CHAPTER 6. HAZARDS ANALYSIS & RISK ASSESSMENT

This Chapter provides details risk associated with the project activities and storage of hazardous chemical.

6.1. Introduction

Industrial plants deal with materials, which are generally hazardous in nature by virtue of their intrinsic chemical properties or their operating temperatures or pressures or a combination of these. Fire, explosion, toxic release or combinations of these are the hazards associated with industrial plants using hazardous chemicals. More comprehensive, systematic and sophisticated methods of Safety Engineering, such as, Hazard Analysis and QuantitativeRisk Assessment have now been developed to improve upon the integrity, reliability and safety of industrial plants.

The primary emphasis in safety engineering is to reduce risk to human life, property and environment. Some of the more important methods used to achieve this are:

- **Quantitative Risk Analysis:** Provides a relative measure of the likelihood and severity of various possible hazardous events by critically examining the plant process and design.
- **Work Safety Analysis:** The technique discerns whether the plant layout and operating procedures in practice have any inherent infirmities.
- **Safety Audit:** Takes a careful look at plant operating conditions, work practices and work environments to detect unsafe conditions.

Together, these three broad tools attempt to minimize the chances of accidents occurring. Yet, there always exists, no matter how remote, probability of occurrence of a major accident. If the accident involves highly hazardous chemicals in sufficiently large quantities, the consequences may be serious to the plant, to surrounding areas and the populations residing therein.

6.2. Risk Assessment

A three 'levels' risk assessment approach has been adopted for the proposed synthetic organic project.The risk assessment levels are generally consistent with the practices encountered through various assignments for medium and large chemical complexes. The brief outline of the three tier approach is given below:

- **Level 1 – Risk Screening**

This is top-down review of worst- case potential hazards/risks, aimed primarily at identifying plant sites or areas within plant, which pose the highest risk. Various screening factors considered include:

- Inventory of hazardous materials;
- Hazardous Materials properties;
- Storage conditions (e.g. temperature and pressure);
- Location sensitivity (distance to residential areas / populace).

The data / information are obtained from plant. The results provide a relative indication of the extent of hazards and potential for risk exposure.

➢ **Level 2 – Major Risk Survey** (Semi - Quantitative)

The survey approach combines the site inspection with established risk assessment techniques applied both qualitative as well quantitative mode. The primary objective is to identify and select major risks at a specific location in the plant considering possible soft spots / weak links during operation / maintenance. Aspects covered in the risk usually include:

- Process Hazards;
- Process Safety Management Systems;
- Fire Protection and Emergency response equipment and programs.
- Security Vulnerability;
- Impact of hazards consequences (equipment damage, business interruption, injury, fatalities);
- Qualitative risk identification of scenarios involving hazardous materials;
- Risk reduction measures.
- Selection of critical scenarios and their potential of damage provide means of prioritising mitigative measures and allocate the resources to the areas with highest risks.

➢ **Level 3 – Quantitative Risk Assessment** (Deterministic)

This is the stage of assessment of risks associated with all credible hazards (scenarios) with potential to cause an undesirable outcome such as human injury, fatality or destruction of property. The four basic elements include:

i. Hazards identification utilizing formal approach (Level 2, HAZOP etc.);
ii. Frequency Analysis. Based on past safety data (incidents / accidents); Identifying likely pathway of failures and quantifying the toxic / inflammable material release;
iii. Hazards analysis to quantify the consequences of various hazards scenarios (fire, explosion, BLEVE, toxic vapour release etc.).Establish minimum value for damage (e.g. IDLH, over pressure, radiation flux) to assess the impact on environment.
iv. Risk Quantification: Quantitative techniques are used considering effect / impact due to weather data, population data, and frequency of occurrences and likely hood of ignition / toxic release. Data are analysed considering likely damage (in terms of injury / fatality, property damage) each scenarios is likely to cause.

QRA provides a means to determine the relative significance of a number of undesired events, allowing analyst and the team to focus their risk reduction efforts where they will be beneficial most.

Otsuka proposed API project is hazardous in nature. The RA for this plant is based on Level 1 and Level 2.

Table in Chapter 2 gives the list of products (and their monthly production capacity) and raw materials to be manufactured and used in the proposed project. Table 6.1below gives the bulk storages of liquid andgaseous raw materials and their monthly consumption.

Table 6.1 List of Solvents / Chemicals to be stored in Bulk in Otsuka Project

Sl. No.	Name of the Raw Material	Storage Area and Capacity	Storage Specifications
13.	Methanol	20 KL	SS-304
14.	Toluene	10 KL	SS-304
15.	Acetone	20 KL	SS-304
16.	IPA	10 KL	SS-304
17.	Ethanol	5 KL	SS-304
18.	Cyclohexane	10 KL	SS-304 (jacketed)
19.	n-Butyl acetate	20 KL	SS-304
20.	Ethyl acetate	20 Kl	SS-304
21.	Methylene Chloride	20 KL	SS-304 (jacketed)

0.

In addition Otsuka will also be storing toxic gases namely Chlorine and Ammonia in 50 kg cylinders; Bromine in bottles. The gases will be stored separately in a ventilated shed.

6.3. Risk Screening Approach

Proposed Plant: Risk screening of Otsuka plant was undertaken through process study and study of data / information provided by Otsuka. Data of major / bulk storages of raw materials, intermediates and other chemicals were collected. MSDS of hazardous chemicals were studied vis a vis their inventories and mode of storage. Otsuka plant will be using number of hazardous chemicals and also producing organic chemicals – hazardous in nature. The chemicals stored in bulk (liquid or gaseous) and defined under MSHIC Rule will be considered for detailed analysis.

Many of the chemicals are hazardous in nature. However hazards potential (for damage) of products and other materials to plant personnel, environment and off-site area is different for different materials. Otsuka will be using a number ofliquid raw materials but onlynineare stored in bulkand all these are listed under “List of hazardous and Toxic Chemicals” category under MSIHC Rules, 1989.In addition three toxic gases are also stored and have been listed below. The raw materials coming under hazardous category as specified by MSIHC Rules, 1989 (including subsequent amendments) is given in Table 6.2 below:

Table 6.2 Hazards Analysis –Raw materials (stored in Bulk)

S. No	Raw material	S. No & Threshold Quantity (TQ in MT) as per MSHIC Rules			Chemicals Hazards Potential		Remarks
		Schedule-1, Part-II	Schedule-2, Part-I	Schedule-3, Part-I	Hazards	Toxic	
1.	Methanol CAS No:67-56-1 UN No:1230 A colorless fairly volatile liquid with a faintly sweet pungent odor like that of ethyl alcohol.	377			Highly Flammable; Behaviour in Fire: Containers may explode. Health Hazards: Exposure to excessive vapor causes eye irritation, head- ache, fatigue and drowsiness. High concentrations can produce central nervous system depression and optic nerve damage. 50,000 ppm will probably cause death in 1 to 2 hrs. Can be absorbed through skin. Swallowing may cause death or eye damage.	ERPG-1: 200 ppm ERPG-2: 1000 ppm ERPG-3: 5000 ppm IDLH: 6000 ppm	
2.	Toluene CAS No: 108-88-3 UN No: 1294 A clear colorless liquid with a characteristic aromatic odor. Flash point 40°F	628			Flammability: Ignites at normal temperatures; Vapor is heavier than air and may travel a considerable distance to a source of ignition and flash back; Health Hazard Vapors irritate eyes and upper respiratory tract; cause dizziness, headache, anesthesia, respiratory arrest. Liquid irritates eyes and causes drying of skin. If aspirated, causes coughing, gagging, distress, and	ERPG-1: 50 ppm ERPG-2: 300 ppm ERPG-3: 1000 ppm IDLH: 500 ppm	

					rapidly developing pulmonary edema. If ingested causes vomiting, griping, diarrhea, depressed respiration.		
3.	Acetone [C3 H6 O] CAS No: 67-64-1 Colourless liquid; Pleasant Etheral odour BP-56.2 0C	4	--	--	Hazardous in case of skin contact (irritant), of eye contact (irritant), of ingestion, of inhalation. Slightly hazardous in case of skin contact (permeator). Flammable: Limits- Lower- 2.6%; Upper- 12.8%	ORAL (LD50): Acute: 5800 mg/kg [Rat]. VAPOR (LC50): Acute: 50100 mg/m 8 hours [Rat].	
4.	(IPA) Isopropyl Alcohols CAS No: 67-63-0	334			Flash Pt: 55.00 F Method Used: TCC Explosive Limits: LEL: 2.5% UEL: 12.1% LD 50/ LC 50: Acute dermal Rabbit 1300 mg/kg; Acute inhalation Rat (8 hours) 12000 ppm.	--	
5.	Ethanol CAS No; 64-17-5 A clear colorless liquid with pleasant odor	248			Colourless liquid Flammable: FP- 16.6 0C; Causes respiratory tract irritation. May cause liver, kidney and heart damage. Causes moderate skin / eye irritation. On ingestion may cause gastrointestinal tract irritation, vomiting and diarrhoea.		
6.	Cyclo Hexane CAS No: 110-82-7	161	---		Slightly hazardous in case of skin contact (irritant, permeator), of eye contact (irritant), ofingestion, of	ORAL (LD50): Acute: 12705	Flammable

	Liquid.with: Chloroform-like odor; LFL: 1.3% UFL:8.4% BP: 80.70C FP: -18 0C				inhalation	mg/kg [Rat]. 813 mg/kg [Mouse]. DERMAL (LD): Acute: >18000 mg/kg [Rabbit].	
7.	n-Butyl Acetate $C_6H_{12}O_2$ CAS No: 123-86-4 UN No:1123 Flammable ‘ colorless liquid with fruity flavor FP: 72-88 0F LFL: 1.7% UFL:7.6% BP: 259.70F	411			HIGHLY FLAMMABLE: Will be easily ignited by heat, sparks or flames.	ERPG-1: 5.0 ppm ERPG-2: 200 ppm ERPG-3: 3000 ppm IDLH: 10 ppm	Health Hazards : SKIN: prolonged or frequently repeated exposures may lead to drying. INHALATION: headaches, dizziness, nausea, irritation of respiratory passages and eyes. (USCG, 1999)
8.	Ethyl Acetate	247	---	---	Hazardous in case of	(LD50):	

	(C4 H8 O2) CAS No: 141-78-6 Colourless liquid; Pleasant Etheral odour BP-77 0C				ingestion, of inhalation. Slightly hazardous in case of skin contact (irritant, permeator), of eye contact (irritant). FLAMMABLE: FP (Closed Cup)- -4.4 ^{0}C Flammable Limits_ Lower 2.2%;Upper-9%	Acute: 5620 mg/kg [Rat]. 4100 mg/kg [Mouse]. VAPOR (LC50): 16000 ppm 6 hours [Rat].	
9.	Methylene Chloride CAS No:75-09-2 C-H2-Cl2 UN No:2790 A clear liquid BP 39.750C	400	---		Very hazardous in case of eye contact (irritant), of ingestion, of inhalation. Hazardous in case of skin contact (irritant, permeator). Inflammation of the eye is characterized by redness, watering, and itching.	Acute oral toxicity (LD50): 1600 mg/kg [Rat]. Acute toxicity of the vapor (LC50): 52000 1 hours [Rat].	May be combus tible at high tempera ture
10.	Chlorine CAS No:7782-50-5 UN No:1017 A greenish yellow gas with a pungent suffocating odor. Toxic by inhalation.	119	5 TQ-1: 10MT TQ-2: 25 MT	108 TQ-1: 10MT TQ-2: 25 MT	(Gas); Non Combustible; May ignite other combustible materials (wood, paper, oil, etc.). Mixture with fuels may cause explosion. Health Hazards: Poisonous; may be fatal if inhaled. Contact may cause burns to skin and eyes. Bronchitis or chronic lung conditions	ERPG-1: 1.0 ppm ERPG-2: 3.0 ppm ERPG-3: 20 ppm IDLH: 10 ppm	
11.	Ammonia	31	2 TQ-1:	105 TQ-1:	Fire Hazards: (Gas); Mixing of ammonia with several chemicals can cause fire	ERPG-1: 25 ppm	Contact with liquid

			60 MT TQ-2: 600 MT	50 MT TQ-2: 500 MT	hazards, / or explosions; vapours are toxic- irritation to eyes and respiratory tract.	ERPG-2: 150 ppm IDLH: 300 ppm	may cause frost bite.
12.	Bromine CAS No:7726-95-6 UN No:1744	84	17 TQ-1: 10 50 MT TQ-2: 500 MT	106 TQ-1: 40 MT TQ-2: 500 MT	Stable. Incompatible with reducing agents, alkali metals, powdered metals, steel, iron, copper, organic materials. **Toxicology** May be fatal if inhaled. Highly toxic by inhalation, ingestion or skin contact. Causes severe burns. Lachrymator. Typical TLV 0.1 ppm. Typical STEL 0.3 ppm		

Note:

1. **TQ-I: Threshold quantity (for application of rules 4,5,7 to 9 and 13 to 15)**
   TQ-II: Threshold quantity (for application of rules 10 to 12)

As detailed in the above table out of 12 liquid materials stored in bulk all comes within Schedule I part II (List of Hazardous and Toxic Chemicals) of MSIHC Rules but only three material (Chlorine, Ammonia and Bromine) of them comes under Schedule 3 (list of hazardous chemicals for application of rules 5 and 7 to 15).

All solvent materials are inflammable and some may be explosive also. Some of these hazardous liquid materials are toxic also such as Methanol, Methylene Chloride and Toluene.

Note:

- Oral Toxicity (OT) in LD_{50} (mg/kg)
- Dermal Toxicity (DT) in LD_{50} (mg/kg)
- Inhalation Toxicity in LC_{50} (mg/l) [4 hrs.]

Acute Exposure Guideline Levels (AEGLs)

- AEGL-3 is "the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening adverse health effects or death."
- AEGL-2 is "the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape."
- AEGL-1 is "the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects.

1. **Emergency Response Planning Guidelines (ERPGs)**

The 3 *ERPG* tiers are defined as follows:

- ERPG-3 is "the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects."
- ERPG-2 is "the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action."
- ERPG-1 is "the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient health effects or perceiving a clearly defined, objectionable odor."

2. **Temporary Emergency Exposure Limits (TEELs)**

TEELs Temporary Emergency Exposure Limits are levels of concern representing the adverse health effects of a hazardous substance on members of the general public. TEELs are defined by the U.S. Department of Energy for use when ERPGs or AEGLs aren't available (see www.hss.energy.gov/HealthSafety/WSHP/chem_safety/teel.html). are used in similar situations as the 60-minute AEGLs Acute Exposure Guideline Levels are levels of concern representing the adverse health effects of a hazardous substance on members of the general public. AEGLs are developed by the National Research Council's National Advisory Committee on AEGLs (www.epa.gov/oppt/aegl). and ERPGs Emergency Response Planning Guidelines are levels of concern representing the adverse health effects of a hazardous substance on members of the general public. ERPGs are developed by the ERPG committee of the American Industrial Hygiene Association (www.aiha.org).. However, in situations where the concentration The amount of a chemical present in a given weight or volume of air. Concentration of a gas in air may be expressed in units such as parts per million (by volume) or milligrams per cubic meter. varies over time, the TEEL developers recommend using a conservative 15-minute time-weighted average concentration The amount of a chemical present in a given weight or volume of air. Concentration of a gas in air may be expressed in units such as parts per million (by volume) or milligrams per cubic meter.. A chemical may have up to 4 TEEL Temporary Emergency Exposure Limits are levels of concern representing the adverse health effects of a hazardous substance on members of the general public. TEELs are defined by the U.S. Department of Energy for use when ERPGs or AEGLs aren't available (see www.hss.energy.gov/HealthSafety/WSHP/chem_safety/teel.html). values, each of which corresponds to a specific tier of health effects.

The 4 TEEL Temporary Emergency Exposure Limits are levels of concern representing the adverse health effects of a hazardous substance on members of the general public. TEELs are defined by the U.S. Department of Energy for use when ERPGs or AEGLs aren't available (see www.hss.energy.gov/HealthSafety/WSHP/chem_safety/teel.html). tiers are defined as follows:

- TEEL-3 is "the maximum concentration The amount of a chemical present in a given weight or volume of air. Concentration of a gas in air may be expressed in units such as parts per million (by volume) or milligrams per cubic meter. in air below which it is believed nearly all individuals could be exposed without experiencing or developing life-threatening health effects."
- TEEL-2 is "the maximum concentration The amount of a chemical present in a given weight or volume of air. Concentration of a gas in air may be expressed in units such as parts per million (by volume) or milligrams per cubic meter. in air below which it is believed nearly all individuals could be exposed without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action."
- TEEL-1 is "the maximum concentration The amount of a chemical present in a given weight or volume of air. Concentration of a gas in air may be expressed in units such as parts per million (by volume) or milligrams per cubic meter. in air below which it is believed nearly all individuals could be exposed without experiencing other than mild transient health effects or perceiving a clearly defined objectionable odor."
- TEEL-0 is "the threshold concentration The amount of a chemical present in a given weight or volume of air. Concentration of a gas in air may be expressed in units such as parts per million (by volume) or milligrams per cubic meter. below which most people will experience no appreciable risk of health effects."
- The National Institute of Occupational Safety and Health (NIOSH National Institute for Occupational Safety and Health (www.cdc.gov/niosh). The federal agency responsible

for conducting research and making recommendations for the prevention of work-related disease and injury. NIOSH is part of the Centers for Disease Control and Prevention (CDC).) defines an immediately dangerous to life or health condition as a situation "that poses a threat of exposure to airborne contaminants when that exposure is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment."

- The IDLH limit Immediately Dangerous to Life and Health limits, levels of concern for adult workers; estimate of the highest concentration from which escape is possible without permanent injury (if their respirators fail). IDLHs ae established by the National Institute for Occupational Safety and Health (www.cdc.gov/niosh). represents the concentration The amount of a chemical present in a given weight or volume of air. Concentration of a gas in air may be expressed in units such as parts per million (by volume) or milligrams per cubic meter. of a chemical in the air to which healthy adult workers could be exposed (if their respirators fail) without suffering permanent or escape-impairing health effects.

6.4. Hazardous Materials Storage

The solid raw materials will be received in bags or drums and will be stored inchemicals godowns. The products (liquid or solid) will be packed in drums and stored in product godowns as per market demand. Many of the materials will be stored in tanks in bulk. Appropriate arrangement will be done for absorption of gases/Cooling of storage tanks/Vent condenser in Oleum tank/ Sealing arrangement for Chloro sulphonic acid etc.

The bulk storages of liquid hazardous materials are given in the Table 6.1.

The solid material powder or granules spillage can results in polluting small area only. The damage to personnel can be through ingress- dermal (if individual come in contact), oral (if individual food gets infected through fugitive dust) or inhalation (fugitive dust). The main route is fugitive dust which incovered area will move to short distance only.

The risk is through liquid / gaseous materials which are volatile material. The toxic vapours due to spillage of such material can travel to some distance (as they are stored in covered godowns) and cause damage.

6.5. QRA Approach

Identification of hazards and likely scenarios (based on Level-1 and Level-2 activities) calls for detailed analysis of each scenario for potential of damage, impact area (may vary with weather conditions / wind direction) and safety system in place. Subsequently each incident is classified according to relative risk classifications provided in Table below asTable 6.3:

Table 6.3 Risk Classification

Stage	Description
High (> 10^{-2}/yr)	A failure which could reasonably be expected to occur within the expected life time of the plant. Examples of high failure likelihood are process leaks or single instrument or valve failures or a human error which could result in releases of hazardous materials.

Moderate (10^{-2} --10^{-4}/yr)	A failure or sequence of failures which has a low probability of occurrence within the expected lifetime of the plant. Examples of moderate likelihood are dual instrument or valve failures, combination of instrument failures and human errors, or single failures of small process lines or fittings.
Low (<10^{-4})	A failure or series of failures which have a very low probability of occurrence within the expected lifetime of plant. Examples of 'low' likelihood are multiple instruments or valve failures or multiple human errors, or single spontaneous failures of tanks or process vessels.
Minor Incidents	Impact limited to the local area of the event with potent for 'knock – on- events'
Serious Incident	One that could cause: ❖ Any serious injury or fatality on/off site; ❖ Property damage of $ 1 million offsite or $ 5 million onsite.
Extensive Incident	One that is five or more times worse than a serious incident.

Assigning a relative risk to each scenario provides a means of prioritising associated risk mitigation measures and planned actions.

6.6. Thermal Hazards

In order to understand the damages produced by various scenarios, it is appropriate to understand the physiological/physical effects of thermal radiation intensities. The thermal radiation due to tank fire usually results in burn on the human body. Furthermore, inanimate objects like equipment, piping, cables, etc. may also be affected and also need to be evaluated for damages.Table 6.4, Table 6.5andTable 6.6(below), respectively give tolerable intensities of various objects and desirable escape time for thermal radiation.

Thermal hazards could be from fires or explosion. Fire releases energy slowly while explosion release energy very rapidly (typically in micro seconds). Explosion is rapid expansion of gases resulting in rapidly moving shock wave. Explosion can be confined (within a vessel or building) or unconfined (due to release of flammable gases).

BLEVE (boiling liquid expanding vapour explosion) occurs if a vessel containing a liquid at a temperature above its atmospheric boiling point ruptures. The subsequent BLEVE is the explosive vaporization of large fraction of its vapour contents; possibly followed by combustion or explosion of the vaporized cloud if it is combustible.

Thermal hazards have been considered for various scenarios including:

- Fire in inflammable chemicals storage tanks.,

Table 6.4 Effects due to Incident Radiation Intensity

Incident Radiation kW/m^2	Damage Type
0.7	Equivalent to Solar Radiation
1.6	No discomfort on long duration
4.0	Sufficient to cause pain within 20 sec. Blistering of

	skin (first degree burn are likely).
9.5	Pain threshold reached after 8 sec. Second degree burn after 20 sec.
12.5	Minimum energy required for piloted ignition of wood, melting of plastic tubing etc.
25	Minimum Energy required for piloted ignition of wood, melting, plastic tubing etc.
37.5	Sufficient to cause damage to process equipment.
62.0	Spontaneous ignition of wood.

Table 6.5 Thermal Radiation Impact to Human

Exposure Duration	Radiation Energy {1% lethality; kW/m^2}	Radiation Energy for 2nd degree burns; kW/m^2	Radiation Energy for 1st degree burns; kW/m^2
10 sec	21.2	16	12.5
30	9.3	7.0	4.0

Table 6.6 Tolerable Intensities for Various Objects

Sl. No	Objects	Tolerable Intensities (kw/m^2)
1	Drenched Tank	38
2	Special Buildings (No window, fire proof doors)	25
3	Normal Buildings	14
4	Vegetation	10-12
5	Escape Route	6 (up to 30 secs.)
6	Personnel in Emergencies	3 (up to 30 secs.)
7	Plastic Cables	2
8	Stationary Personnel	1.5

6.7. Damage due to Explosion

The explosion of a dust or gas (either as a deflagration or detonation) results in a reaction front moving outwards from the ignition source preceded by a shock wave or pressure front. After the combustible material is consumed the reaction front terminates but the pressure wave continues its outward movement. Blast damage is based on the determination of the peak overpressure resulting from the pressure wave impacting on the object or structure. Damage estimates based on overpressure are given in Table 6.7below:

Table 6.7 Damage due to Overpressure

Sl. No	Overpressure (psig / bar)	Damage
1.	0.04	Loud Noise / sonic boom glass failure
2.	0.15	Typical pressure for glass failure
3.	0.5 - 1	Large and small windows usually shattered
4.	0.7	Minor damage to house structure
5.	1	Partial demolition of houses, made uninhabitable.
6.	2.3	Lower limit of serious structure damage

7.	5 – 7	Nearly complete destruction of houses
8.	9	Loaded train box wagons completely demolished
9.	10	Probable total destruction of houses
10.	200	Limits of crater lip

6.8. Toxic Release

Damage criteria: For toxic release the damage criteria considered is IDLH concentration (if data are available). In the absence of non-availability of IDLH, 'Inhalation Toxicity (AEGL) data are considered. 'AEGL' norms are used for chemicals, as IDLH are not available for these chemicals.

6.8.1. Acid / Alkali Hazards

Various hazards that can occur due to the acid and alkali incidents are

- Skin irritation and corrosive effects after spillage
- Spill pool evaporation of sulphuric/ hydrochloric acid or Caustic lye storage tanks catastrophic failure are limited only
- Catastrophic failure giving rise to spill pool evaporation dispersion up to LC50, IDLH and TLV level

The more hazardous scenario likely are if spilled acid comes in contact with metal and hydrogen is generated resulting in fire / explosion hazards.

Based on the outcome of the risk assessment, following recommendation has been made to avoid any risk associated with the storage and use ofacid and other hazardous liquid chemicals in the plant:

- Double drain valve will be provided to storage tank.
- Full body protection will be provided to operator.
- Caution note and emergency first aid will be displayed
- All employees will be trained for use of emergency first aid.
- Safety shower and eye wash will be provided in storage tank area and plant area.
- Total close process will be adopted for hazardous chemicals handling.
- Dyke wall will be provided to storage tank
- Tanker unloading procedure will be prepared.
- SOP will be prepared for sulphuric acid handling.
- Training programme will be conducted for safe handling and emergency handling of hazardouschemicals.
- In Storage Tank Area, reaction with water generating fumes should be displayed and avoided
- Suitable extinguishing media-Extinguish with dry powder / sand. DO NOT USE WATER.

Fire and explosion hazards-Not flammable. May evolve toxic fumes in fire (sulphur oxides/ Carbon Monoxide or other toxic gases).

6.9. Likely Failure Scenarios

Few likely failure scenarios have been selected after critical appraisal of raw materials and storage inventories. Failure scenarios selected are as given in Table 6.8 below:

Table 6.8 Different Failure Scenarios

S. No.	Scenario	Remark
Raw materials		
RM-1	Methanol Tank heavy Spillage	Toxic
RM-2	Toluene Tank heavy Spillage	Toxic
RM-3	Acetone Tank heavy Spillage & Fire	Fire
RM-4	Ethyl Acetate Tank heavy Spillage& Fire	Fire
RM-5	Chlorine Cylinder Heavy Leakage	Toxic
RM-6	Bromine Bottle Failure	Toxic

6.10. Weather Effect

The effect of ambient conditions on the impact of fire / heat radiation and GLC of hazardous / toxic material can be beneficial as well as harmful. A high wind (turbulence) can dilute the toxic material while stable environment can extend the reach of IDLH or IT (inhalation LC_{50} rats for products) or AEGL (in absence of IDLH data) concentration to long distance. Any inflammable gas / vapour release in turbulent weather will soon dilute the hazardous gases below LEL and thus save the disaster. For toxic materials Stability class “F” (wind speed 1.5 m/sec and Temp. 15 ^{0}C) has been considered and for inflammable materials stability class “E” (wind speed 3.5 m/sec and Temp. 35 ^{0}C) has been considered.

6.11. Incidents Impacts

The identified failure scenarios (Table 6.8) have been analysed(Using ALOHA Module) for the impact zones considering damage due to thermal and toxic impacts. Each incident will have Impact on the surrounding environment which in extreme case may cross plant boundary. The impact zones for various scenarios are given in Table 6.9.

Table 6.9 : HazardsScenario Impact

Scenario No.	Scenario	Impact Zone (m)	Remarks
Material			
RM-1	Methanol Tank heavy Spillage	❖ IDLH 20	Stability Class F Template 1
RM-2	Toluene Tank heavy Spillage	❖ IDLH 11	Stability Class F
RM-3	Acetone Tank heavy Spillage & Fire	❖ 11	1st degree burn Stability Class D Template 2
RM-4	Ethyl Acetate Tank heavy	❖ 10	1st degree burn Stability

	Spillage & Fire		Class D Template -3
RM-5	Chlorine Cylinder Heavy Leakage	❖ IDLH 862	Stability Class F Template -4
RM-6	Bromine Bottle Failure	❖ IDLH 217	Stability Class F Template -5

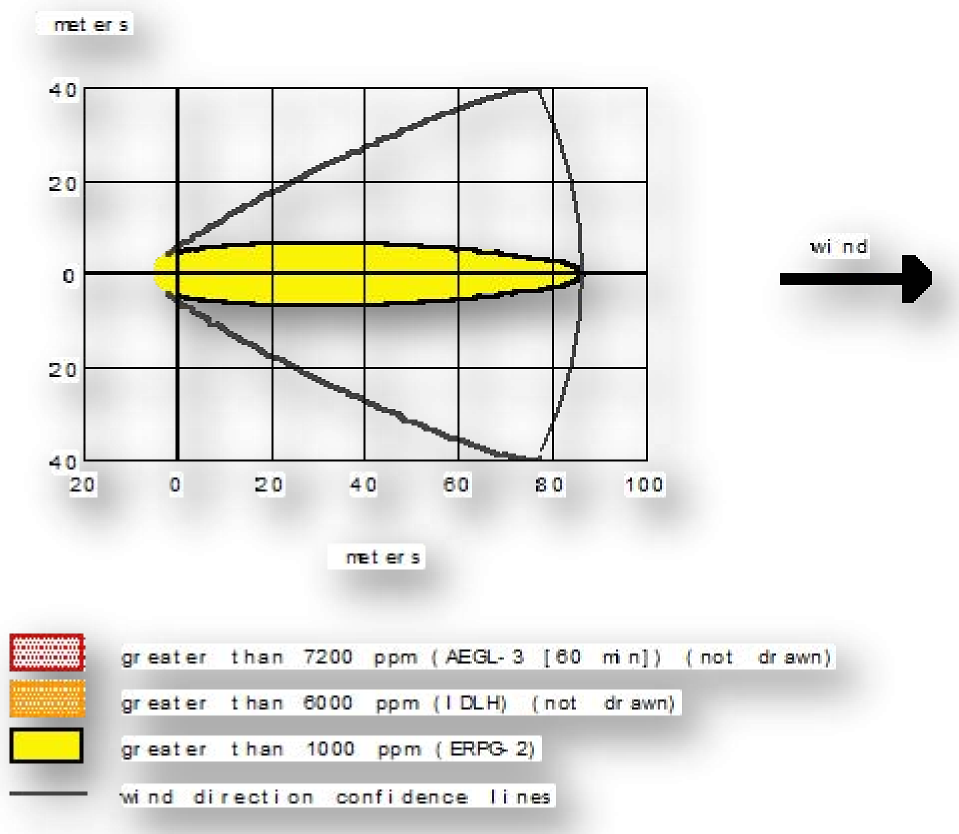

Figure 6.1 Template -1: Methanol Spillage and Evaporating Toxic Pool

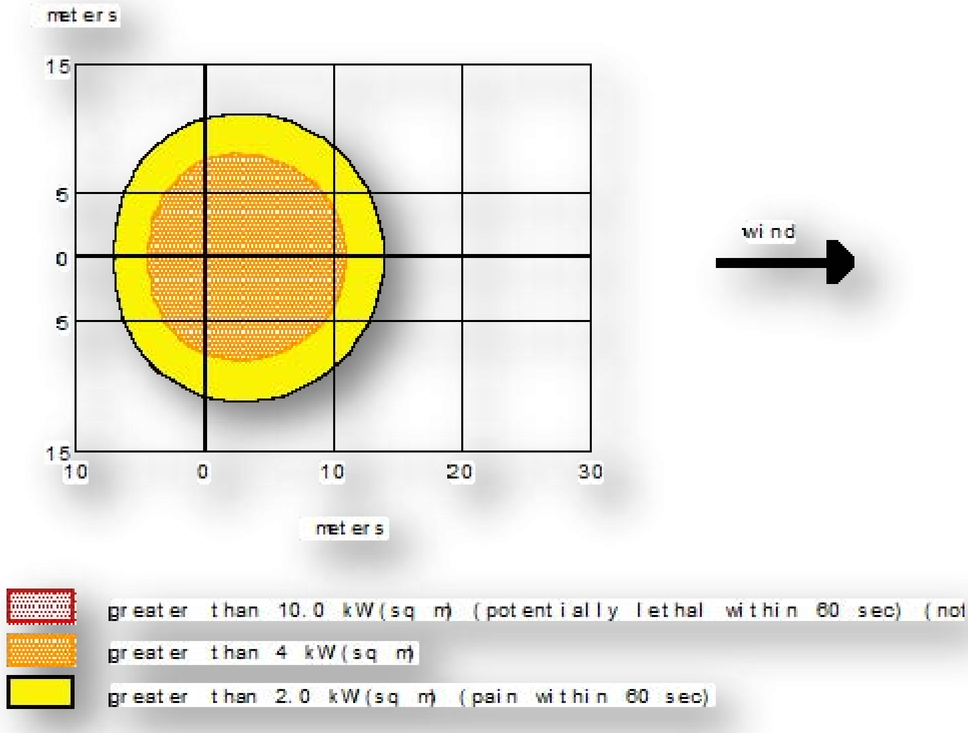

Figure 6.2 Template-2: Acetone Spillage and Pool Fire

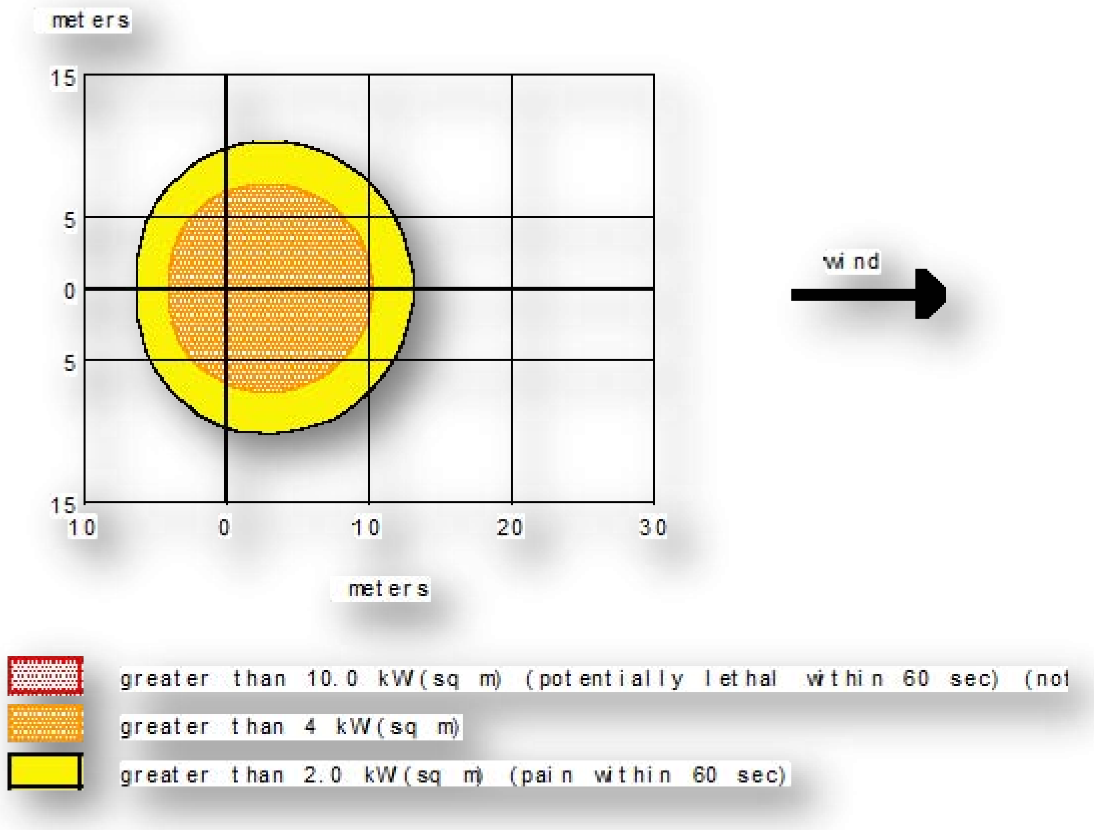

Figure 6.3 Template -3: Ethyl Acetate Spillage and Pool Fire

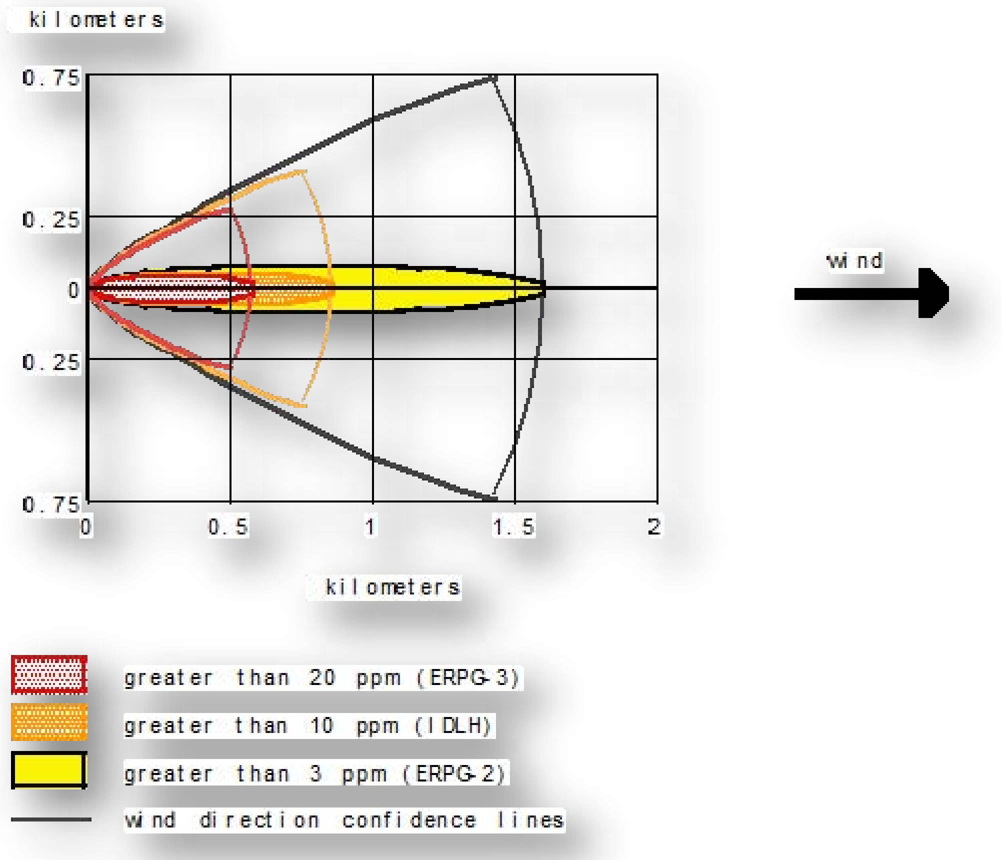

Figure 6.4 Template -4: Chlorine Cylinder Leakage

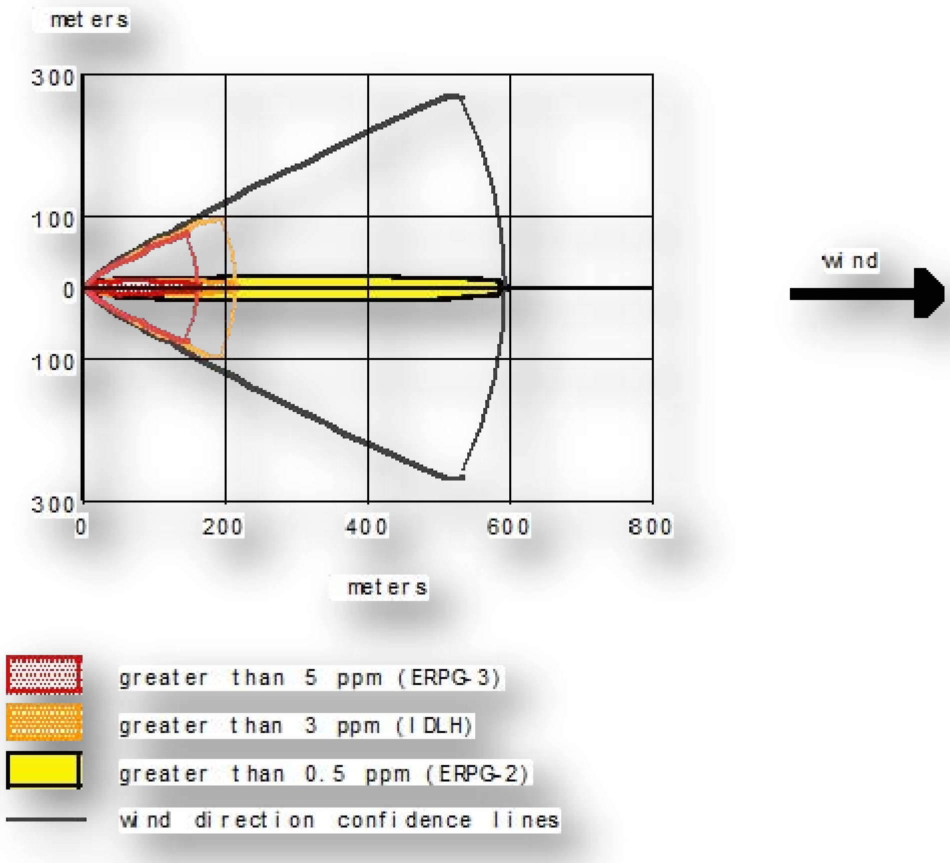

Figure 6.5 Template -5: Bromine Bottle failure andevaporating Toxic bromine fumes

6.12. Consequential Impacts

The consequential impacts from each incident scenarios can be though thermal, over pressure wave and toxic route. The damage can be on plant personnel (and neighbouring industry/ residents in case incident crosses boundary), property and also loss in production.

6.12.1. Thermal and Explosion Hazards

Incidents involving thermal hazards are mainly due to raw material fire (in tank farms). The impact (1st degree burn) is limited to ~11 m only (i.e. within plant boundary).

6.12.2. Toxic Hazards

Toxic hazards are mainly due toChlorine and Bromine gas and other chemicals leakageand their impact can cross the plant boundary (if not controlled in time). The impact due to Chlorine and Bromine release may go up to ~862 and 217mi.e. it may cross plant area /storage area and may also have impact on adjoining industries. Any suchrelease will have adverse impact outside the plant battery limit and may involve district authorities to contain the damage.

6.12.3. Other Hazards

The other hazards in the plant include (but not limited to):

- Other toxic hazards due to acids / other toxic spillages (mainly limited to spillage area only.).
- Mechanical hazards due to machines / equipment.
- Hazards due to individual soft spots like walking casually and noticing a pit and falling or colliding/ stumbling or slipping (not noticing a wet place etc.).

6.12.4. Other Toxic Hazards

Acid spillage-its impact will be limited to spillage area. The spillage if comes in contact with metal parts will produce hydrogen which is highly flammable gas. Any person moving in area and getting splash will get the injury. In addition the spillage will cause pollution problem. The spillage is to be collected and neutralized for toxic contents before disposal.

6.13. Occupational Health

Otsuka will have a well-equipped first aid post. It will also have staff personnel trained in first aid. Injured personnel will be immediately rushed to hospital after giving first aid.Allemployees will have regular medical checkup as per norms.

An emergency vehicle / ambulance will always (round the clock) available for meeting any eventuality.