Risk Assessment

Industrial accidents result in severe impact on Environment including human life and significant financial loss. The impacts could be so huge that it drives the project towards non-viability besides other significant hardships. Therefore, risk assessment is done to ensure that hazards associated with each and every activity related to the project are identified. Risk Assessment involves the identification and quantification of various hazards (unsafe conditions) that exists in the plant.

Methodology

Risk associated with each of these hazards is assessed and quantified. Based on the significance of risk suggest mitigation measures and plan for an on-site emergency preparedness and disaster management plan. The mitigation measures, in the order of priority, would be aimed at eliminating the risk, minimising the risk, prepare for the risk.

The project deals with handling of some chemicals which are hazardous in nature due to their intrinsic chemical properties and/or due to their operating parameters. The list of hazardous chemicals as identified under MSHIC are given in Table 7.1 below

Properties of chemicals

Chemical	Max Quantity stored m3	Properties/Hazard associated with the chemical
HCl Hydrochloric acid CAS No: 7647-01-0 UN No:1789	40	Not Flammable; Inhalation of fumes results in coughing and choking sensation, and irritation of nose and lungs. Liquid causes burns
Ethyl Acetate CAS No: 141-78-6 UN No:1173 A clear colourless liquid with a fruity odour.	20	Flammability: Highly Flammable Health Hazard: Causes respiratory irritation and irritation of eyes
Toluene CAS No: 108-88-3 UN No: 1294 A clear colourless liquid with a characteristic aromatic odour. Flash point 40°F	10	Flammability: Ignites at normal temperatures; Vapour is heavier than air and may travel a considerable distance to a source of ignition and flash back. Health Hazard: Vapours irritate eyes and upper respiratory tract, cause dizziness, headache, respiratory arrest. Liquid irritates eyes and causes drying of skin. If aspirated, causes coughing, gagging, distress, and rapidly developing pulmonary oedema. If ingested causes vomiting, griping, diarrhoea, depressed respiration.
Chlorine CAS No:7782- 50-5 UN No:1017. A greenish	7.0 tonnes	(Gas); Non Combustible; May ignite other combustible materials (wood, paper, oil, etc.). Mixture with fuels

yellow gas with a pungent suffocating odour. Toxic by inhalation.		may cause explosion. Health Hazards: Poisonous; may be fatal if inhaled. Contact may cause burns to skin and eyes. Bronchitis or chronic lung conditions

Scenarios considered for hazard identification

1. The materials involved in storage and transfer system have flammable and toxic hazards. Potential failure scenarios considered are as under:
2. Spillage of material from above-ground storage tanks due to overflow from tank or leakage from tank and connected piping;
3. Spillage of material during tanker unloading or transfer to process unit
4. Spillage of material contained in underground tanks from discharge line of transfer pump.
5. Storage of chlorine cylinder and chlorination operation

A risk rating matrix (Table 7.2 below) is devised

- to identify the hazards associated with all activities at project site during construction and operation phase
- Identify the risks associated with these hazards and
- Rate the risks to identify the major risks for focussed attention for developing and
- suggesting mitigation measures

Risk Rating Matrix

IDENTIFICATION OF RISKS AND RATING OF RISKS						
Sl. No.	**Activity**	**Cause/Aspect**	**Risk**	**Risk**		**Risk Rating = S x P**
				S Severity 1 to 5	**P Probability of Occurrence 1 to 5**	
Construction Phase						
1	Civil work like levelling/Excavation (includes vehicular movement)	Mis-handling of earth moving equipment	Accident	3	2	6
		Unsecured pits	Fall hazard	3	2	6
2	Erection of Reactors	Work at height without PPE	Fall Hazard	4	1	4
		Use of Non-standard tools	Injury	1	4	4
Operation Phase						

1	Operation of Boiler	Explosion due not maintaining process parameters	Injury	5	1	5
2	Operation of DG set	Working without PPE to protect against noise	Injury	3	2	6
		Spillage of Oil	Fire hazard	4	1	6
3	Chlorine handling	Tonner leakage	Toxic release	5	1	5
	Solvent Storage	Leakage/Fugitive emissions	Fire hazard	5	1	5
			Toxic release	5	1	5
	HCl storage	Gaseous emissions	Toxic release	1	5	5
		Leakage	Toxic release	1	3	3
			Injury	2	3	6
	Risks with risk rating 5 and above are considered as unacceptable risks needing immediate attention					

Classification of risks is given in Table below:

Risk classification

Risk Rating	Risk Level	Risk Control Measures	Note
6	Extreme	Reduction risk measures need to be taken immediately, and tasks should not be started until the risk is reduced.	Unacceptable risks
5	Very High	Risk control measures must be taken within a certain period of time, and tasks cannot be started until the risk is reduced.	
4	High	Based on cost or financial considerations, risk reduction measures should be taken gradually.	Needs attention
3	Medium	There is no need to take risk reduction measures at the moment, but it is necessary to ensure the effectiveness of existing protection facilities.	Acceptable risks
1-2	Low	No risk reduction measures are required, but the effectiveness of existing safeguards must be ensured.	

Criteria for Risk rating for Severity and Probability

Severity S	Rating
Minor Injury requiring first aid	1
Injury requiring hospitalisation	2
Temporary disability	3
Permanent disability	4
Loss of life/s	5

Probability of Occurrence P	Rating
Once a Year	1
Once a month	2
Once a week	3
Daily but intermittently	4
Continuous	5

The following aspects and related risks are considered for the risk rating carried out above.

Sl. No.	Cause/Aspect	Risk
1	• Leakage from unloading hose • Damaged hose • Improper hose connection • Flange gasket leak • Movement of tanker during unloading	• Exposure to toxic chemicals • Fire/ explosion hazard due to flammable liquid release. • Loss of chemical. • Soil/ water contamination
2	Leakage from pump seal	• Exposure to toxic chemicals • Fire/ explosion hazard due to flammable liquid release • Loss of chemical • Soil/ water contamination
3	Unloading of wrong chemical into tank	• Contamination of large inventory of tank contents • Possible reaction hazard due to mixing of incompatible chemicals.
4	Static electric charge accumulation in road tanker.	Ignition hazard due to static electricity during tanker unloading.
5	Overflow from storage tank by excess filling due to malfunction of tank level instrument.	• Exposure to toxic chemical • Fire/ explosion hazard due to flammable liquid release • Loss of chemical
6	Release of chemical vapour from tank vent during filling and high ambient temperature.	• Air pollution due to volatile organic chemical emission • Loss of chemical from tank

Maximum Credible Accident (MCA) analysis

Further, the study included risk assessment for consequence by estimating maximum damage distance by Maximum Credible Accident (MCA) analysis. The study helps in drawing damage contours to assess the consequence of an event. The analysis does not consider probability of occurrence. The probability is therefore rated on experience and previous similar experience elsewhere.

Consideration of a large number of scenarios in the same geographical location serves little purpose if the dominant scenario has been identified and duly considered. Therefore, the Consequence Analysis has been done for selected scenarios by ALOHA (version 5.4.7) of EPA.

Hazardous Materials stored above-ground

Solvent/chemical	Dia m	Height m	Volume m3	Max Quantity stored
HCl	2.4	4.5	20	15 KL
Ethyl Acetate	2.5	4.5	20	15 KL
Toluene	2.0	4.0	10	5 KL

Chlorine	900-980 kg Tonners	7.0 Tonnes

Out of the chemicals mentioned in above table, severity mapping is done for Toluene and Ethyl Acetate using ALOHA software.

ALOHA simulation analysis:

TOLUENE

Site Data

- Location: Jigani, Bangalore, India
- Building Air Exchanges Per Hour: 0.76 (sheltered single storied)
- Time: March 30, 2019 1032 hours ST (using computer's clock)

Chemical Data

- Chemical Name: Toluene
- CAS Number: 108-88-3, Molecular Weight: 92.14 g/mol
- AEGL-1 (60 min): 67 ppm AEGL-2 (60 min): 560 ppm AEGL-3 (60 min): 3700 ppm
  (AEGL – Acute Exposure Guideline Level)
- IDLH: 500 ppm, LEL: 11000 ppm, UEL: 71000 ppm
- IDLH - Immediately Dangerous to Life or Health
- Ambient Boiling Point: 224.5° F
- Vapour Pressure at Ambient Temperature: 0.048 atm
- Ambient Saturation Concentration: 53,816 ppm or 5.38%

Atmospheric Data: (Manual Input of Data)

- Wind: 4.4 m/s from NE at 3 m
- Ground Roughness: open country, Cloud Cover: 3 tenths
- Air Temperature: 30° C, Stability Class: C
- No Inversion Height, Relative Humidity: 50%

Scenario 1- Leaking tank, chemical is not burning and forms an evaporating puddle

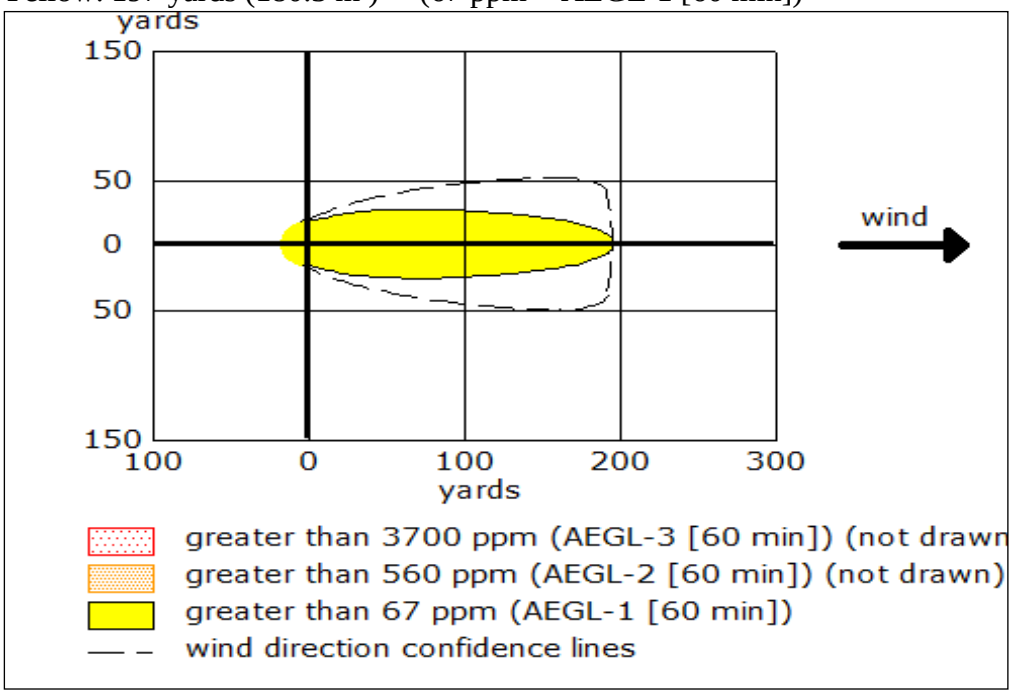
Source Strength

- Leak from hole in vertical cylindrical tank
- Flammable chemical escaping from tank (not burning)
- Tank Diameter: 2 m, Tank height: 4 m
- Tank Volume: 12.6 m3
- Tank contains liquid, Internal Temperature: 30° C
- Chemical Mass in Tank: 10.1 ton, Tank is 85% full.
- Circular Opening Diameter: 10 cm
- Opening is at a height of 2.00 m from tank bottom
- Ground Type: Concrete

- Ground Temperature: equal to ambient
- Max Puddle Diameter: Unknown
- Release Duration: ALOHA limited the duration to 1 hour
- Max Average Sustained Release Rate: 146 pounds/min (averaged over a minute or more)
- Total Amount Released: 8,289 pounds
    - Note: The chemical escaped as a liquid and formed an evaporating puddle.
- The puddle spread to a diameter of 35 yards.

Threat zone

- Threat Modelled: Toxic area of vapour cloud
- Model Run: Gaussian
- Red : 17 yards (15.54 m) --- (3700 ppm = AEGL-3 [60 min])
    - Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.
- Orange: 35 yards (32.004 m) --- (560 ppm = AEGL-2 [60 min])
    - Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.
- Yellow: 197 yards (180.3 m)--- (67 ppm = AEGL-1 [60 min])



Threat zone

- Threat Modeled: Flammable Area of Vapor Cloud
- Model Run: Gaussian
- Red : 17 yards --- (6600 ppm = 60% LEL = Flame Pockets)
    - Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.
- Yellow: 32 yards --- (1100 ppm = 10% LEL)

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

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
- No explosion: no part of the cloud is above the LEL at any time

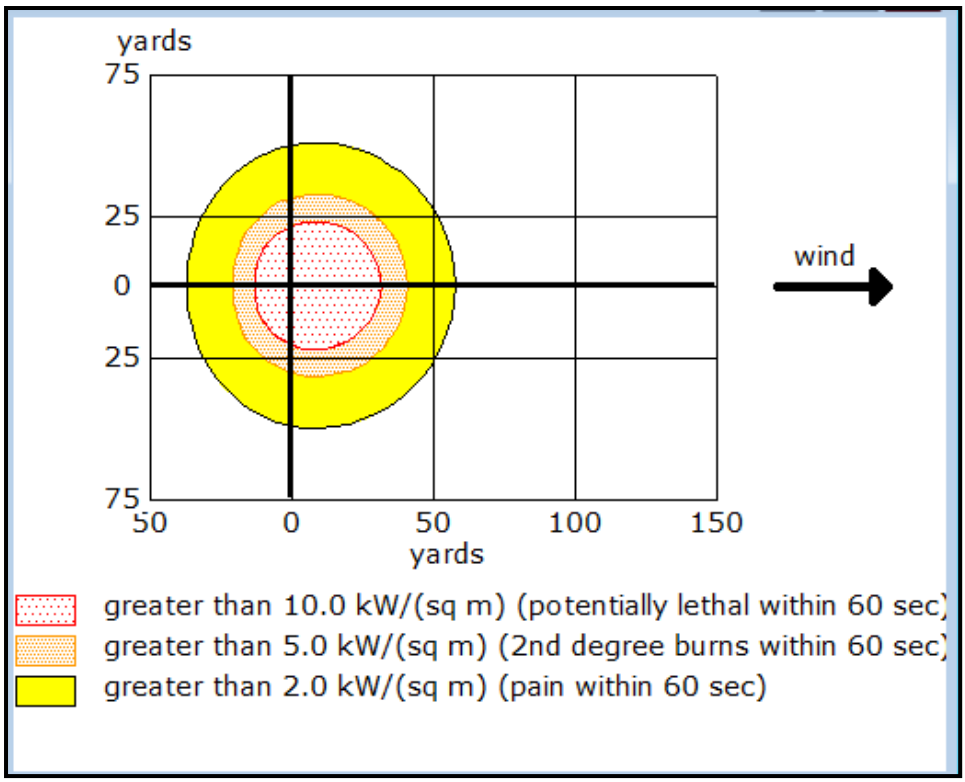
Scenario- 2 leaking tank chemical is burning and pool fire

Source strength

- Leak from hole in vertical cylindrical tank
- Flammable chemical is burning as it escapes from tank
- Tank Diameter: 2 m, Tank Length: 4 m
- Tank Volume: 12.6 m3
- Tank contains liquid, Internal Temperature: 30° C
- Chemical Mass in Tank: 10.1 tons, Tank is 85% full
- Circular Opening Diameter: 10 cm
- Opening is 2.00 m from tank bottom
- Max Puddle Diameter: Unknown
- Max Flame Length: 20 yards, Burn Duration: 12 minutes
- Max Burn Rate: 836 pounds/min
- Total Amount Burned: 8,349 pounds
- Note: The chemical escaped as a liquid and formed a burning puddle.
- The puddle spread to a diameter of 10.8 yards.

Threat Zone

- Threat Modelled: Thermal radiation from pool fire
- Red : 32 yards --- (10.0 kW/(sq m) = potentially lethal within 60 sec)
- Orange: 41 yards --- (5.0 kW/(sq m) = 2nd degree burns within 60 sec)
- Yellow: 58 yards --- (2.0 kW/(sq m) = pain within 60 sec)



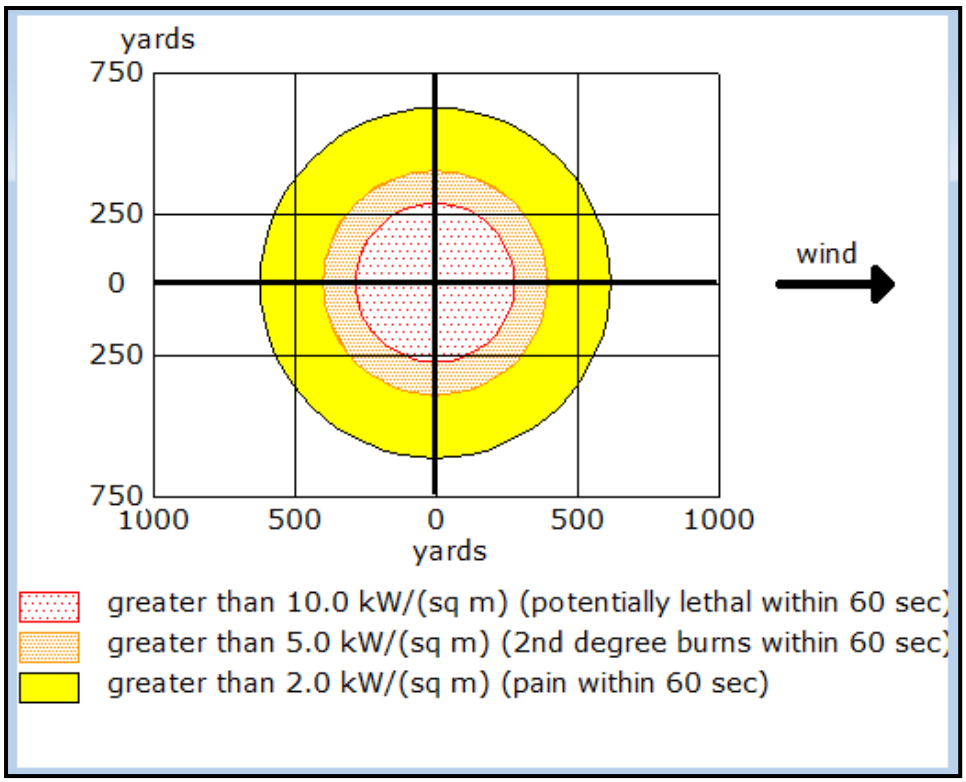
Scenario 3 – BLEVE, tank explodes and chemical burns in a fireball

Source Strength

- BLEVE of flammable liquid in vertical cylindrical tank
- Tank Diameter: 2 m, Tank Length: 4 m
- Tank Volume: 12.6 m3
- Tank contains liquid
- Internal Storage Temperature: 30° C
- Chemical Mass in Tank: 10.1 tons, Tank is 85% full
- Percentage of Tank Mass in Fireball: 100%
- Fireball Diameter: 133 yards, Burn Duration: 9 seconds

Threat Zone

- Threat Modelled: Thermal radiation from fireball
- Red : 279 yards --- (10.0 kW/(sq m) = potentially lethal within 60 sec)
- Orange: 395 yards --- (5.0 kW/(sq m) = 2nd degree burns within 60 sec)
- Yellow: 617 yards --- (2.0 kW/(sq m) = pain within 60 sec)



Ethyl acetate

Site Data

- Location: Jigani, Bangalore, India
- Building Air Exchanges Per Hour: 0.72 (sheltered single storied)
- Time: March 30, 2019 1110 hours ST (using computer's clock)

Chemical Data

- Chemical Name: Ethyl Acetate
- CAS Number: 141-78-6, Molecular Weight: 88.11 g/mol
- PAC-1: 1200 ppm, PAC-2: 1700 ppm, PAC-3: 10000 ppm
- IDLH: 2000 ppm, LEL: 21800 ppm, UEL: 115000 ppm
- Ambient Boiling Point: 165.1° F
- Vapour Pressure at Ambient Temperature: 0.16 atm
- Ambient Saturation Concentration: 173,526 ppm or 17.4%
- Atmospheric Data: (Manual Input Of Data)
- Wind: 4.4 m/s from NE at 3 m
- Ground Roughness: urban or forest Cloud Cover: 3 tenths
- Air Temperature: 30° C, Stability Class: C
- No Inversion Height, Relative Humidity: 50%

Scenario 1- Leaking tank, chemical is not burning and forms an evaporating puddle

Source Strength

- Leak from hole in vertical cylindrical tank
- Flammable chemical escaping from tank (not burning)
- Tank Diameter: 2.5 m, Tank Length: 4.5 m
- Tank Volume: 22.1 m3
- Tank contains liquid, Internal Temperature: 30° C
- Chemical Mass in Tank: 18.4 tons, Tank is 85% full
- Circular Opening Diameter: 10 cm
- Opening is 2.25 m from tank bottom
- Ground Type: Concrete
- Ground Temperature: equal to ambient
- Max Puddle Diameter: Unknown
- Release Duration: 40 minutes
- Max Average Sustained Release Rate: 465 pounds/min (averaged over a minute or more)
- Total Amount Released: 15,211 pounds
    - Note: The chemical escaped as a liquid and formed an evaporating puddle.
- The puddle spread to a diameter of 39 yards.

Threat Zone

- Threat Modelled: Toxic area of vapour cloud
- Model Run: Gaussian
- Red : 20 yards --- (10000 ppm = PAC-3)
- Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.
- Orange: 22 yards --- (1700 ppm = PAC-2)
    - Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.
- Yellow: 26 yards --- (1200 ppm = PAC-1)
    - Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.

Threat Zone

- Threat Modelled: Flammable Area of Vapour Cloud
- Model Run: Gaussian
- Red : 20 yards --- (13080 ppm = 60% LEL = Flame Pockets)
    - Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.
- Yellow: 26 yards --- (2180 ppm = 10% LEL)
    - Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.

Threat Zone

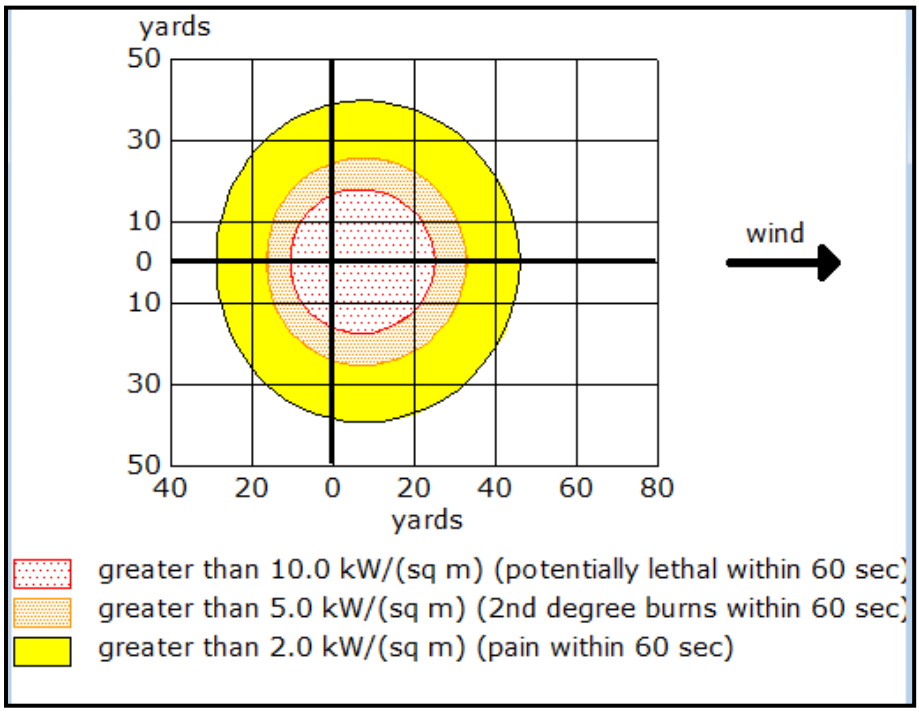
- Threat Modelled: Overpressure (blast force) from vapour cloud explosion
- Type of Ignition: ignited by spark or flame

- Level of Congestion: congested
- Model Run: Gaussian
- No explosion: no part of the cloud is above the LEL at any time

Scenario- 2 leaking tank chemical is burning and pool fire

Threat Zone

- Threat Modeled: Thermal radiation from pool fire
- Red : 26 yards --- (10.0 kW/(sq m) = potentially lethal within 60 sec)
- Orange: 33 yards --- (5.0 kW/(sq m) = 2nd degree burns within 60 sec)
- Yellow: 46 yards --- (2.0 kW/(sq m) = pain within 60 sec)



Scenario 3 – BLEVE, tank explodes and chemical burns in a fireball

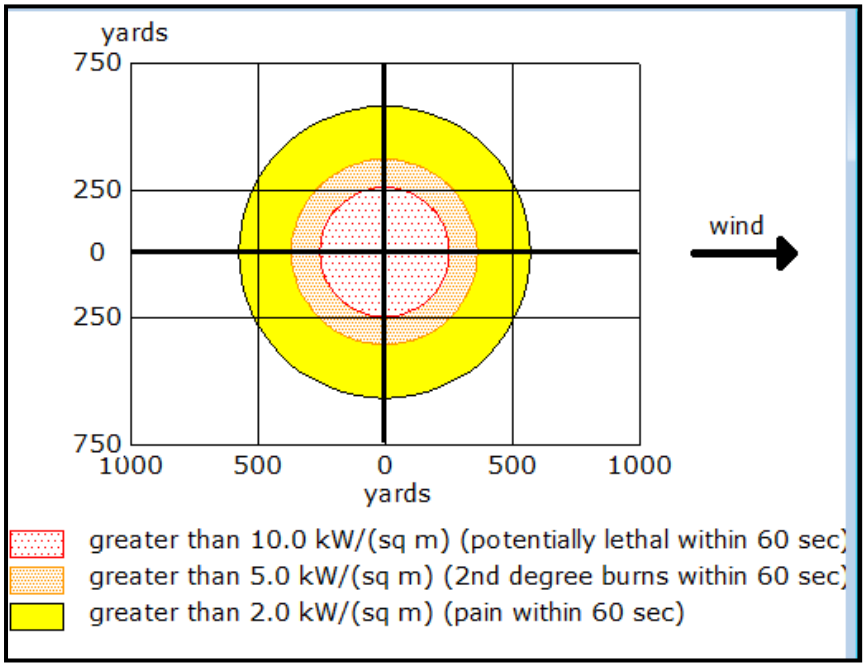
Source Strength

- BLEVE of flammable liquid in vertical cylindrical tank
- Tank Diameter: 2.5 m, Tank Length: 4.5 m
- Tank Volume: 22.1 m3
- Tank contains liquid
- Internal Storage Temperature: 30° C
- Chemical Mass in Tank: 18.4 tons, Tank is 85% full
- Percentage of Tank Mass in Fireball: 100%
- Fireball Diameter: 162 yards, Burn Duration: 10 seconds

Threat Zone

- Threat Modelled: Thermal radiation from fireball
- Red : 253 yards --- (10.0 kW/(sq m) = potentially lethal within 60 sec)
- Orange: 364 yards --- (5.0 kW/(sq m) = 2nd degree burns within 60 sec)

- Yellow: 572 yards --- (2.0 kW/(sq m) = pain within 60 sec)



Summary of MCA analysis:

Toluene:

Sl. No.	Scenario	Threat Modelled	Damage Distance in m	
1	Leaking tank, chemical is not burning and forms an evaporating puddle	Toxic area of vapour cloud	180	67 ppm = AEGL-1 [60 min]
		Flammable Area of Vapour Cloud	29.3	1100 ppm = 10% LEL
		Overpressure (blast force) from vapour cloud explosion	0.0	No part of the cloud is above the LEL at any time
2	Leaking tank chemical is burning and there is pool fire	Thermal radiation from pool fire	53.1	2.0 kW/(sq m) = pain within 60 sec
3	BLEVE, tank explodes and chemical burns in a fireball	Thermal radiation from fireball	564.6	2.0 kW/(sq m) = pain within 60 sec

Ethyl Acetate:

Sl. No.	Scenario	Threat Modelled	Damage Distance in m	Damage distance

1	Leaking tank, chemical is not burning and forms an evaporating puddle	Toxic area of vapour cloud	23.8	1200 ppm = PAC-1
		Flammable Area of Vapour Cloud	23.8	2180 ppm = 10% LEL
		Overpressure (blast force) from vapour cloud explosion	0.00	No part of the cloud is above the LEL at any time
2	Leaking tank chemical is burning and there is pool fire	Thermal radiation from pool fire	42.0	2.0 kW/(sq m) = pain within 60 sec
3	BLEVE, tank explodes and chemical burns in a fireball	Thermal radiation from fireball	564.6	2.0 kW/(sq m) = pain within 60 sec

Risk Mitigation Measures

Safety Measures for Transportation, Storage & Handling of chemicals

- Solvent unloading standard procedure shall be followed for safe unloading of chemicals from tanker
- Static earthing provision shall be made for tanker unloading
- Display Boards shall be provided on all storage tanks to communicate the material of construction, Name of the chemical stored and MSDS
- On-site detectors for fire & smoke detection with alarm system shall be provided as required
- Relevant Fire extinguishers shall be provided at accessible places
- First aids boxes shall also be provided in all control rooms/cabins
- The entire premises will be declared as “NO SMOKE ZONE”.
- Flammable chemicals and gas shall be stored in open area outside the plant with all the safety measures.
- Hazardous material handling shall be carried out by using all PPE with proper ventilation and under supervision.

Safety Measures for Process Units

- Any reaction upsets shall be confined to the reaction vessel itself as defined quantity of raw materials will be issued to the reaction vessel by metering pumps
- Process parameters control shall be provided vide Standard Operating Procedures.
- Hazardous materials shall be transferred by pipelines and in controlled manner
- Trained person shall be engaged for handling of hazardous materials and proper safety precautions shall be taken
- All solvents and flammable materials shall be stored away from the process plant and required quantity of material will be charged in reactor by pump
- All the vessels and equipments shall be well earthed appropriately and well protected against Static Electricity
- Flame proof light fittings shall be installed in the plant

- All the plant personnel shall be provided with Personal Protection Equipments like Helmets, Safety Shoes and Safety Glasses
- Material Safety Data Sheets of raw materials and products shall be kept readily available

Safety measures to prevent spillage / leakage of toxic chemicals

- Relevant Personal Protective Equipment like goggles, gloves, protective clothes will be provided to those handling toxic chemicals
- All the toxic chemicals shall be stored under adequate safe condition
- The storage of corrosive and toxic chemicals shall be segregated from each other
- The piping shall be examined thoroughly for finding out any defects
- Smoking shall be prohibited inside the factory
- All tankages storing hazardous chemicals shall be tested periodically for the thickness
- Record shall be maintained
- All pipe joints shall be provided with heavy duty gaskets to prevent any leakage
- Dyke wall shall be provided to areas where hazardous chemicals are stored
- Spare barrels of sufficient quantity shall be kept ready for any emergency spillage or leakage

Mitigation measures for solvents storage, handling and transportation

- All hazardous raw materials should be stored in carboys, drums etc. in a ware house. The list of non-compatible chemicals is made and displayed in the ware house.
- Storage quantities should be kept at the bare minimum and planned carefully depending on production plan. Overstocking or stocking for long time should be avoided.
- Loading and unloading procedure for solvents should be prominently displayed near the tanks.
- All pump motors, switches, lighting should be made flameproof.
- Safety instructions and MSDS should be displayed prominently at the storage area, both in English as well as local language.
- Safe clear distances between the tanks should be maintained.
- Firefighting hydrant system, hydrant layout, dedicated water storage tank for firefighting, firefighting pumps should be designed and installed as per IS code 13039 and IS 9668 and other applicable codes.

General safety measures/precautions

- Employees should be trained in the safe handling practices of hazardous chemicals such as solvents, acids, caustics, ammonia etc.
- Standard operating procedures should be established and followed when cleaning up chemical spills, handling of toxic/hazardous chemicals
- To know the material nature, potential hazards (health, fire, reactivity and environmental) and how to work safely with the materials MSDS should be provided at the work place
- Materials which give off toxic, asphyxiate, or anaesthetic vapours or fumes should be stored in remote or isolated locations when not in use, e.g. bulk ammonia storage

- While handling of toxic gas cylinders to identify leakages, gas detector system is provided at ammonia gas handling area
- In case of leakage the toxic / hazardous materials automatic water sprinkler systems are switched on to control the toxic vapours at work place
- Goggles/face shields are provided for eye/face protection
- In case of spillage/leakage while handling of hazardous materials spill control kit should be provided at work place

Specific Recommendations based on Hazard and severity mapping for hazardous raw materials

According to the ALOHA simulation analysis, the consequential impacts from each incident scenarios can be though thermal radiation, over pressure wave and toxic release. The damage distance indicates that consequential impacts with respect to over pressure wave and toxic release would be on plant personnel, equipment and machinery. Whereas, consequential impacts with respect to thermal radiation, would be to men and material of the plant and could be even beyond up to a distance of 565 m in the downwind direction. The storage of Toluene and Ethyl Acetate needs utmost attention owing to the magnitude of the impact.
The specific engineering or management recommendations based on the simulation analysis are as under:

Mechanical and equipment integrity

Following are the Engineering Recommendations:

- The material of construction and thickness of storage vessels are designed to accommodate the maximum pressure.
- The tanks are located in isolated areas where there are no/minimum personnel would be working in the downwind direction at any given point of time
- To ensure no equipment sensitive to thermal radiation are installed in the downwind direction of these tanks
- The tanks should be provided with dyke wall with arrangement to recover the spillage/leakage
- Provide with high pressure detector with interlock to the incoming material
- Provide high temperature alarm with an interlock to cut off the heat source

Management Approach

Following are the Management Recommendations:

- The operating personnel are trained on the consequential impacts and the action to be taken under different scenarios
- The operating personnel have relevant PPE
- List of Dos and Don’ts to be displayed
- These storage tanks are tested every 6 months to confirm that there is no loss of material of construction and the tank thickness is intact. Record of such testing is maintained for reference.