the risk is expressed as the product of likelihood and the consequence of the risk event, expressed as follows:

Significance = Likelihood X Consequence

The *Table 7.7* below illustrates all possible product results for the five likelihood and consequence categories while the *Table 7.8* assigns risk significance criteria in three regions that identify the limit of risk acceptability. Depending on the position of the intersection of a column with a row in the risk matrix, hazard prone activities have been classified as low, medium and high thereby qualifying for a set of risk reduction / mitigation strategies.

Table 7.7 Risk Matrix

			Likelihood →				
			Frequent	Probable	Unlikely	Remote	Improbable
			5	4	3	2	1
Consequence →	Catastrophic	5	25	20	15	10	5
	Major	4	20	16	12	8	4
	Moderate	3	15	12	9	6	3
	Minor	2	10	8	6	4	2
	Insignificant	1	5	4	3	2	1

Table 7.8 Risk Criteria and Action Requirements

S.N.	Risk Significance	Criteria Definition & Action Requirements
1	**High (16 - 25)**	**"Risk requires attention"** – Project HSE Management need to ensure that necessary mitigation are adopted to ensure that possible risk remains within acceptable limits
2	**Medium (10 – 15)**	**"Risk is tolerable"** – Project HSE Management needs to adopt necessary measures to prevent any change/modification of existing risk controls and ensure implementation of all practicable controls.
3	**Low (5 – 9)**	**"Risk is acceptable"** – Project related risks are managed by well-established controls and routine processes/procedures. Implementation of additional controls can be considered.
4	**Very Low (1 – 4)**	**"Risk is acceptable"** – All risks are managed by well-established controls and routine processes/procedures. Additional risk controls need not to be considered

7.8.1 *Consequence Analysis – Tankages*

The main hazards associated with the storage and handlings of chemicals with respect to the proposed project are toxic vapour cloud including pool fire, jet fire and VCEs resulting from the ignition of released material. The hazards may be realised following tank overfilling and leaks/failures in the storage tank and ancillary equipment such as transfer pumps, metering equipment, etc. all of which can release significant quantities of flammable material on failure.

The *Section 7.5.1* had previously provided an explanation of the events, which may occur as a result of release of flammable material, followed by ignition.

Risk Modelling Scenarios

In addition to overfill, the scenarios considered for chemical/fuels storage tanks and containers were leaks and catastrophic failures. Factors that have been identified as having an effect on the integrity of tanks are related to design, inspection, maintenance, and corrosion[1]. The following representative scenarios for the tanks were considered (Refer *Table 7.9*).

Table 7.9 Flammable & Toxic Chemical Storages– Risk Modelling Scenarios

Sl. No	Chemical Name	Total Storage including expansion (KL)	Event	Scenario
1	Thionyl Chloride	50	Toxic Gas Release	5mm leak
			Toxic Gas Release	10mm leak
			Toxic Gas Release	MCLS
2	Methanol	70	Pool Fire	50mm leak
			Pool Fire	100mm leak
			VCE	MCLS
3	Bromine	5	Toxic Gas Release	2.5mm leak
			Toxic Gas Release	5mm leak
			Toxic Gas Release	MCLS
4	Triethyl Amine(TEA)	1	Pool Fire	50mm leak
			Pool Fire	100mm leak
			VCE	MCLS
5	Ammonia (30%)	260	Toxic Gas Release	2m dia puddle
			Toxic Gas Release	4m dia puddle
			Toxic Gas Release	8m dia puddle
6	Acetic Anhydride	370	Pool Fire	50mm leak
			Pool Fire	100mm leak
			VCE	MCLS
7	Ethyl Acetate	40	Pool Fire	50mm leak
			Pool Fire	100mm leak
			VCE	MCLS
8	Chlorine Tonners	5	Toxic Gas Release	2.5mm leak
			Toxic Gas Release	5mm leak
			Toxic Gas Release	MCLS
9	Phosphorous Oxy chloride (POCl3)	10	Toxic Gas Release	2.5mm leak
			Toxic Gas Release	5mm leak
			Toxic Gas Release	MCLS
10	Acetone	2	Pool Fire	50mm leak
			Pool fire	100mm leak
			VCE	MCLS
11	Acetone Cyanohydrin	1	Pool Fire	50mm leak
			Pool fire	100mm leak
			VCE	MCLS
12	Ethanol	200	Pool Fire	50mm leak
			Pool fire	100mm leak
			VCE	MCLS
13	O-Cresol	10	Pool Fire	50mm leak
			Pool fire	100mm leak
			VCE	MCLS
14	Phosphorus Trichloride	110	Toxic Gas Release	2.5mm leak
			Toxic Gas Release	5mm leak
			Toxic Gas Release	MCLS

[1] AEA Technology, HSE Guidance Document

Sl. No	Chemical Name	Total Storage including expansion (KL)	Event	Scenario
15	Methyl Chloride	24 Tonners	Jet Fire	50mm leak
			Jet fire	100mm leak
			VCE	MCLS
16	Furnace Oil	60	Pool Fire	50mm leak
			VCE	MCLS

NOTE: Monocrotophos, Formaldehyde, Sodium Cyanide, Caustic (48%)-Devrinol and Caustic (32%)-Clomazone are not considered for risk assessment as they are not likely to pose any immediate threat (like toxic exposure, pool fire etc.) from their accidental release unless subjected to any physical contact

The chemical storage tank and container failure scenarios have been modeled using ALOHA and interpreted in terms of Thermal Radiation and Toxic Level of Concern (LOC) encompassing the following threshold values (measured in kilowatts per square meter) and ppm or mg/m^3 respectively to create the default threat zone.

Toxic Level of Concern

Toxic Level of Concern has been interpreted in the form of Acute Exposure Level Guidelines (AEGLs) and Emergency Response Planning Guidelines (ERPGs) calculated for– 60 minutes.

AEGL "levels" are dictated by the severity of the toxic effects caused by the exposure, with Level 1 being the least and Level 3 being the most severe. All levels are expressed as parts per million or milligrams per cubic meter (ppm or mg/m^3) of a substance above which it is predicted that the general population could experience, including susceptible individuals:

AEGL-1 (Yellow): Notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure;

AEGL-2 (Orange): Irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape; and

AEGL-3 (Red): Life-threatening health effects or death.

ERPGs estimate the concentrations at which most people will begin to experience health effects if they are exposed to a hazardous airborne chemical for 1 hour. The three ERPG tiers are defined as follows:

- *ERPG-3 (Red): This is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.*
- *ERPG-2 (Orange) This is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.*
- *ERPG-1 (Yellow): This is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing more*

than mild, transient adverse health effects or without perceiving a clearly defined objectionable odour.

Thermal Radiation Level of Concern

Red: 10 kW/ (sq. m) -- potentially lethal within 60 sec;

Orange: 5 kW/ (sq. m) -- second-degree burns within 60 sec; and

Yellow: 2 kW/ (sq. m) -- pain within 60 sec

For vapour cloud explosion, the following threshold level of concern has been interpreted in terms of blast overpressure as specified below:

Red: 8.0 psi – destruction of buildings;

Orange: 3.5 psi – serious injury likely; and

Yellow: 1.0 psi – shatters glass

The MSDS of the Products and Raw materials is included as *Annex F*.

The risk contours for Maximum Credible Loss Scenario (MCLS) for flammable and toxic chemical storages have been have been included in *Annex F*.

The risk significance as established based on risk scenarios modelled and failure frequencies considered presented in *Table 7.10*.

Table 7.10 Hazardous Chemical Storages – Risk Modelling Results

S. N	Chemical Name	Event	Scenario	LOC 1 (in m)			LOC 2 (in m)			LOC 3 (in m)			Likelihood	Consequence	Significance
				AEGL-3 /EPRG-3	8 psia	10 kW/m²	AEGL-2 /EPRG-2	3.5 psia	5 kW/m²	AEGL-1 /EPRG-1	1 psia	2 kW/m²			
1	Thionyl Chloride	Toxic Gas Release	5mm leak	51			125			-			3	3	9
		Toxic Gas Release	10mm leak	97			237			-			3	4	12
		Toxic Gas Release	MCLS	154			379			-			2	4	12
2	Methanol	Pool Fire	50mm leak			12			14			18	3	2	6
		Pool Fire	100mm leak			22			26			35	3	2	6
		VCE	MCLS			-			-		268		2	3	6
3	Bromine	Toxic Gas Release	MCLS	104			645			1900			3	3	9
4	Triethyl Amine(TEA)	Pool Fire	50mm leak		14			18			25		3	3	9
		Pool Fire	100mm leak		19			25			35		3	3	9
		VCE	MCLS		-			42			70		2	3	6
5	Ammonia (30%)	Toxic Gas Release	2m dia puddle	19			52			121			3	3	9
		Toxic Gas Release	4m dia puddle	38			101			237			3	3	9
		Toxic Gas Release	8m dia puddle	73			198			467			2	5	10
6	Acetic Anhydride	Pool Fire	50mm leak			12			14			19	3	3	9
		Pool Fire	100mm leak			22			27			36	3	3	9
7	Ethyl Acetate	Pool Fire	50mm leak			13			16			22	3	2	6
		Pool Fire	100mm leak			23			30			41	3	2	6
8	Chlorine	Toxic Gas Release	2.5mm leak	67			220			454			3	5	15
		Toxic Gas Release	5mm leak	137			452			912			3	5	15
		Toxic Gas Release	MCLS	233			769			1500			2	5	10
9	Phosphorous Oxy chloride (POCl3)	Toxic Gas Release	2.5mm leak	83									3	3	9
		Toxic Gas Release	5mm leak	155			-			-			3	4	12
		Toxic Gas Release	MCLS	180			-			-			2	5	10
10	Acetone	Pool Fire	50mm leak			13			17			23	3	3	9
		Pool fire	100mm leak			24			30			42	3	3	9
		VCE	MCLS		-			53			82		2	3	6
11	Acetone Cyanohydrin	Pool Fire	50mm leak			<10			<10			<10	3	1	3
		Pool fire	100mm leak			<10			<10			<10	3	1	3
12	Ethanol	Pool Fire	50mm leak			13			16			21	3	2	6
		Pool fire	100mm leak			24			29			40	3	2	6
		VCE	MCLS		-			-			676		2	3	6

S. N	Chemical Name	Event	Scenario	LOC 1 (in m)			LOC 2 (in m)			LOC 3 (in m)			Likelihood	Consequence	Significance
				AEGL-3 /EPRG-3	8 psia	10 kW/m²	AEGL-2 /EPRG-2	3.5 psia	5 kW/m²	AEGL-1 /EPRG-1	1 psia	2 kW/m²			
13	O-Cresol	Pool Fire	50mm leak			12			14			19	3	2	6
		Pool fire	100mm leak			13			16			22	3	2	6
14	Phosphorus Trichloride	Toxic Gas Release	2.5mm leak	38			64			156			3	2	6
		Toxic Gas Release	5mm leak	76			128			315			3	4	12
		Toxic Gas Release	MCLS	152			257			641			2	5	10
15	Methyl Chloride	Jet Fire	50mm leak			10			24			45	3	2	6
		Jet fire	100mm leak			12			25			44	3	2	6
		VCE	MCLS								27	27	2	3	6
16	Furnace Oil (FO)	Pool Fire	50mm leak			15			19			28	3	2	6
		Pool fire	100mm leak			27			36			53	3	2	6

7.9 *RA OUTCOME*

The RA results for storage tanks indicates that in most of the scenarios involving leakages leading to Pool/Jet Fire, the risk significance is assessed as *"Low"*. For scenarios with low risk significance, the effective distance for damage in terms of radiation intensity is likely to remain up to 53m.

For medium risk significance, catastrophic failures of highly flammable chemical and fuel storage tanks were found to result in VCEs. For VCEs, the maximum blast overpressure of 8.0 psi, which may cause destruction of building, did not exceed the LOC in all cases except for triethyl amine (TEA) which will be up to ~19m within the Plant premises. While the blast overpressure of 3.5 psi (which may cause serious injury) is expected to remain up to a radial distance of 53m.

Hence, damaging effects from thermal radiation and VCE are expected to remain limited within the plant premises to nearby process equipment and machineries. The damaging effects may result in occupation injuries/fatalities to site personnel and workers operating in the immediate vicinity, requiring adequate risk mitigation measures be in place together with strict use of adequate PPEs by personnel working in nearby areas.

The potential threat from toxic releases were found to be particularly significant with respect to chlorine tonners wherein the life threatening health effects are likely to be experienced up to a distance of 233 m from source. The release scenario leading to irreversible or other serious, long lasting adverse health effects are expected up to 769 m due to catastrophic rupture of a chlorine tonner (i.e. maximum credible leak scenario).

The RA results show requirement of implementation of appropriate engineering and administrative controls together with strict risk mitigation measures to minimize potential exposure risks.

The above RA outcome shows requirement of implementation of appropriate engineering and administrative controls together with strict risk mitigation measures to minimize potential exposure risks. Following risk mitigation measures need to be included:

- Preventing and controlling exposure by
    - Engineering controls such as chlorine enclosure, ventilation with automatic or remote shut-down device;
    - Provision of neutralizing systems for toxic gases and liquid chemicals;
    - Administrative controls with alarm systems, multi-gas instruments, detection sensors;
    - Chemicals, which upon fire give rise to toxic fumes, requiring special fire control measures. In addition, runoff fire-water from toxic chemicals is to be dyked for its neutralization and treatment prior to disposal.
- Written safe work procedures
- A Workplace Hazardous Materials Information System (WHMIS) program.

- Exposure control plan
- Respiratory protection program (personal protective equipment)
- Written emergency procedures
- Written preventive maintenance procedures
- Checking on a worker working alone
- Training, instruction, and supervision

In addition, adequate fire protection system is required to be in place and supplemented by implementation of focussed training and awareness sessions and organizing periodic Onsite and occasional Offsite Emergency Preparedness drills to check effectiveness of existing risk management system. UPL's emergency preparedness and response plan will comply with requirement of the Gujarat Factories Rules 1963 & MSIHC Rules, 1989 as amended.

UPL is to conduct a detailed process hazard analysis and HAZOP at two stages i.e. as part of the Front End Engineering and Design (FEED) study and prior to commissioning of each process of the proposed expansion to assess associated risks and implement recommendation for safe operations.

7.10 *EMERGENCY PREPAREDNESS AND RESPONSE PLAN*

UPL handles various hazardous chemicals and employ processes involving high pressure and temperature. In spite of precautions and safety measures one take, an incidence of potential damage may arise by system failure or unavoidable circumstances. An emergency preparedness and response plan for proposed expansion project will lay down guidelines to handle such emergencies. UPL's Emergency preparedness and response plan will comply with requirement of schedule 8-A of sub rule 68-J-(12) (1) of Gujarat Factory Rule 1963 & Schedule-11 of Rule 13(1) of MSIHC Rule 1989.

7.10.1 *Classification of Emergency*

Emergencies at UPL have been classified in three categories:

Level – 1[1]: The incident or emergency which are confinable, controllable within the plant premises, which under normal circumstances does not affect area outside the said plant battery limit and controlling does not involve / require external help. This situation is called emergency stand by and affected unit / plant have to handle emergency

Level – 2: When the incident or emergency level-1 is not controlled within 10 to 15 minutes or does not come under control within 10 to 15 minutes, incident controller, site main controller reviews the situation and decides. If situation is Worsening.

Level – 3: After surveying off-site implications of level – 2 emergency if there is a likelihood of chlorine gas cloud formation and spreading of cloud in down wind direction affecting neighbouring population of industry and villagers and /or in case of following incident IC (Incident Controller) and SMC (Site Main Controller) are of the opinion that there will be off-site implications.

The emergencies have been identified and categorized in three modes:
Man-made: Heavy Toxic Leakage/Spillage, Fire, Explosion, Failure of Critical Control system, Design deficiency, unsafe acts, In-adequate maintenance

Natural Calamities: Flood, Earthquake, Cyclone, Outbreak of Disease, Tsunami, Lightning

Extraneous: Riots/Civil Disorder/Mob Attack, Terrorism, Sabotage, Bomb Threat, War/Hit by missiles, Abduction, Food Poisoning/Water Poisoning

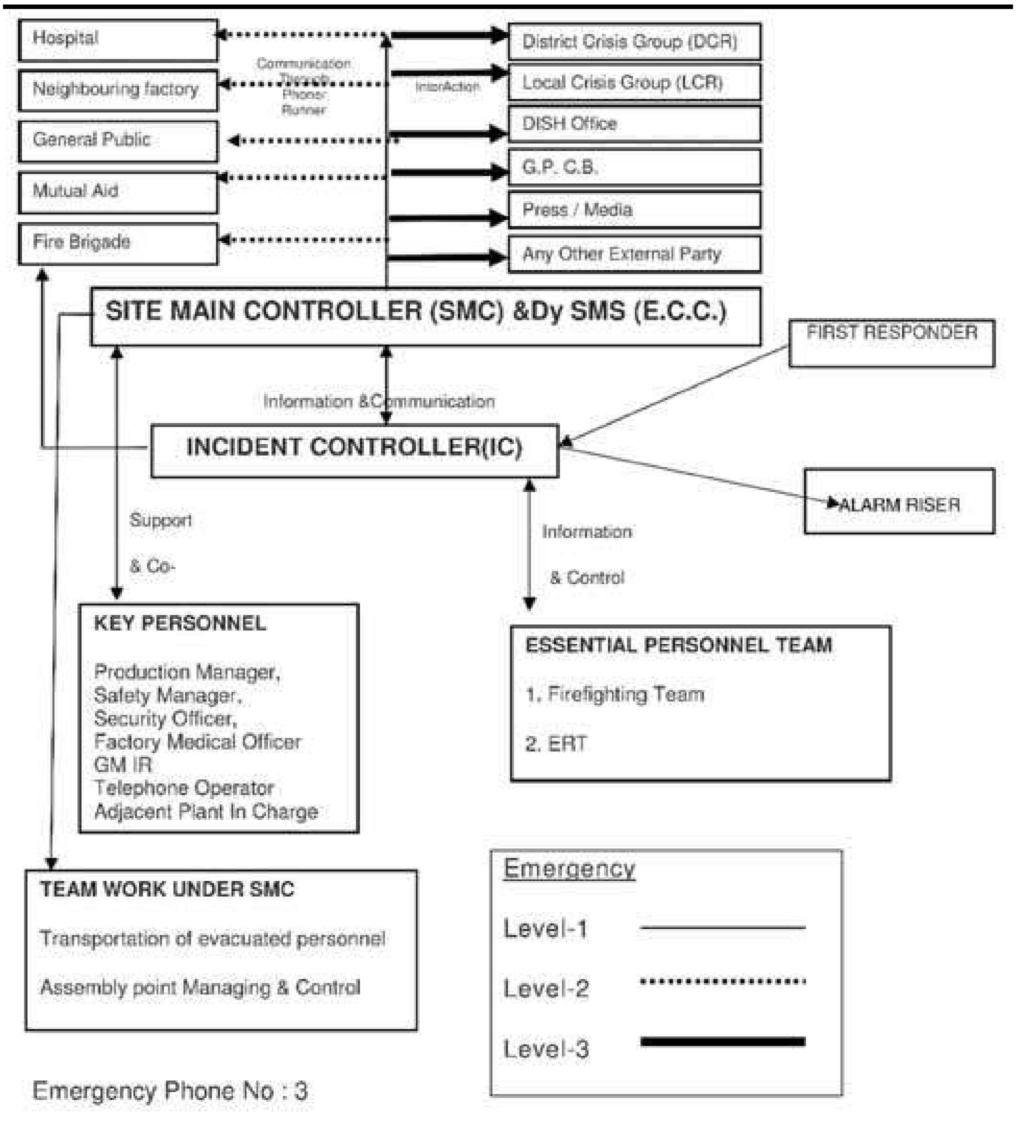
The On-site emergency plan deals with, measures to prevent and control emergencies within the factory and not affecting outside public or Environment.

The Off-site emergency plan deals with, measures to prevent and control emergencies affecting public and the environment outside the premises.

[1] Level-I and Level- II shall normally be grouped as onsite emergency and Level-III as off- site emergency

The organizational structure and communication management for Emergency response is given below in *Figure 7.3*.

Figure 7.3 *IRT Organizational Support Matrix*



7.10.2 *Emergency Response Personnel*

First responder: Any person who notices the abnormal incident of hazardous nature, must act as a first responder.

Alarm Riser: After getting instruction from Respective Incident Controller, the Alarm riser will raise the siren. In case of failure of power supply, a manual bell will be rung loudly.

Site Main Controller: Site Main Controller is the head authority of the Emergency Organization. He/she is having overall responsibility for directing operation and calling for outside help from Emergency Control Centre. In absence of Unit Head, Incident site Group Head will Act as a Deputy Site Main Controller and during Silent hours, NDO/ DDO will be holding responsibility of Dy. Site Main Controller.

Incident Controller: If the incident occurs in the plant area, Respective Shift In-charge of the Plant (Site) & Head of the Department holds the responsibility of the Incident Controller. On being informed of the emergency and its location, incident controller will rush to the site and will do the specific set of assessment and actions.

Deputy Incident Controller: In the absence of Shift In-charge (Incident Controller), Deputy Incident Controller of respective Plant will hold the responsibility of the Incident Controller.

Key Personnel: On being informed of the emergency he will rush to the incident site and will report to incident controller or Site Main Controller at ECC. The key personnel identified in UPL's ERP are:

A. Production Manager
B. Safety Manager
C. Security officer
D. Factory Medical Officer
E. P& A &IR
F. Adjacent Plant in-charge
G. Telephone Operator

Essential Personnel Team: As soon as the essential personnel hear the emergency siren or any emergency brought to the knowledge, they first report to incident controller (After hand over their charge to other plant supervisor) with fully equipped themselves. (For proper information all team member have to contact immediately on telephone Number). The team of the essential personnel is trained in firefighting, first aid and engineering controls and they are available in factory in all shifts.

7.10.3 Emergency Control Centre

The emergency control centre (or room) is the place from which the operations to handle the emergency are directed and coordinated. The site main controller, key personnel and senior officers of the fire, police, factory inspectorate, district authorities and emergency services will attend it. The centre should be equipped to receive and transmit information and directions from and to the incident controller and areas of the works as well as outside. It should also have equipment for logging the development of the incident to assist the controllers to determine any necessary action.

In addition to the means of communication, the centre should be equipped with relevant data and equipment which will assist those manning the centre to be conversant with the developing situation and enable them to plan accordingly. It should be sited in an area of minimum risk and close to a road to allow for ready access by a radio-equipped vehicle for use if other systems fail or extra communication facilities are needed. The centre should be equipped with adequate number of supplies required to handle emergency situation such as plant layout and surrounding areas map, sirens, safety equipment, fire extinguishers and emergency vehicles.

7.10.4 *Other companies/ external organizations to be involved in on-site emergency*

Site main controller is responsible to inform below authorized organizations in case of on/off site emergencies:

1. UPL Limited Unit 1 – GIDC, Ankleshwar
2. UPL Limited Unit -3 – GIDC. Ankleshwar
3. UPL Limited Unit-5 – GIDC, Jaghadia
4. DPMC – GIDC, Ankleshwar (full scale fire brigade services with rescue team)

Site main controller (SMC) and deputy SMC are responsible for liaising with government authority, nearby organization, journalist, population, employees and nest of kin of the employees.

Further mutual aid arrangements with neighbouring industries and nearby hospitals will be made to respond to level-II emergencies.

7.10.5 *List of Emergencies*

UPL's emergency response plan has identified emergency situations which are categorized as man-made emergencies, natural calamities and extraneous emergencies. The list of emergencies is provided below in *Table 7.11* which can be rehearsed and updated on regular basis.

Table 7.11 List of Emergencies identified at UPL

Man made	**Natural Calamities**	**Extraneous**
Toxic gas release	Flood	Riot/Civil disorder Mob attack
Fire	Earthquake	Terrorism
Explosion	Cyclone	Sabotage
Failure of critical control system	Outbreak of disease	Bomb threat
Spillage of strong acid and alakalis	Tsunami, Lightning	War/hit by missiles
		Abduction
		Food poisoning/ water poisoning

7.10.6 *Identification and Assessment of Hazards*

This is the most crucial stage to both on-site and off-site emergency planning, as the hazard would range from small events which can be dealt by works personnel without outside help, to the large accidents, for which it is vital to have a plan systematically designed to combat the disaster.

UPL is to conduct a detailed process hazard analysis and HAZOP at two stages i.e. as part of the Front End Engineering and Design (FEED) study and prior to commissioning of each process of the proposed expansion to assess associated risks and implement recommendation for safe operations.

7.10.7 *Emergency due to Natural Calamities*

UPL has identified possibility of occurrence of following natural calamities at the project site and has developed a response plan to each of these calamities as part of ERP:

1. Earthquake
2. Lighting and Thunderstorm
3. Heavy rain

7.10.8 *Communication Arrangements for On-site and Off-site Emergencies*

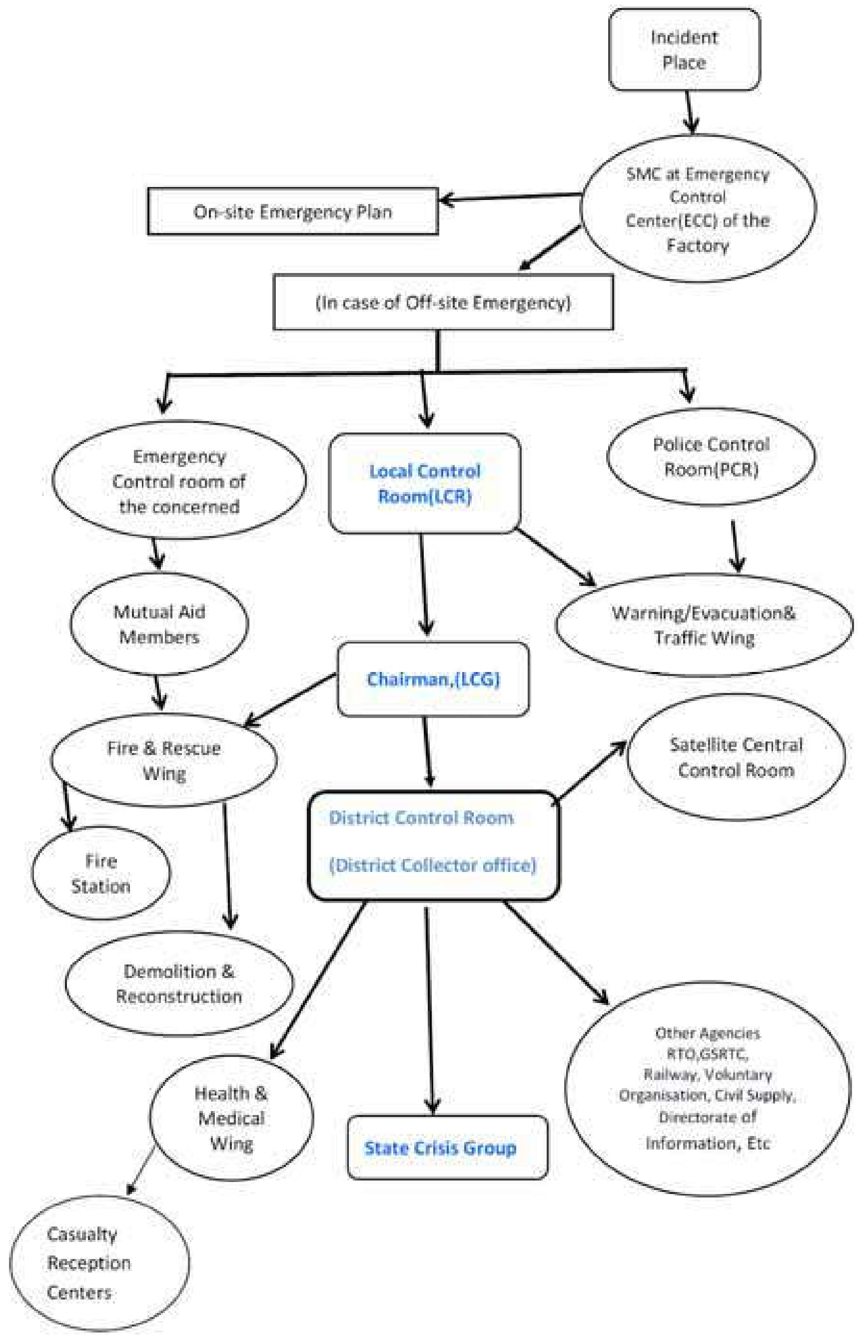
For the purpose of on-site and off-site emergency plan, UPL has quick and effective communication system to make the emergency known:

a. Inside the factory;
b. To key personnel outside normal working hours;
c. To outside emergency services and authorities; and
d. To neighbouring factories and public in vicinity.

Arrangement of off-site emergency plan and communication is explained below in *Figure 7.4.*

The details of Onsite Emergency Response Plan (ERP) is included as *Annex H*.

Figure 7.4 Arrangement for off-site emergency plan and communication



7.11 OCCUPATIONAL HEALTH AND SAFETY

7.11.1 *In-Plant Safety Precautions Employed*

- M/s. UPL is having a full-fledged safety department headed by safety manager. The safety department undertakes various safety-related activities to improve awareness among the employees. Continuous training is imparted to all concerned employees at all the levels.
- For chemical transportation and unloading of tankers, all unloading points are identified and are equipped with grounding / earthling facilities.

- All vehicles going inside the process premises are fitted with mufflers at security gate itself to avoid any probable fire risk.
- The Hazardous Chemical - Ethanol which is having low flash point, is stored underground
- For highly flammable reactants, the storage tanks are fitted with sprinkler type cooling arrangements and flame arrestors in their vent.
- All solvent transfer lines are provided with the earthing strips to avoid the accumulation of any static charges during its transfer operations.
- All plants are well equipped with self-contained breathing apparatus and compressed air to take care of any accidental leakage/spillage/gas release.
- Provision of portable gas detectors/handy samplers to know the concentration of the gases in ambient air, which would help decide the evacuation of the surrounding people in case of gaseous cloud formation, thereby reducing the environmental hazards.
- For safe handling of solids, a flameproof type caged hoist fitted with necessary interlock system is provided.
- All warehouses are equipped with exhaust ventilation and portable type fire extinguishers to take care of any fire.
- The provision has also been made for sufficient storage of water for firefighting requirement, extinguisher at all critical locations and sufficient manpower to combat fire hazards.
- Canister / cartridge type gas masks are provided to the employees for their day-to-day working.

7.11.2 Approach for Safety Management

The approach to safety management may divide into the following categories:

- Provision of personal protective devices like chemical resistant suits, gloves, glass, shoes etc.
- Provision of plant safety measures - this includes the provision of proper colour coding and labelling of pipelines, identification of safety assembly points, placing of caution boards at several locations within the plant, emergency showers.

Protective measures for safe storage and transportation of hazardous chemicals/wastes are as follows:

- All necessary precautions for the safe storage and transportation of all raw materials and other recyclable chemicals. Utmost care has been taken for the siting of storage locations of the above chemicals keeping in mind the proper spacing, ventilation and compatibility of the chemicals to be stored.
- While transporting the above hazardous chemicals/wastes, all the provisions mentioned in Central Motor Vehicles Rules, 1989 are complied with. The tankers carrying the chemicals are labelled properly and carry all the instructions like technical name of the chemical transported, urgent actions to be taken in case of leakage / fire, contact telephone numbers for

emergencies etc. Compliance with the provisions of on-site and off-site emergency plans.

- Provision of medical assistance including the First-Aid provisions.
- Yearly safety audit through expert agencies like – Tata AIG Risk Management Services Ltd – is being carried out.

7.11.3 *Occupational health programs*

At UPL, health of employees is given great importance. The company is having medical doctor and Occupational Health Center (OHC) and an ambulance. Pre-employment and routine medical examinations are being carried out. We are also doing full body medical check-up by external expert agency every year for physical examination, haemoglobin, complete blood count, ESR, complete urine examination, lever function, kidney function, creatinine, blood sugar, Electro Cardiogram, X Ray for chest and Sonography etc. regular blood cholinesterase activity (BCA) test for employees is also being carried out All medical records are being maintained. During July-Dec 2017, medical check-up done for total 289 employees including contract employee.

- Experienced part time doctor for each unit who visits the site 3 times a week
- Occupational health centre for with availability of male nurse in general shift
- Detailed Health check-up of each employee every 2 years (this check -up includes X ray, ECG, physical check-up, lung function test, eye check-up etc.)
- For employees working in pesticide environment, check up by company doctor every 3 months
- Check-up of all contract workers by FMO during / after their entry to company
- Blood and urine test of each employee working in Pesticide environment once in 6 months
- Individual health file is maintained for each employee working at site.
- Regular blood Choline Esterase tests for all contract workers coming to the site and ensuring that minimum 75 % BCA number is maintained as prerequisite for job. At Unit 2, frequency is 15 days.
- Regular BCA tests for employees working in Pesticide environment at frequency of 30 days.

Beyond the programs mentioned above, FMO (Factory Medical Officer) conduct HOD sessions for bringing the health awareness.

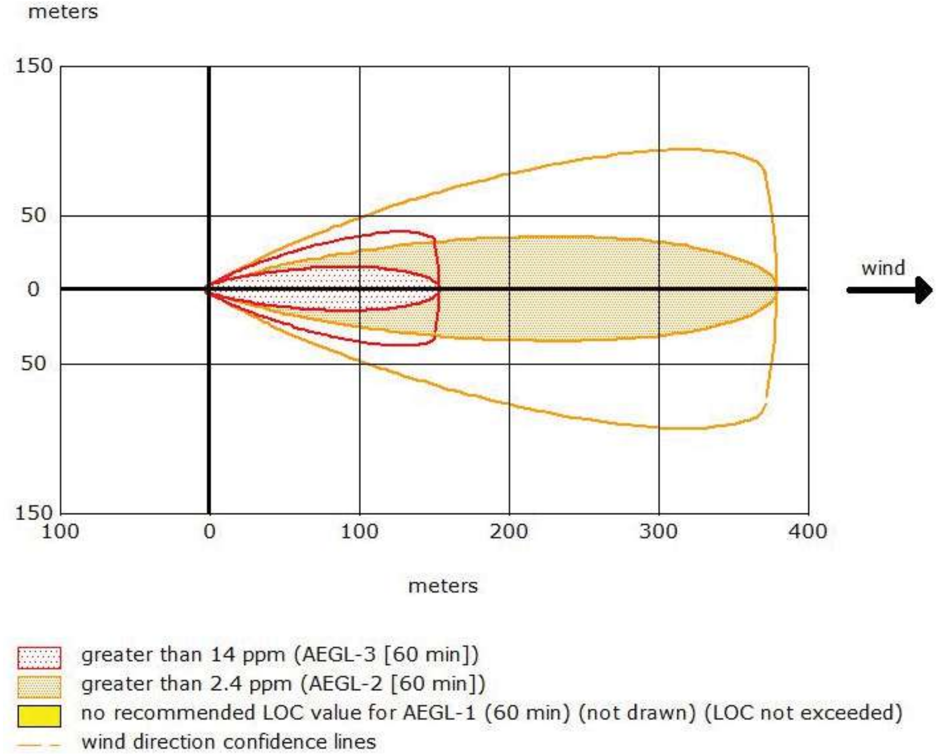
The Medical Examination Record and Annual Medical Check-up records is included as *Annex I*.

Annex G

Risk contours for flammable and toxic chemical storages

Thionyl Chloride Storage Tank – Maximum Credible Loss Scenario
The toxic threat zone plot for MCLS of thionyl chloride storage is represented in ***Figure.1*** below.

Figure.1 ***Threat Zone (MCLS) Plot – Thionyl Chloride Storage***



Source: ALOHA

THREAT ZONE:

Threat Modeled: Toxic Level of Concern

Model Run: Gaussian

Red : 154 meters --- (14 ppm = AEGL-3 [60 min])

Orange: 379 meters --- (2.4 ppm = AEGL-2 [60 min])

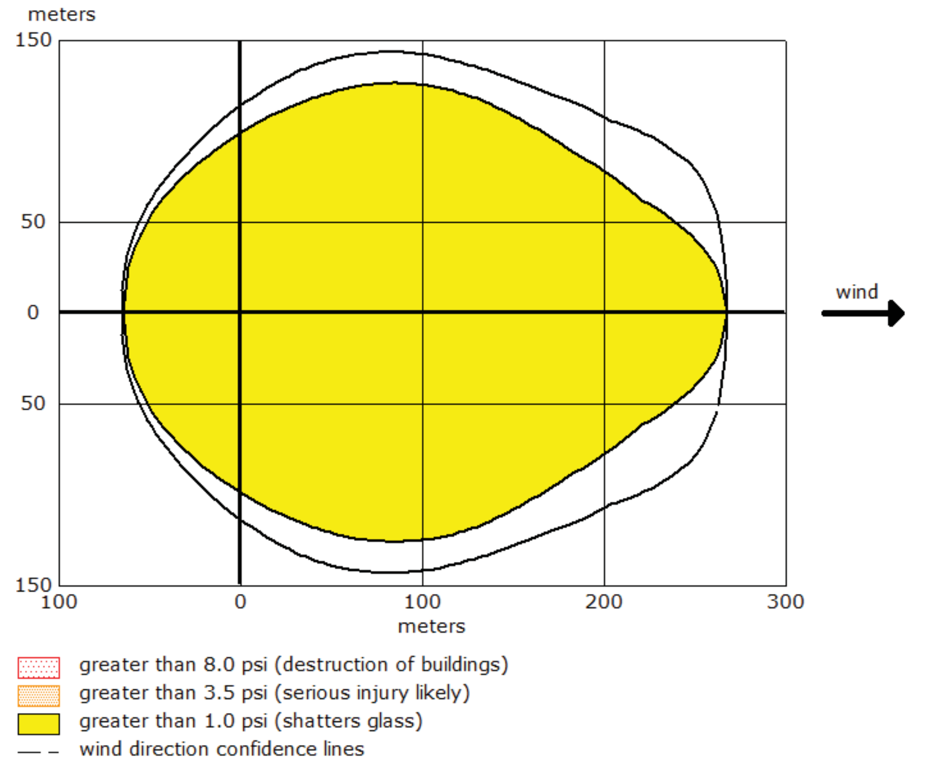
Yellow: no recommended LOC value --- (N/A = AEGL-1 [60 min])

The maximum effect resulting from catastrophic failure of thionyl chloride storage tank will be experienced within a maximum radial distance of 154m from the source with potential lethal effects within 1 hour.

Methanol Storage Tank – Maximum Credible Loss Scenario

The vapour cloud explosion (VCE) threat zone plot for Maximum Credible Loss Scenario of methanol storage tank is represented in ***Figure.2*** below.

Figure.2 ***Threat Zone Plot – Methanol Storage (VCE)***



Source: ALOHA

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: Gaussian

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

Orange: LOC was never exceeded --- (3.5 psi = serious injury likely)

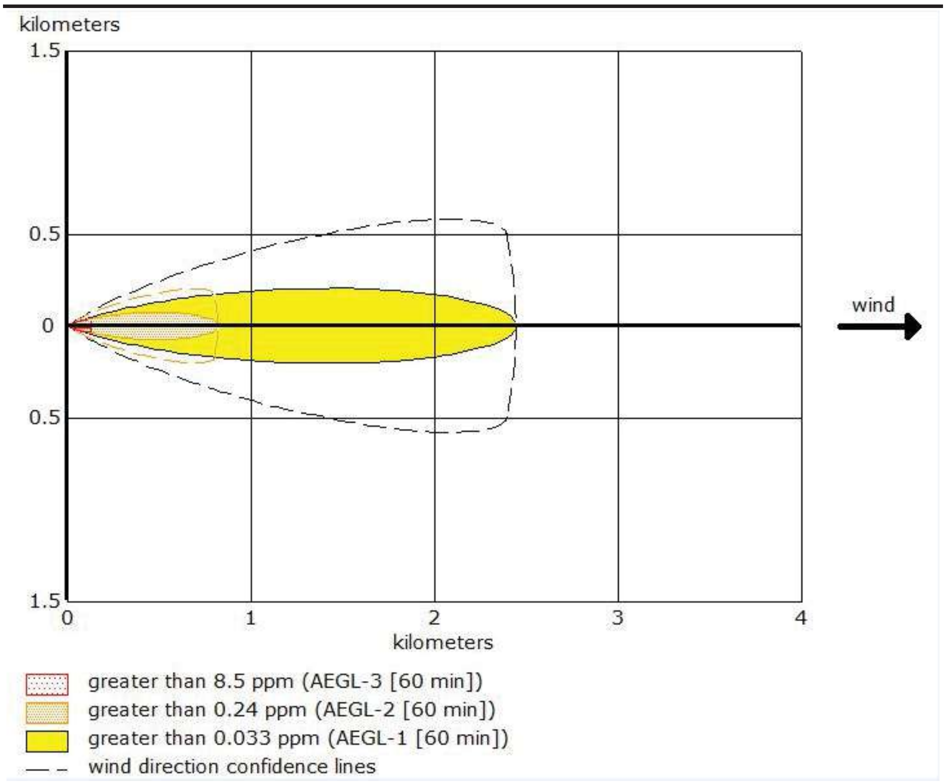
Yellow: 268meters --- (1.0 psi = shatters glass)

The blast overpressure of 1.0 psi generated from VCE is likely to be experienced within a radial distance of 268m. The Level of Concern (LOC) was never exceeded for blast overpressures of 8.0 psi and 3.5 psi respectively.

Bromine Storage Tank – Maximum Credible Loss Scenario

The toxic vapour threat zone plot for Maximum Credible Loss Scenario of bromine storage tank is represented in ***Figure.3*** below.

Figure.3 ***Threat Zone Plot (MCLS) – Bromine Storage***



Source: ALOHA

THREAT ZONE:

Threat Modeled: Toxic Level of Concern

Model Run: Gaussian

Red : 104 meters --- (8.5 ppm = AEGL-3 [60 min])

Orange: 645 meters --- (0.24 ppm = AEGL-2 [60 min])

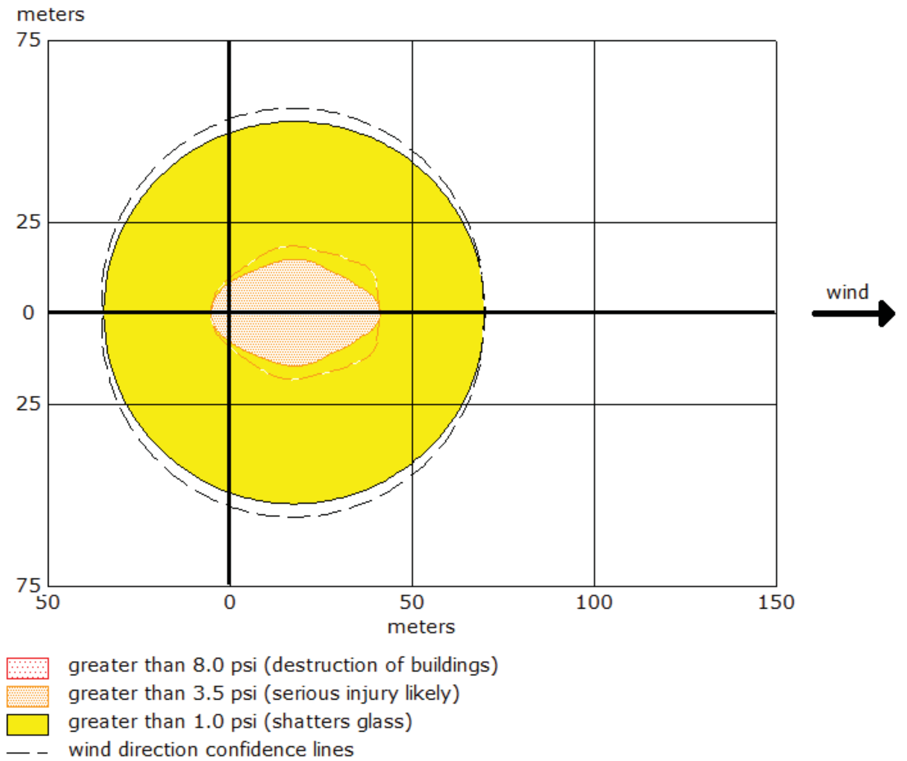
Yellow: 1900 meters --- (0.033 ppm = AEGL-1 [60 min])

The maximum effect resulting from catastrophic failure of bromine storage tank will be experienced within a maximum radial distance of 104m from the source with potential lethal effects within 1 hour.

Tri-Ethyl Amine Storage Tank – Maximum Credible Loss Scenario

The vapour cloud explosion (VCE) threat zone plot for Maximum Credible Loss Scenario of tri-ethyl amine (TEA) storage tank is represented in ***Figure.4*** below.

Figure.4 ***Threat Zone Plot – Tri-Ethyl Amine Storage (VCE)***



Source: ALOHA

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: Gaussian

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

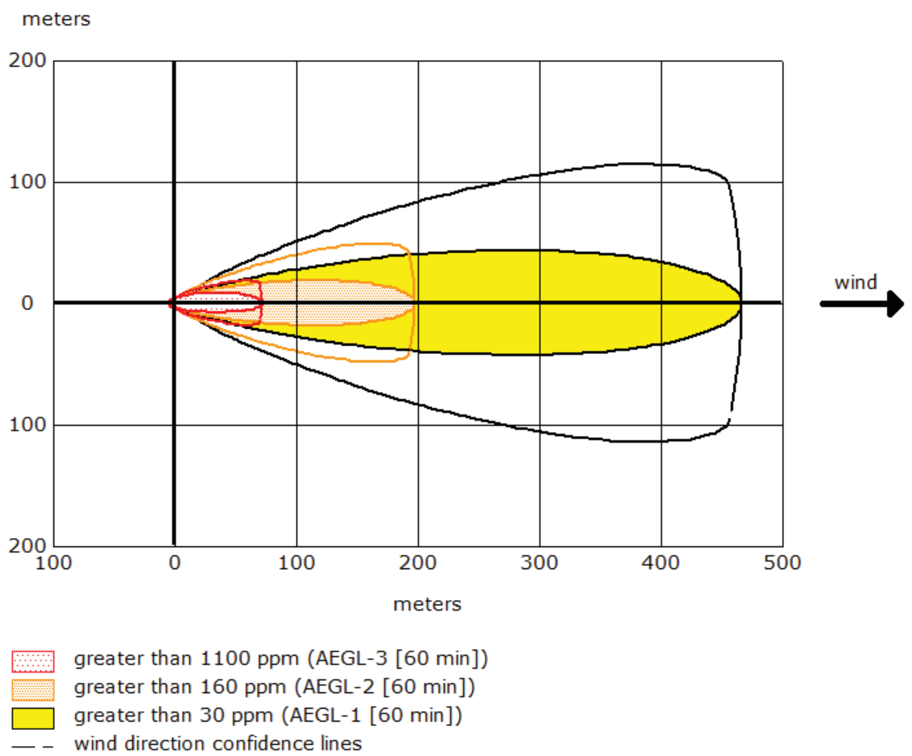
Orange: 42 meters --- (3.5 psi = serious injury likely)

Yellow: 70 meters --- (1.0 psi = shatters glass)

The blast overpressure of 3.5 psi and 1.0 psi generated from VCE is likely to be experienced within a radial distance of 42m and 70m respectively. The Level of Concern (LOC) was never exceeded for blast overpressures of 8.0 psi.

Ammonia (30%) Storage – Maximum Credible Loss Scenario
The toxic threat zone plot for Maximum Credible Loss Scenario of ammonia (30%) storage is represented in ***Figure.5*** below.

Figure.5 ***Threat Zone Plot – Ammonia (30%) Storage Tank***



Source: ALOHA

THREAT ZONE:

Threat Modeled: Toxic Level of Concern

Model Run: Gaussian

Red : 73 meters --- (1100 ppm = AEGL-3 [60 min])

Orange: 198 meters --- (160 ppm = AEGL-2 [60 min])

Yellow: 467 meters --- (30 ppm = AEGL-1 [60 min])

The maximum effect resulting from catastrophic failure of ammonia (30%) storage tank will be experienced within a maximum radial distance of 73m from the source with potential lethal effects within 1 hour.

Acetic Anhydride Storage Tank – Pool Fire 100 mm Leak Scenario
The pool fire threat zone plot for acetic anhydride storage tank will be as following:

THREAT ZONE:

Threat Modeled: Pool fire

Red : 22 meters --- (10 kw/m2 = potentially lethal within 60 seconds)

Orange: 27 meters --- (5 kw/m2 = second degree burns within 60 seconds)

Yellow: 36 meters --- (2 kw/m2 = pain within 60 seconds)

The thermal radiation potentially lethal within 60 seconds is likely to be experienced within a radial distance of 22m.

Ethyl Acetate Storage Tank – Pool Fire 100 mm Leak Scenario
The pool fire threat zone plot for ethyl acetate storage tank will be as following:

THREAT ZONE:

Threat Modeled: Pool fire

Red : 23 meters --- (10 kw/m2 = potentially lethal within 60 seconds)

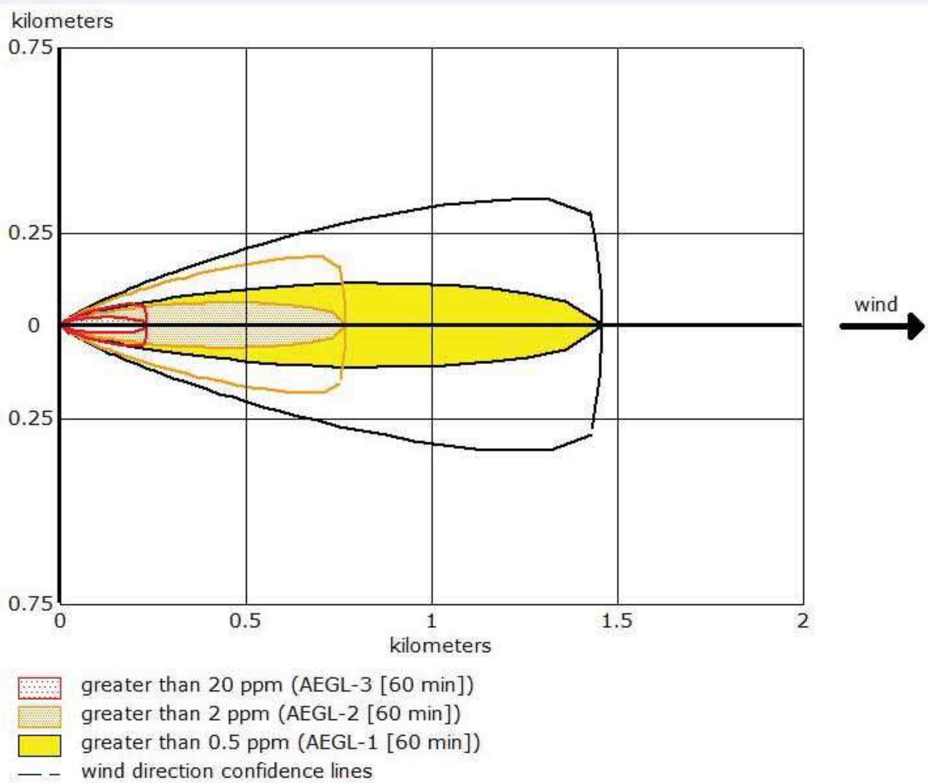
Orange: 30 meters --- (5 kw/m2 = second degree burns within 60 seconds)

Yellow: 41 meters --- (2 kw/m2 = pain within 60 seconds)

The thermal radiation potentially lethal within 60 seconds is likely to be experienced within a radial distance of 23m.

Chlorine Tonner – Maximum Credible Loss Scenario
The toxic vapour threat zone plot for Maximum Credible Loss Scenario of chlorine tonner is represented in ***Figure.6*** below.

Figure.6 ***Threat Zone (MCLS) Plot – Chlorine Tonner***



Source: ALOHA

THREAT ZONE:

Threat Modeled: Toxic Level of Concern

Model Run: Gaussian

Red : 233 meters --- (20 ppm = AEGL-3 [60 min])

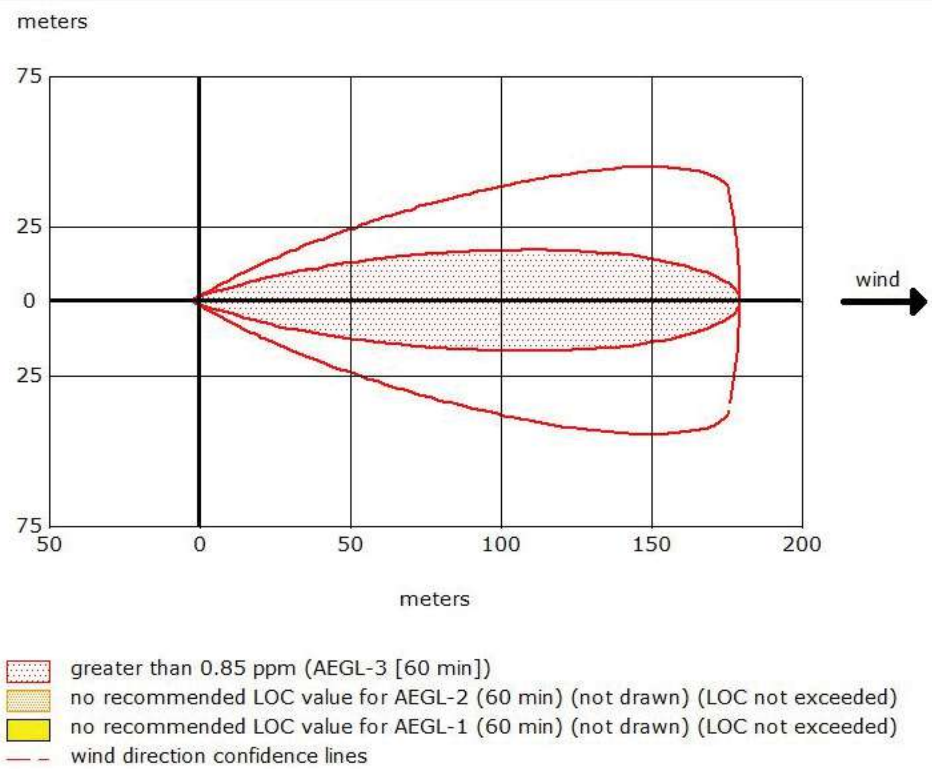
Orange: 769 meters --- (2 ppm = AEGL-2 [60 min])

Yellow: 1500 meters --- (0.5 ppm = AEGL-1 [60 min])

The maximum effect resulting from catastrophic failure of chlorine tonner will be experienced within a maximum radial distance of 233m from the source with potential lethal effects within 1 hour.

Phosphorous Oxychloride Storage Tank – Maximum Credible Loss Scenario
The toxic vapour threat zone plot for Maximum Credible Loss Scenario of phosphorous oxychloride is represented in ***Figure.7*** below.

Figure.7 ***Threat Zone (MCLS) Plot – Phosphorous Oxychloride Storage***



Source: ALOHA

THREAT ZONE:

Threat Modeled: Toxic Level of Concern

Model Run: Gaussian

Red : 180 meters --- (0.85 ppm = AEGL-3 [60 min])

Orange: no recommended LOC value --- (N/A = AEGL-2 [60 min])

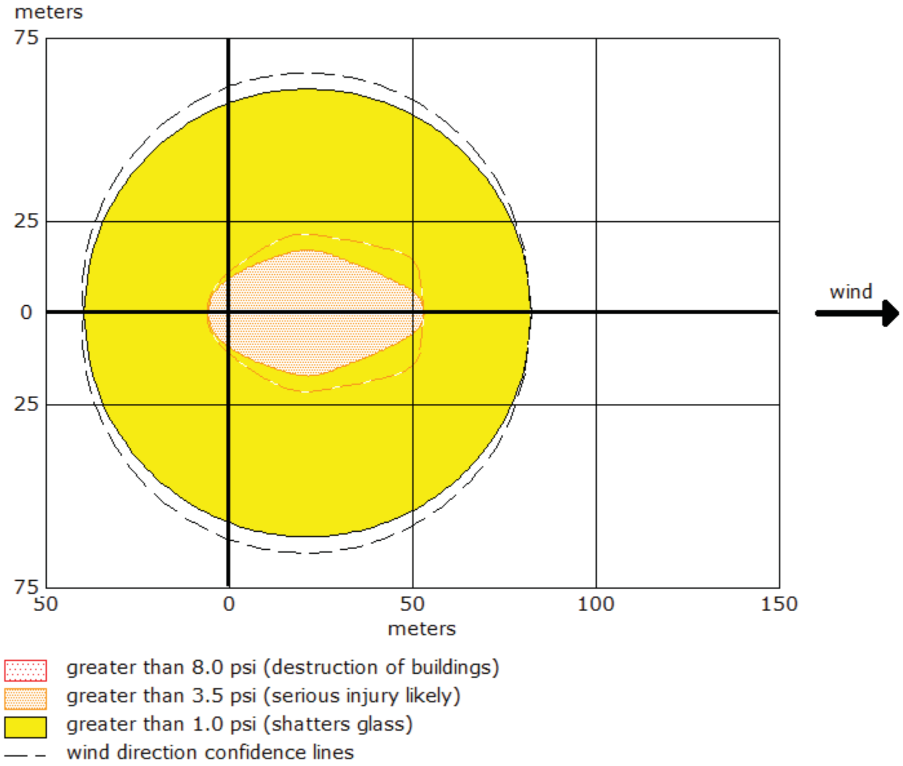
Yellow: no recommended LOC value --- (N/A = AEGL-1 [60 min])

The maximum effect resulting from catastrophic failure of phosphorous oxychloride storage tank will be experienced within a maximum radial distance of 180m from the source with potential lethal effects within 1 hour.

Acetone Storage – Maximum Credible Loss Scenario

The vapour cloud explosion (VCE) threat zone plot for Maximum Credible Loss Scenario of acetone storage is represented in ***Figure.8*** below.

Figure.8 ***Threat Zone Plot – Acetone Storage (VCE)***



Source: ALOHA

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: Gaussian

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

Orange: 53 meters --- (3.5 psi = serious injury likely)

Yellow: 82 meters --- (1.0 psi = shatters glass)

The blast overpressure of 3.5 psi and 1.0 psi generated from VCE is likely to be experienced within a radial distance of 53m and 82m respectively. The Level of Concern (LOC) was never exceeded for blast overpressures of 8.0 psi.

Acetone Cyanohydrin Storage – Pool Fire 100 mm Leak Scenario

The pool fire threat zone plot for acetone cynohydrin storage tank will be as following:

THREAT ZONE:

Threat Modeled: Pool fire

Red : < 10 meters --- (10 kw/m2 = potentially lethal within 60 seconds)

Orange: < 10 meters --- (5 kw/m2 = second degree burns within 60 seconds)

Yellow: < 10 meters --- (2 kw/m2 = pain within 60 seconds)

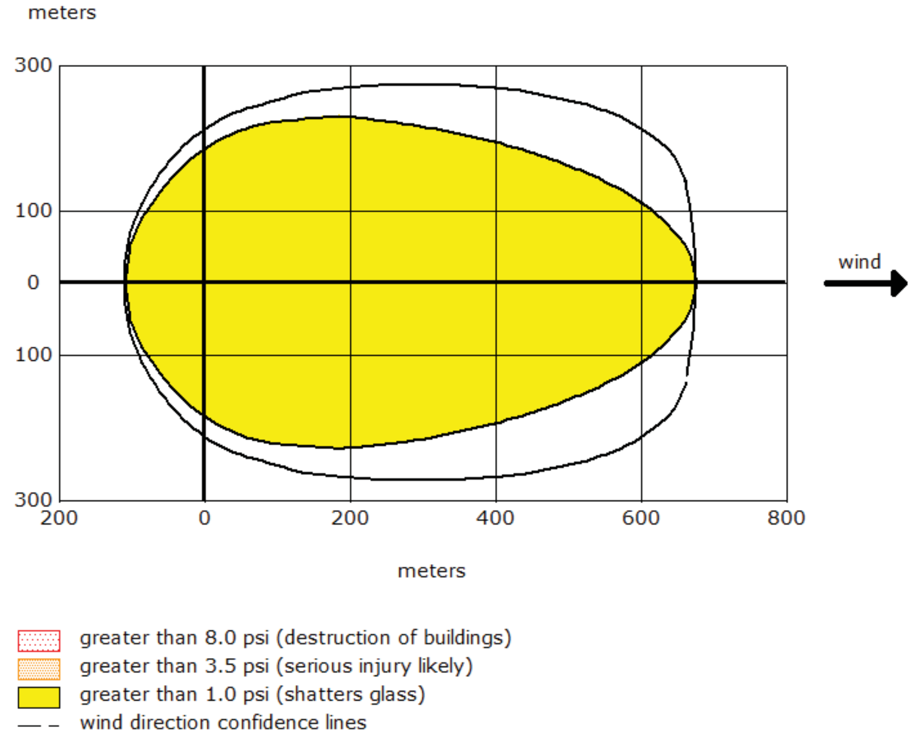
The thermal radiation potentially lethal within 60 seconds is likely to be experienced within a radial distance of < 10 m.

Fumes from fire being toxic needs special fire protection care.

Ethanol Storage Tank – Maximum Credible Loss Scenario

The vapour cloud explosion (VCE) threat zone plot for Maximum Credible Loss Scenario of ethanol storage tank is represented in ***Figure.9*** below.

Figure.9 ***Threat Zone Plot – Ethanol Storage Tank (VCE)***



Source: ALOHA

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: Gaussian

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

Orange: LOC was never exceeded --- (3.5 psi = serious injury likely)

Yellow: 676meters --- (1.0 psi = shatters glass)

The blast overpressure of 1.0 psi generated from VCE is likely to be experienced within a radial distance of 676m. The Level of Concern (LOC) never exceeded for blast overpressures of 8.0 psi and 3.5 psi respectively.

O-Cresol Storage – Pool Fire 100 mm Leak Scenario
The pool fire threat zone plot for O-Cresol from storage tank will be as following:

THREAT ZONE:

Threat Modeled: Pool fire

Red : 13 meters --- (10 kw/m2 = potentially lethal within 60 seconds)

Orange: 16 meters --- (5 kw/m2 = second degree burns within 60 seconds)

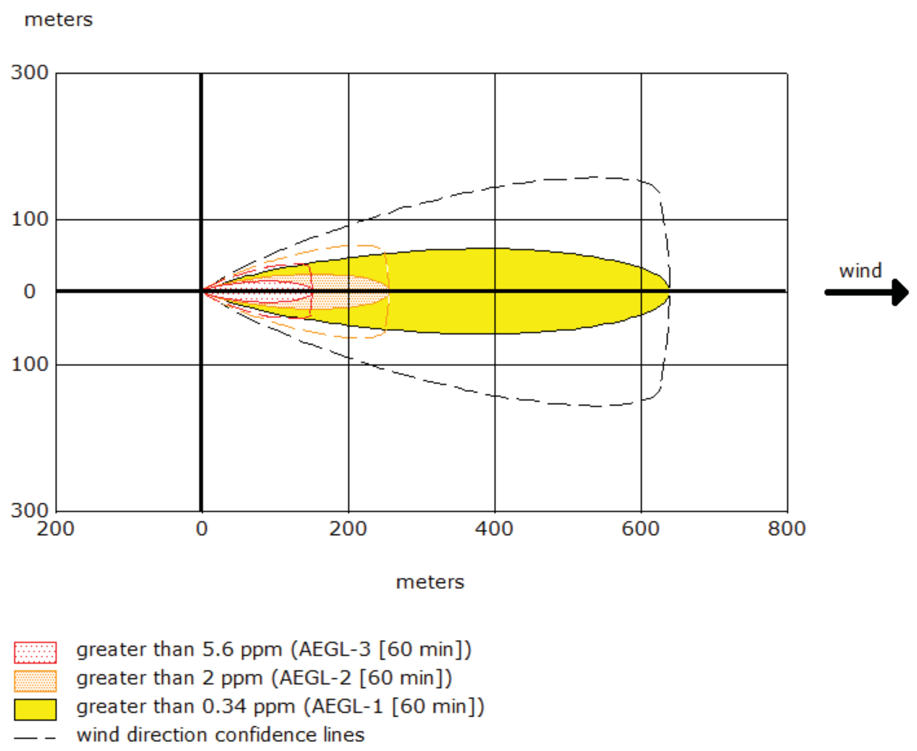
Yellow: 22 meters --- (2 kw/m2 = pain within 60 seconds)

The thermal radiation potentially lethal within 60 seconds is likely to be experienced within a radial distance of 13m.

Fumes from fire being toxic needs special fire protection care.

Phosphorous Tri-chloride – Maximum Credible Loss Scenario
The toxic vapour threat zone plot for Maximum Credible Loss Scenario of phosphorous tri-chloride storage is represented in ***Figure.10*** below.

Figure.10 ***Threat Zone Plot – Phosphorous Tri-Chloride Storage***



Source: ALOHA

THREAT ZONE:

Threat Modeled: Toxic Level of Concern

Model Run: Gaussian

Red : 152 meters --- (5.6 ppm = AEGL-3 [60 min])

Orange: 257 meters --- (2 ppm = AEGL-2 [60 min])

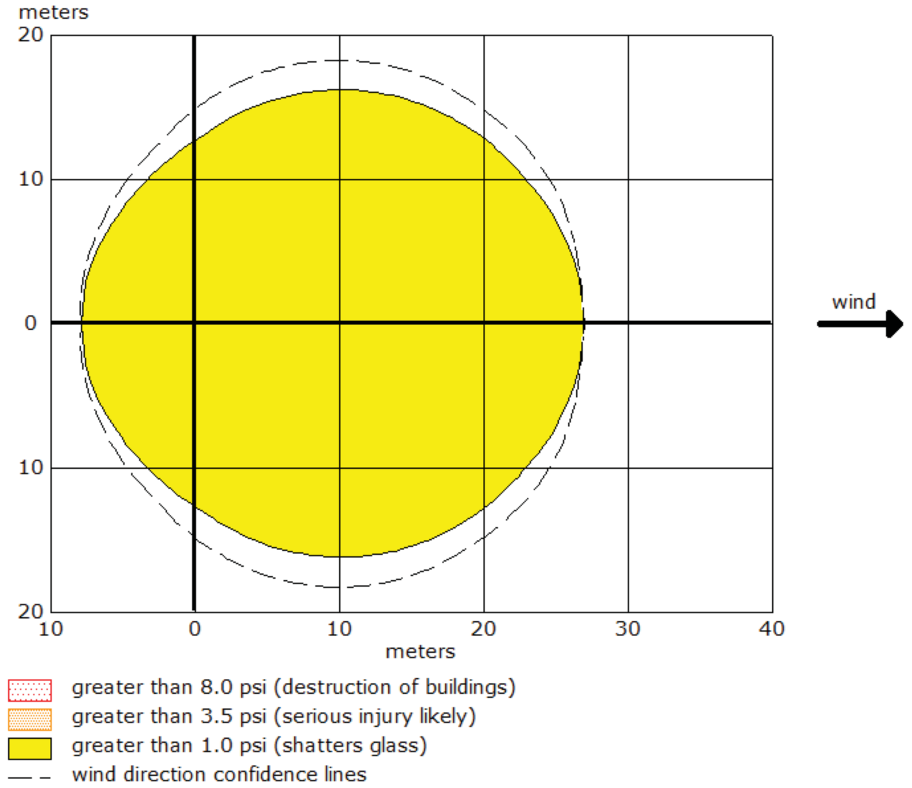
Yellow: 641 meters --- (0.34 ppm = AEGL-1 [60 min])

The maximum effect resulting from catastrophic failure of phosphorous tri-chloride storage likely to be experienced within a maximum radial distance of 152m from the source with potential lethal effects within 1 hour.

Methyl Chloride Storage – Maximum Credible Loss Scenario

The thermal radiation threat-zone plot for Maximum Credible Loss Scenario of methyl chloride storage represented in ***Figure.11*** below.

Figure.11 ***Threat Zone Plot – Methyl Chloride Storage (VCE)***



Source: ALOHA

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: Gaussian

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

Orange: LOC was never exceeded --- (3.5 psi = serious injury likely)

Yellow: 27 meters --- (1.0 psi = shatters glass)

The blast overpressure of 3 1.0 psi generated from VCE is likely to be experienced within a radial distance of 27m and 61m respectively. The Level of Concern (LOC) never exceeded for blast overpressures of 8.0 psi and 3.5 psi.

Furnace Oil Storage – Pool Fire 100 mm Leak Scenario
The pool fire threat zone plot for Furnace Oil leak from storage tank will be as following:

THREAT ZONE:

Threat Modeled: Pool fire

Red : 27 meters --- (10 kw/m2 = potentially lethal within 60 seconds)

Orange: 36 meters --- (5 kw/m2 = second degree burns within 60 seconds)

Yellow: 53 meters --- (2 kw/m2 = pain within 60 seconds)

The thermal radiation potentially lethal within 60 seconds is likely to be experienced within a radial distance of 27m.