1.1 RISK ASSESSMENT

1.1.1 INTRODUCTION

As indicated in the earlier chapter this establishment project will facilitate to manufacture agrochemicals and chemical intermediates which pose various types of hazards due to storage, handling & transportation of various chemicals, which are indicated in Chapter no. 2. In order to study the risks envisaged by the activities, the following methodology was adopted.

- HAZOP studies have been carried out for hazardous operations and process. The suitable recommendations are suggested in the study. M/s Astec Lifesciences Ltd (ALL) will follow all the recommendations in the operations.
- A detailed scrutiny of all the raw materials and products was done which would be stored on the site. For each chemical, the flammable, toxic and hazardous nature is identified by referring the M.S.D.S. The consumption of each raw material is related with the maximum quantity of storage of that respective chemical. The detailed list of products and raw materials is tabulated below in Table no – 1.
- For determining the impacts due to flammable nature of each chemical, DOW index is studied and computed. Based on the results, suitable storage recommendations are suggested, which will be followed by ALL. In the case of ALL, chemical with highest degree of flammability is assumed to be stored for all the maximum quantity of storage, which can be stated as a worst case scenario of storage.
- Similarly, impacts are identified due to toxic nature of chemicals by computing Mond's toxicity index considering the degree of hazard of the chemicals and their maximum quantity of storage.
- Based on the storage scenarios in tank storages, ALOHA software is utilized for the prediction of impacts considering certain scenarios. The area of extent and impact in terms of concentration is determined by this. Based on these studies, maximum credible loss scenario is estimated and recommendations are suggested accordingly.
- On site and Off site emergency preparedness plan (Hereafter referred as disaster management plan) is prepared based on these studies and linked with the district disaster management plan.

- Plot layouts showing locations of tanks, fire hydrant tanks & other safety features are depicted in the plot layout discussed in the onsite emergency plan.

1.1.2 M.S.D.S & HAZOP

M.S.D.S.s of all the chemicals and other raw materials which would be used in the manufacturing processes of products are used as reference for preparation of Quantitative risk assessment & also the Piping and Instrumentation Diagram (PNIDs) for each process are referred to carry HAZOP study.

1.1.3 ALOHA

A Quantitative Risk Assessment based on the software ALOHA – Arial Locations of Hazardous Atmospheres was carried out. The criteria failure scenarios considered for ALOHA depend on the type of storage whether above ground/ underground, physical state of the chemical stored, chemical properties of the chemical. The summary of the ALOHA footprints are attached in **Annexure 7.1**

Table 1: Details of Raw Materials/By products/ Products Stored in Above Ground Tank for ALOHA

Sr. No.	Name of Tank	Location	Dimension (mm)		Tank Capacity (Litres)	Dyke Wall Dimensions (mm)			Tank Position
			Diameter (m)	Height (m)		Length (L)	Width (W)	Height (H)	
1	Sodium Hydroxide Tank - 1	Tank Farm	3	6	40	3.9	27.4	1	Above Ground
2	Sodium Hydroxide Tank – 2	Tank Farm	2.1	6	20				
3	Sodium Hydroxide Tank – 3	Tank Farm	2.1	6	20				
4	Hydrochloric Acid Tank - 1	Tank Farm	2.4	3.5	15	2.6	6.5	1	Above Ground
5	Methanol Tank - 1	Tank Farm	2.3	6	45	3.9	27.4	1	Above Ground
6	Methanol Tank - 2	Tank Farm	2.1	6					
7	Phosphorous Oxychloride Tank - 1	Tank Farm	2	2.6	20	5.9	13.6	1	Above Ground
8	Phosphorous Oxychloride Tank - 2	Tank Farm	2	2.6					
9	Toluene	Tank Farm	1.8	6	15	3.9	27.4	1	Above Ground
10	Dimethyl Formamide Tank - 1	Tank Farm	2.3	6	65	3.9	27.4	1	Above Ground
11	Dimethyl Formamide Tank - 2	Tank Farm	2.1	6					
12	Dimethyl Formamide Tank - 3	Tank Farm	1.8	6					
13	Hydrochloric Acid Tank - 2	Tank Farm	1.6	2.38	5	2.6	6.5	1	Above Ground
14	Chlorine - Tonner – (Total 10 Nos. of tonner).		0.8	2.2	990	NA	NA	NA	
15	Hydrogen Cylinder		0.232	1.37	0.058	NA	NA	NA	

ALOHA CONSIDERATIONS

ALOHA was performed for all the liquids stored in above ground tanks except for Sodium Hydroxide. For Sodium Hydroxide Mond's is performed , as the chemical was not listed in ALOHA database.

Table 2: Summary of ALOHA footprints

Substance	Scenario.	Effects considered	LOC		Distance (m)
HYDROCHLORIC ACID (36%)	**EVAPORATING PUDDLE:** Spill of entire chemical contained in tank	*Toxic area of vapour cloud*	AEGL-3	100 ppm	37 m
			AEGL-2	22 ppm	79 m
			AEGL-1	1.8 ppm	278 m
HYDROCHLORIC ACID (30%)	**EVAPORATING PUDDLE:** Spill of entire chemical contained in tank	*Toxic area of vapour cloud*	AEGL-3	100 ppm	less than 10
			AEGL-2	22 ppm	18 m
			AEGL-1	1.8 ppm	67 m
PHOSPHORYL CHLORIDE	**EVAPORATING PUDDLE:** Spill of entire chemical contained in tank	*Toxic area of vapour cloud*	AEGL-3	0.85 ppm	785 m
			AEGL-2	No recommended LOC value	
			AEGL-1	No recommended LOC value	
TOLUENE	**EVAPORATING PUDDLE:** Spill of entire chemical contained in tank	*Toxic area of vapour cloud*	AEGL-3	3700 ppm	less than 10
			AEGL-2	560 ppm	less than 10
			AEGL-1	67 ppm	40 m
		Flammable Area of Vapour Cloud	60% LEL = Flame Pockets	6600 ppm	less than 10
			10% LEL = Flame Pockets	1100 ppm	less than 10
		Overpressure (blast force) from vapour cloud explosion ignited by spark or flame	No explosion	-	No part of the cloud is above the LEL at any time
	BURNING PUDDLE /	*Thermal radiation from*	Red	10.0 kW/(sq m)	27 m

Substance	Scenario.	Effects considered	LOC		Distance (m)
	POOL FIRE	*pool fire*	Orange	5.0 kW/(sq m)	39 m
			Yellow	2.0 kW/(sq m)	63 m
			Orange	3.5 psi	
			Yellow	1.0 psi	13.7 m
	DIRECT SCENERIO: Leakage during pumping by transfer pump	*Toxic area of vapour cloud*	AEGL-3	3700 ppm	32 m
			AEGL-2	560 ppm	92 m
			AEGL-1	67 ppm	300 m
		Flammable Area of Vapour Cloud	60% LEL = Flame Pockets	6600 ppm	23 m
			10% LEL	1100 ppm	62 m
		Overpressure (blast force) from vapour cloud explosion ignited by spark or flame	Red	8.0 psi	LOC was never exceeded
			Orange	3.5 psi	17 m
			Yellow	1.0 psi	37 m
DIMETHYL FORMAMIDE	**DIRECT SCENERIO:** Leakage during pumping by transfer pump	*Toxic area of vapour cloud*	AEGL-3	530 ppm	118 m
			AEGL-2	91 ppm	305 m
			AEGL-1	No recommended LOC value	
		Flammable Area of Vapour Cloud	60% LEL = Flame Pockets	13800 ppm	18 m
			10% LEL	2300 ppm	48 m
		Overpressure (blast force) from vapour cloud explosion	Red	8.0 psi	LOC was never exceeded
			Orange	3.5 psi	13 m
			Yellow	1.0 psi	32 m

Substance	Scenario.	Effects considered	LOC		Distance (m)
	EVAPORATING PUDDLE: Spill of entire chemical contained in tank	*Toxic area of vapour cloud*	AEGL-3	530 ppm	less than 10
			AEGL-2	91 ppm	less than 10
			AEGL-1	No recommended LOC value	
		Flammable Area of Vapour Cloud	60% LEL = Flame Pockets	13800 ppm	less than 10
			10% LEL	2300 ppm	less than 10
		Overpressure (blast force) from vapour cloud explosion ignited by spark or flame	No explosion:	No part of the cloud is above the LEL at any time	
	BURNING PUDDLE / POOL FIRE	*Thermal radiation from pool fire*	Red	10.0 kW/(sq m)	16 m
			Orange	5.0 kW/(sq m)	22 m
			Yellow	2.0 kW/(sq m)	33 m
CHLORINE	**TANK SCENERIO:** Leak from hole in horizontal cylindrical tank. Non-flammable chemical is escaping from tank	*Toxic area of vapour cloud*	AEGL-3	20 ppm	801m (0.8 km)
			AEGL-2	2 ppm	2414.02 m (2.41 km)
			AEGL-1	0.5 ppm	4667.1 m (4.67 km)
HYDROGEN	**TANK SCENERIO:** Leak from hole in	*Toxic area of vapour cloud*	PAC-3	400000 ppm	less than 10
			PAC-2	230000 ppm	less than 10

Substance	Scenario.	Effects considered	LOC		Distance (m)
	horizontal cylindrical tank Flammable chemical escaping from tank (not burning)		PAC-1	65000 ppm	less than 10
		Flammable Area of Vapour Cloud	60% LEL	24000 ppm	less than 10
			10% LEL	4000 ppm	22 meters
	Leak from hole in horizontal cylindrical tank Flammable chemical is burning as it escapes from tank	*Thermal radiation from jet fire*	Red	(10.0 kW/(sq. m)	less than 10
			Orange	(5.0 kW/(sq. m)	less than 10
			Yellow	(2.0 kW/(sq. m)	less than 10

1.1.4 INTERPRETATION

Based on the unsafe distances identified by the software output, the MCLS (maximum credible loss scenario) for Toxic area of vapour cloud works out for the factory to about 4.67 km for Chlorine. The scenario considered for assessing the impact by quantitative risk assessment was taken from the scenario considered for assessing the impact by quantitative risk assessment was taken from CPR18 E. The probability of occurrence of the scenario is 5×10^{-6} y^{-1} which is very less. The Disaster management plan highlights the suggestive measures to be taken during the occurrence of such an accident.

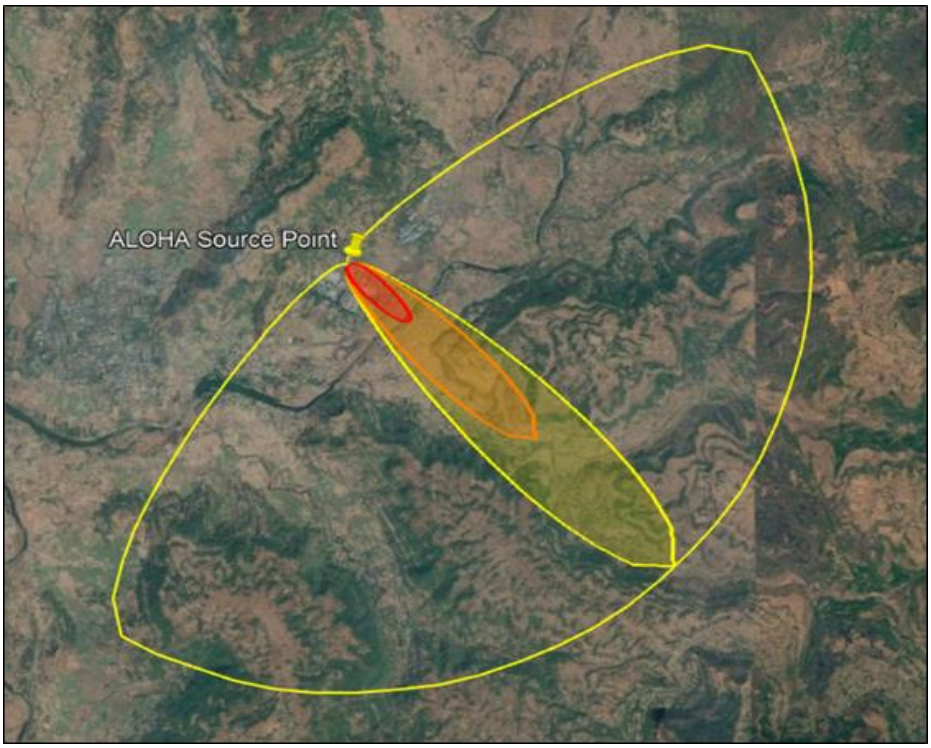

Figure 1: Interpretation of MCLS for Chlorine

Table 1: Impact Interpretation

Threat zone	Toxic Level of Concern	Receptors	Effects
Red - 801 m (0.8 km)	**AEGL-3 - 20 ppm** *Susceptible individuals could* ***experience life-threatening health effects or death.***	Open area, Internal MIDC Road, Mahad Dhapoli Road.	**Environmental Effects :-** ▪ Chlorine dissolves when mixed with water. It can also escape from water and enter air under certain conditions. Most direct releases of chlorine to the environment are to air and to surface water. ▪ Once in air or in water, chlorine reacts with other chemicals. It combines with inorganic material in water to form chloride salts, and with organic material in water to form chlorinated organic chemicals. ▪ Chlorine causes environmental harm at low levels. Chlorine is especially harmful to organisms living in water and in soil. **Human Effects: -** ▪ ***Target Organs:*** Respiratory system, gastrointestinal system, teeth, eyes, skin. ***Effects:*** ▪ Breathing small amounts of chlorine for short periods of time adversely affects the human respiratory system. Effects differ from coughing and chest pain, to water retention in the lungs. ▪ Chlorine irritates the skin, the eyes, and the respiratory system. These effects are not likely to occur at levels of chlorine that are normally found in the environment.
Orange- 2414.02 m (2.41 km)	**AEGL-2 - 2 ppm** *Susceptible individuals could experience* ***irreversible or other serious, long-lasting adverse health effects*** *or an impaired ability to escape.*	Mahad Dhapoli Road , Kal River , SH 70and nearby Agricultural Field & Residential Area.	
Yellow – 4667.1 m (4.67 km)	**AEGL-1 – 0.5 ppm** *Susceptible individuals could* ***experience notable discomfort, irritation, or certain asymptomatic no sensory effects.*** *However, the* ***effects*** *are* ***not disabling*** *and are transient and reversible upon cessation of exposure.*	Agricultural fields , Open field & Bhave Village.	

However to further reduce the occurrence of such accidents; following precautions would be taken by M/s. Astec Lifesciences Ltd.

I. SPECIFIC RECOMMENDATIONS FOR CHLORINE STORAGE

- Chlorine storage shall be **enclosed and separated** from other operating areas.
- Non-combustible building material is recommended and chlorine gas detector should be installed in the facility
- An air intake near the ceiling & an exhaust near the floor.
- Chlorine storage facilities should be maintained at 60-120℉ (15-50℃).
- **Cl_2 gas Scrubber** will be provided
- **Cl_2 detectors** will be provided.
- **Periodic checkups** will be carried out along with **preventive maintenance.**
- **SOP** of chlorine handling will be prepared and followed strictly.
- Provide **water gutter system.**
- **Training** to be provided to workers.
- Provide **emergency PPE** (Body suit etc) to workers.

II. GENERAL RECOMMENDATIONS FOR STORAGE OF RAW MATERIALS

- **Dedicated storage area** to be provided.
- **Containers shall be tightly closed**/sealed until ready for use.
- Keep containers in **cooled and ventilated area**.
- Avoid all possible **source of ignition**.
- Keep away from **heat and their sources**.
- Use suitable **PPE** during handling of chemicals.
- Storage area should be away from **incompatibilities such as oxidizing agents, metals & acid.**
- Avoid **direct contact** with body.
- Chemical **spill kit** to be maintained to avoid possible effects from spillage.
- Chemical transfer line should be periodically inspected and well maintained to avoid possibility for **leakage** of chemical.
- Periodic **inspection of dykes** to be done.

III. RECOMMENDATIONS/SUGGESTIONS FOR ABOVE GROUND STORAGE TANKS

- Facilities of **Water sprinklers** will be provided for the above ground tanks so that the temperature can be maintained.

- Inert gas like **Nitrogen purging** will be provided to the tanks of flammable liquids.
- **Dyke of adequate volume (110%) of the total tank volume** will be provided.
- **Temperature, Pressure & Level indicators** will be provided for inspection of the tank.
- **Safety valve** will be provided to the tanks.
- The dyke enclosure will be lined with impervious coating
- Regular inspection of the tank, transfer pipelines and dyke will be done visually and records maintained.
- It is recommended to establish foam monitor in the solvent tank yard farm.

The safety features provided for the above ground tanks are appropriate, **but it is highly recommended to connect the tanks with the scrubber for scrubbing the vapors.** It would be add on safety features which should be provided for the storage tanks.

IV. RECOMMENDATIONS FOR CORROSIVE LIQUID STORAGE:

- Acid/Lye storage tank breather valve will be connected to scrubber to control the vapors in atmosphere.
- Dedicated storage area will be provided.
- **HCL, Caustic Soda etc storage tank** will be covered with acid proof tiles, the dyke will be coated with acid/alkali proof paint and the flooring will also be covered with acid/alkali proof tiles.
- Store away from the combustible materials.
- Appropriate PPEs to be used during handling of solutions / chemicals.

1.1.5 DOW INDEX

The Dow index has been calculated for flammable chemicals stored in drums/bags. The DOW index estimation or prediction is performed for flammable chemical which is to be stored in raw material storage building for proposed activity. Worst case scenario of total chemical storage with highest degree of flammability hazard is considered. The recommendations are suggested accordingly.

From the available Material Safety Data Sheet, highest Nf of 4 was observed for Diethyl Ether. Hence, DOW index was calculated for Diethyl Ether considering the total quantity of storage in drums (165 MT) for all raw materials in order to perform the **worst-case scenario**. Also, fuel storage for FO & HSD is performed separately considering DOW Index.

Details of DOW index are given in table below, The DOW sheet is displayed below in Table no. 7.4. The DOW index worksheet is attached below the summary of the results**.** The penalty factor is considered as zero if the factor is related with the process and not about the storage condition.

Table 2 : Storage details of Raw Material – Diethyl Ether

Sr. No	Raw Material	Storage Considered	Flash Point ^{O}C	Maximum Storage Qty at any given point of time (MT)
1	Diethyl Ether	Drums	-45	165 MT
Fuel Storage				
2	FO	Tank	65	FO: 22 KL Tank 3 dia x 4.5 meter
3	HSD	Drum	93.3	2000 lit

Table 3: DOW Index Summary Sheet for Raw Materials

Chemical	Diethyl Ether	FO	HSD
Storage Considered	Drum	Drum	Drum
Maximum Quantity stored at any given point of time (MT)	165	9.5	2000 Lit
N_h	2	0	1
N_f	4	2	2
N_r	1	0	0
Material Factor, MF	21	10	10
F1 (General Process Hazard)	2.5	2.05	1.6
F2 (Special Process Hazard)	2.1	1.82	1.6
F3 (Hazard Factor)	5.25	3.731	2.56
Fire & Explosion Index	110.25	37.31	25.6
Degree of Hazard	**Intermediate**	**Light**	**Light**

Calculation of F&EI – Di Ethyl Ether

Tank No.	--			Equipment Name		**Di Ethyl Ether – 165 MT**			
Basic Material for Material factor			Drum		**Density, Kg/l**		0.713		
Properties of material									
N h	2	**N f**	4	**N r**	1	**M.F.**			**21**
Boil. Pt.	94.3	**^{0}F**	34.6	**^{0}C**	**Flash pt.**	-49	**^{0}F**	-45	**^{0}C**
ΔHC = Heat of Comb.	-14550	**BTU / lb**							
Quantity of the material	231417	**L**	**165000**	**kg**		363762.8	**lb**		
Storage conditions	**Temp**	15	**^{0}C**	**Pressure**		1	**Atm**		

		Penalty factor	Penalty
1. General Process Hazard	**Base Factor**	1.00	**1.00**
	Exothermic Chemical Reaction	0.30 to 1.25	0.00
	Endothermic Processes	0.20 to 0.40	0.00
	Material handling and transfer	0.25 to 1.05	**0.85**
	Enclosed or Indoor Process Units	0.25 to 0.90	0.45
	Access	0.20 to 0.35	**0.20**
	Drainage and Spill Control	0.25 to 0.50	**0.00**
	General Process Hazard Factor (F1)		**2.5**
2.Special Process	**Base Factor**	1.00	**1.00**
	Toxic material(s)	0.20 to 0.80	**0.40**
	Sub atmospheric pressure (< 500 mm Hg)	0.50	0.00
	Operation in or near flammable range_____inerted _____non inerted	0.00 to 0.80	0.00
	1. Tank farm storage flammable liquids	0.50	0.00
	2. Process upset or purge failure	0.30	0.00
	N. **Always in contact of Flame process**	0.80	0.00
	Dust Explosion	0.25 to 2.00	0.00
	Pressure Operating pressure ___psig Relief setting _____ psig		0.00
	Low temperature	0.20 to 0.30	0.00
	Quantity of flammable / unstable		
	1. Liquids or gases in process		0.0
	2. Liquids or gases in storage		**0.5**

	3. Combustible Solids in Storage, Dust in Process		0.00
	Corrosion & Erosion	0.10 to 0.75	**0.10**
	Leakage – Joints & Packing	0.10 to 1.50	**0.10**
	Use of Fired Equipment		0.00
	Hot oil heat exchange system	0.15 to 1.15	0.00
	Rotating Equipment	0.50	0.00
	Special Process Hazard Factor (F2)		**2.1**
Process Unit Hazard Factor (F3 = F1 x F2)			**5.25**
Fire & Explosion Index (F. & E.I. = F3 x M.F.)			**110.25**
Degree of Hazard		**Intermediate**	

Interpretation

The calculation for Dow Fire and Explosion Index is given and from the calculations it is seen that the storage will have a **Dow Index of 110.25 indicating Intermediate Hazard Potential.** Based on the unsafe distances identified by the DOW Index, the radius of exposure from the raw material storage area is around **27 meters** and the area of exposure is around **2289.06 sq. m.**

Degree of Hazard for F & EI

F & EI Index Range	Degree of Hazard
1-60	Light
61-96	Moderate
97-127	Intermediate
128-158	Heavy
159-up	Severe

RECOMMENDED MINIMUM FEATURES ACCORDING TO DOW FIRE AND EXPLOSION INDEX

Preventive & Protective Features	Fire & Explosion Index Number						Index for the present case			
	0-20	20-40	40-60	60-75	75-90	>90	110.25			
							Optional	Suggested	Feature recommended	Feature required
1) Fireproofing	1	2	2	3	4	4				√
2) Water spray										
a) directional	1	2	3	3	4	4				√
b) area	1	2	3	3	4	4				√
c) curtain	1	1	2	2	2	4				√
3) Special instrumentation										
a) temperature	1	2	3	3	4	4				√
b) pressure	1	2	3	3	3	4				√
c) flow control	1	2	3	4	4	4				√
4) Dust, blowdown, spill control	1	1	2	3	3	4				√
5) Internal examination	1	2	3	3	4	4				√
6) Combustible gas monitors										
a) signal alarm	1	1	2	3	3	4				√
b) actuate equipment	1	1	2	2	3	4				√
7) Remote operation	1	1	2	3	3	4				√
8) Diking, (Not Applicable as barrel storage)	1	4	4	4	4	4				√
9) Blast & barrier walls separation	1	1	2	3	4	4				√

1) Feature optional 2) Feature suggested 3) Feature recommended 4) Feature required

2. FURNACE OIL (FO)

Tank No.	--			Equipment Name			Furnace Oil – **22 KL**		
Basic Material for Material factor			Tank		**Density, kg/l**		0.97		
Properties of material									
N h	2	**N f**	2	**N r**	0		**M.F.**		**10**
Boil. Pt.		**^{0}F**	185-500	**^{0}C**	**Flash pt.**	150.8	**^{0}F**	66	**^{0}C**
ΔHC = Heat of Comb.		**18700**	**BTU / lb**						
Quantity of the material	22000	**L**	**18746**	**kg**		**41327.856**	**Lb**		
Storage conditions	**Temp**	32	**^{0}C**	**Pressure**		1	**bar**		

		Penalty factor	Penalty
1.General Process Hazard	**Base Factor**	1.00	**1.00**
	Exothermic Chemical Reaction	0.30 to 1.25	0.00
	Endothermic Processes	0.20 to 0.40	0.00
	Material handling and transfer	0.25 to 1.05	**0.40**
	Enclosed or Indoor Process Units	0.25 to 0.90	0.45
	Access	0.20 to 0.35	**0.20**
	Drainage and Spill Control	0.25 to 0.50	**0.00**
	General Process Hazard Factor (F1)		**2.05**
2.Special Process	**Base Factor**	1.00	**1.00**
	Toxic material(s)	0.20 to 0.80	**0.40**
	Sub atmospheric pressure (< 500 mm Hg)	0.50	0.00
	Operation in or near flammable range_____inerted _____non inerted	0.00 to 0.80	0.00
	1. Tank farm storage flammable liquids	0.50	0.00
	2. Process upset or purge failure	0.30	0.00
	N. **Always in contact of Flame process**	0.80	0.00
	Dust Explosion	0.25 to 2.00	0.00
	Pressure Operating pressure ___psig Relief setting _____ psig		0.00
	Low temperature	0.20 to 0.30	0.00
	Quantity of flammable / unstable		
	4. Liquids or gases in process		0.0
	5. Liquids or gases in storage		**0.22**

	6. Combustible Solids in Storage, Dust in Process		0.00
	Corrosion & Erosion	0.10 to 0.75	**0.10**
	Leakage – Joints & Packing	0.10 to 1.50	**0.10**
	Use of Fired Equipment		0.00
	Hot oil heat exchange system	0.15 to 1.15	0.00
	Rotating Equipment	0.50	0.00
	Special Process Hazard Factor (F2)		**1.82**
Process Unit Hazard Factor (F3 = F1 x F2)			**3.731**
Fire & Explosion Index (F. & E.I. = F3 x M.F.)			**37.31**
Degree of Hazard		**Light**	

NA-Not Available

Interpretation

The calculation for Dow Fire and Explosion Index is given and from the calculations it is seen that the storage will have a **Dow Index of 37.31 indicating Light Hazard Potential.** Based on the unsafe distances identified by the DOW Index, the radius of exposure from the raw material storage area is around **8.5 meters** and the Area of Exposure is around **226.86 sq. m.**

Degree of Hazard for F & EI

Degree of Hazard for F & EI	
F & EI Index Range	**Degree of Hazard**
1-60	Light
61-96	Moderate
97-127	Intermediate
128-158	Heavy
159-up	Severe

RECOMMENDED MINIMUM FEATURES ACCORDING TO DOW FIRE AND EXPLOSION INDEX

Preventive & Protective Features	Fire & Explosion Index Number						Index for the present case			
	0-20	20-40	40-60	60-75	75-90	>90	37.31			
							Optional	Suggested	Feature recommended	Feature required
1) Fireproofing	1	2	2	3	4	4		√		
2) Water spray										
a) directional	1	2	3	3	4	4		√		
b) area	1	2	3	3	4	4		√		
c) curtain	1	1	2	2	2	4	√			
3) Special instrumentation										
a) temperature	1	2	3	3	4	4		√		
b) pressure	1	2	3	3	3	4		√		
c) flow control	1	2	3	4	4	4		√		
4) Dust, blowdown, spill control	1	1	2	3	3	4	√			
5) Internal examination	1	2	3	3	4	4		√		
6) Combustible gas monitors										
a) signal alarm	1	1	2	3	3	4	√			
b) actuate equipment	1	1	2	2	3	4	√			
7) Remote operation	1	1	2	3	3	4	√			
8) Diking, (Not Applicable as barrel storage)	1	4	4	4	4	4				√
9) Blast & barrier walls separation	1	1	2	3	4	4	√			

1) Feature optional 2) Feature suggested 3) Feature recommended 4) Feature required

3. High Speed Diesel (HSD)

Tank No.	--			Equipment Name		HSD – **2000 Lit**			
Basic Material for Material factor			Tank		**Density, kg/l**	0.82			
Properties of material									
N h	1	**N f**	2	**N r**	0	**M.F.**			**10**
Boil. Pt.	--	**^{0}F**	--	**^{0}C**	**Flash pt.**	200	**^{0}F**	93.3	**^{0}C**
ΔHC = Heat of Comb.	10000	**BTU / lb**							
Quantity of the material	2000	**L**	1640	**kg**	3615.58	**Lb**			
Storage conditions	**Temp**	30	**^{0}C**	**Pressure**	1.0	**atm**			

		Penalty factor	Penalty
1.General Process Hazard	**Base Factor**	1.00	**1.00**
	Exothermic Chemical Reaction	0.30 to 1.25	**0.00**
	Endothermic Processes	0.20 to 0.40	0.00
	Material handling and transfer	0.25 to 1.05	**0.40**
	Enclosed or Indoor Process Units	0.25 to 0.90	0.00
	Access	0.20 to 0.35	**0.20**
	Drainage and Spill Control	0.25 to 0.50	**0.00**
	General Process Hazard Factor (F1)		**1.60**
2.Special Process	**Base Factor**	1.00	**1.00**
	Toxic material(s)	0.20 to 0.80	**0.40**
	Sub atmospheric pressure (< 500 mm Hg)	0.50	0.00
	Operation in or near flammable range_____inerted _____non inerted	0.00 to 0.80	0.00
	1. Tank farm storage flammable liquids	0.50	0.00
	2. Process upset or purge failure	0.30	0.00
	N. **Always in contact of Flame process**	0.80	0.00
	Dust Explosion	0.25 to 2.00	0.00
	Pressure Operating pressure ___psig Relief setting _____ psig		0.00
	Low temperature	0.20 to 0.30	0.00
	Quantity of flammable / unstable		
	7. Liquids or gases in process		0.0
	8. Liquids or gases in storage		**0.0**

	9. Combustible Solids in Storage, Dust in Process		0.00
	Corrosion & Erosion	0.10 to 0.75	**0.10**
	Leakage – Joints & Packing	0.10 to 1.50	**0.10**
	Use of Fired Equipment		0.00
	Hot oil heat exchange system	0.15 to 1.15	0.00
	Rotating Equipment	0.50	0.00
	Special Process Hazard Factor (F2)		**1.60**
Process Unit Hazard Factor (F3 = F1 x F2)			**2.56**
Fire & Explosion Index (F. & E.I. = F3 x M.F.)			**25.6**
Degree of Hazard		**Light**	

NA-Not Available

Interpretation

The calculation for Dow Fire and Explosion Index is given and from the calculations it is seen that the storage will have a **Dow Index of 25.6 indicating Light Hazard Potential.** Based on the unsafe distances identified by the DOW Index, The radius of exposure from the raw material storage area is around **6.1 meters** and the Area of Exposure is around **116.83 sq. m.**

Degree of Hazard for F & EI

Degree of Hazard for F & EI	
F & EI Index Range	**Degree of Hazard**
1-60	Light
61-96	Moderate
97-127	Intermediate
128-158	Heavy
159-up	Severe

RECOMMENDED MINIMUM FEATURES ACCORDING TO DOW FIRE AND EXPLOSION INDEX

Preventive & Protective Features	Fire & Explosion Index Number						Index for the present case			
	0-20	20-40	40-60	60-75	75-90	>90	25.6			
							Optional	Suggested	Feature recommended	Feature required
1) Fireproofing	1	2	2	3	4	4		√		
2) Water spray										
a) directional	1	2	3	3	4	4		√		
b) area	1	2	3	3	4	4		√		
c) curtain	1	1	2	2	2	4	√			
3) Special instrumentation										
a) temperature	1	2	3	3	4	4		√		
b) pressure	1	2	3	3	3	4		√		
c) flow control	1	2	3	4	4	4		√		
4) Dust, blowdown, spill control	1	1	2	3	3	4	√			
5) Internal examination	1	2	3	3	4	4		√		
6) Combustible gas monitors										
a) signal alarm	1	1	2	3	3	4	√			
b) actuate equipment	1	1	2	2	3	4	√			
7) Remote operation	1	1	2	3	3	4	√			
8) Diking, (Not Applicable as barrel storage)	1	4	4	4	4	4				√
9) Blast & barrier walls separation	1	1	2	3	4	4	√			

1) Feature optional 2) Feature suggested 3) Feature recommended 4) Feature required

1.1.6 STORAGE RECOMMENDATION FOR FLAMMABLE CHEMICALS

1. All the chemicals will be stored according to its **compatibility** to each other.
2. **Earthing** shall be provided to the storage area for dealing with the static charges that might generate during the loading and unloading of the solvents.
3. **Provision of sand buckets, foam monitor, fire extinguishers & hydrant line** area will be made available.
4. Appropriate **drainage with the slope of 2 %** to be provided to remove small and large spillage of the chemicals.
5. Provision of **spill kit** shall be provided to deal with the minor spillage scenario.
6. **Smoke detectors, alarm** to be provided to detect any leakage.
7. The **secondary containment** shall be provided and be kept clean and free from any accumulation of inflammable liquids.
8. The **storage shed shall be ventilated** near the **ground level and also near the roof.** The ventilators shall be covered with two layers of fine copper or non-corrodible metal wire gauge of mesh not less than 11 meshes per linear cm.
9. No alterations shall be carried out without written permission of licensed authority.
10. All the empty receptacles will be kept securely closed unless they have been thoroughly cleaned.
11. The **suitable extinguishers** shall be kept immediately outside the storage shed.
12. **Access of unauthorized person** to flammable chemicals receptacles will be **restricted.**
13. Daily inventory of such chemicals shall be maintained.

1.1.7 STORAGE RECOMMENDATIONS FOR ABOVE GROUND FUEL STORAGE TANKS

- The tanks will be **fabricated taking into account the corrosion resistance** properties of the raw materials.
- The tanks will be **provided with breather valves** due reduce the vapor losses directly to the atmosphere.
- The dyke enclosure **will be lined with impervious coating.**

- Regular inspection of the **tank, transfer pipelines and dyke** will be done and records will be maintained.
- **Mechanical seals** will be provided to be **pumps** used in the tank farm yard **to prevent leakages.**

1.1.8 INTERPRETATION

According to the Dow Index the F & EI is calculated for the storage of **Diethyl Ether** indicates **Intermediate** degree of hazard. As the worst-case scenario is considered for prediction, rest of raw materials will inevitably be having degree of hazard lower than the Intermediate**.** Also for fuel storage (FO & HSD) the Dow Index is calculated. To reduce the intensity of the identified hazard, recommendations and suggestions must be followed strictly which are addressed above**.**

1.2 TOXICITY (MONDS) INDEX

1.2.1 INTRODUCTION

The principle and general approach used in the DOW method of hazard evaluation have been further developed by ICI Mond Division, the revised Mond Fire, Explosive and Toxicity index is a series of papers by Lewis (1979). The main developments made to the DOW Index in the Mond Index are:

- It covers a wider range of process and storage installation
- It covers the processing of chemicals with explosive properties.
- A calculation procedure is included to allow for the off-setting effects of good design and control and safety instrumentation.
- The procedure has been extended to cover plant layout.
- Separate indices are calculated to access the hazards of fire, internal explosion and aerial explosion.

Some of the raw materials stored in the site are toxic in nature. Hence appropriate standard operating procedures are established by the company for ensuring the safety of the workers handling the raw materials on daily basis. Some selected toxic raw materials are used for calculating the toxicity index using Mond's index. The raw materials are selected based on their degree of hazard. (i.e. Nh = 4)
The Caustic Soda was not available in the ALOHA software. So its Mond’s index was calculated.
Monds Index work sheet is attached as **Annexure 7.2.**

Table 6: Toxic Raw materials stored in Drums & Bags

Sr. No.	Raw Materials	Maximum Quantity at any point of time (Kg)	Type of Storage	Nh	Exposure limit, ppm
1	Phosphorous Oxychloride	6872	Drums	4	0.1 ppm
2	Hydrazine Hydrate	840	Drums	4	<5 ppm
3	Ethyl Chloroformate	824	Drums	4	<5 ppm
4	Methane Sulfonyl Chloride	980	Drums	4	<5 ppm
5	Nitric Acid	871	Drums	4	2 ppm
6	Sodium Azide	508	Bags	4	0.1 ppm
7	Thiocarbohydrazide	1128	Bags	4	<5 ppm
8	Dimethyl Sulphate	1893	Drums	4	1 ppm
9	Phosphorus Trichloride	1563	Drums	4	0.5 ppm
10	Mesityl Chloride	2400	Drums	4	<5 ppm
11	Bromine	2379	Drums	4	0.2 ppm
12	Acetone Cyanohydrin	402	Drums	4	4.7 ppm
13	Sulfuryl Chloride	1688	Drums	4	<5 ppm
14	Phenyl Chloroformate	1098	Drums	4	<5 ppm
15	Methyl Chloroformate	581	Drums	4	0.1 ppm

Table 7: Toxic Products stored in Drums & Bags

Sr. No.	Product	Maximum Quantity at any point of time (MT)	Type of Storage	Nh	Exposure limit, ppm
1	PMPC (4- Methyl Phenacyl Chloride)	20	Drums	4	0.5 ppm

Table 8: Calculated Mond's Index and Degree of Hazard for Hazardous Chemicals.

Chemicals	Phosphorous Oxychloride	Hydrazine Hydrate	Ethyl Chloroformate	Methane Sulfonyl Chloride	Nitric Acid	Sodium Azide	Thio Carbohydrazide	Dimethyl Sulphate
Storage	Drums	Drums	Drums	Drums	Drums	Bags	Bags	Drums
N_h (NFPA Index Number)	4	4	4	4	4	4	4	4
T_h(Toxicity factor)	325	325	325	325	325	325	325	325
Ts (Correction factor)	125	125	125	125	125	125	125	125
F1 General Process Hazard	1.7	1.7	2.55	1.7	1.7	1.7	1.7	1.7
F2 Special Process Hazard	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Toxicity Index	9.125	9.125	10.187	9.125	9.125	9.125	9.125	9.125
Degree of Hazard	Moderate	Moderate	**High**	Moderate	Moderate	Moderate	Moderate	Moderate

Chemicals	Phosphorus Trichloride	Mesityl Chloride	Bromine	Acetone Cyanohydrin	Sulfuryl Chloride	Phenyl Chloroformate	Methyl Chloroformate	PMPC (Product)
Storage	Drums	Drums	Drums	Drums	Drums	Drums	Drums	Drums
N_h(NFPA Index Number)	4	4	4	4	4	4	4	4
T_h(Toxicity factor)	325	325	325	325	325	325	325	325
Ts (Correction factor)	125	125	125	125	125	125	125	125
F1 General Process Hazard	1.7	1.7	1.7	1.7	1.7	1.7	2.55	1.7
F2 Special Process Hazard	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Toxicity Index	9.125	9.125	9.125	9.125	9.125	9.125	10.187	9.125
Degree of Hazard	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	**High**	Moderate

1.2.2 INTERPRETATION

According to the Mond's Index the toxicity index is calculated for the storage of Phosphorous Oxychloride, Hydrazine Hydrate, Ethyl Chloroformate, Methane Sulfonyl Chloride, Nitric Acid, Sodium Azide, Thio Carbohydrazide, Dimethyl Sulphate, Phosphorus Trichloride, Mesityl Chloride, Bromine, Acetone Cyanohydrin, Sulfuryl Chloride, Phenyl Chloroformate, and Methyl Chloroformate.

Out of that, **Ethyl Chloroformate & Methyl Chloroformate** indicating **high degree** of hazard and remaining raw materials indicating moderate degree of hazard and however to reduce the intensity of risk associated with such storage following recommendations are suggested and the same should be followed.

Recommendations/ Suggestions

1. Materials to be stored according to their compatibility.

2. Toxic materials to be stored in cool and kept away from heat.

3. Toxic material can cause breathing difficulty therefore storage area should be well ventilated.

4. Good house-keeping practice to be ensured in storage area.

5. Recommendations given in MSDS"s to be strictly adhered to while handling and storage of these materials.

1.3 HAZOP STUDY

HAZOP study has been carried out for hazardous operations and process. For the preparation of the HAZOP study P & IDs, Operating Procedures, Mass balances and MSDS were used. The brief recommendations of the HAZOP studies are highlighted below. HAZOP report is attached as **Annexure 7.3.**

1.3.1.1 GENERAL RECOMMENDATIONS

- Regular calibration & verification of the level indicator
- Regular preventive check up by competent person
- On job training to the operator to handle the reaction & parameter as prescribed in the SOP.
- Design appropriate scrubbing system as a per the requirement
- Appropriate flow should be measured online
- Appropriate design of glass column & condenser
- Heat exchangers to be of appropriate design to handle proper heat load.

- Procedure to proper handling of system & regular check & replace of solution based on concentration
- On job training to the operator to handle the process of distillation & parameter as prescribed in the SOP.
- Operator training to identify vacuum & vapor leak in the reactor as well as distillation assembly.
- On job training to the operator to handle the high vacuum ejector system
- Connection of cool water line with valve in to the ejector sump is to be provide
- On job training to the operator to handle the toxic material
- SOP to be made & displayed near the location in local language
- In case of gas poisoning what to do SOP to be made & displayed near the location in local language
- Preventive maintenance of critical equipment's
- Location of spill control kit & how to use kit should available.
- Calibration date & due date tag should be displayed near by the instrument

1.3.1.2 SPECIFIC RECOMMENDATIONS

- Temp ind provided on reactor & vapor line.
- Vacuum PG/PT Provided ,Manometer Provided
- RD & PSV Provided on Reactor & Connected to Closed System with Dump Tank
- PSV,PG,NRV Provided on Reactor & PRS Station
- Air Line Provided with PG & Moisture Separator ,Regulator
- Anti-Syphone Hole Provided on Dip Pipe of Charging line
- Trained Operator to Ensure Proper Material is Receieved with Label.
- V9011A & B are of Glass
- R9010 Provided with View Glass
- Hot Oil Line Provided with TI & Interlock with Auto Cut-off of TFH
- Mech Seal Provided,PSV RD Provided
- SCBA,PPEs Provided
- Side glass provided at bottom of Nf 9080.
- Chilling Water Provided to R9050 Jacket
- Trained Operator to Check Quantity as Per BMR
- Fire hydrant system including sprinklers system provided.
- Pressure Gauge Provided AOD Pump Discharge

- Weigh Balance Provided & Calibration to be done Periodically
- PP Hood Connected to Drum with Vacuum through Scrubber Blower