# 1.0 RISK ASSESSMENT

## 1.1 Introduction

Risk analysis follows an extensive hazard analysis. Identification of causes and types of hazards is the primary task for planning for risk assessment. Hazard can happen because of the nature of chemicals handled and also the nature of process involved. So, for risk analysis first step is to identify the hazardous chemicals which are to be studied for risk analysis.

It involves the identification and assessment of risks at the project site and in the neighboring population who could get exposed to, as a result of hazards present. This requires a thorough knowledge of failure probability, credible accident scenario, vulnerability of population etc.

In the sections below, the identification of various hazards, probable risks in the proposed power plant, maximum credible accident analysis, consequence analysis are addressed which gives a broad identification of risks involved in the plant.

***Approach to the Study***

Risk involves the occurrence or potential occurrence of some accidents consisting of an event or sequence of events. The risk assessment study covers the following:

- Identification of potential hazard areas;
- Identification of representative failure cases;
- Visualization of the resulting scenarios in terms of fire (thermal radiation) and explosion;
- Assess the overall damage potential of the identified hazardous events and the impact zones from the accidental scenarios;
- Assess the overall suitability of the site from hazard minimization and disaster mitigation point of view
- Furnish specific recommendations on the minimization of the worst accident possibilities; and
- Preparation of broad Disaster Management Plan (DMP), On-site and Off-site Emergency Plan, which includes Occupational and Health Safety Plan.

**MANUFACTURING DETAILS OF PROCESS AT M/s. Swastik Chloroffin LLP**

Heavy Normal Paraffin/Normal Paraffin/ Normal Paraffin/ L.R.2030 are saturated alkane of hydrocarbon chain $C^9$-$C^{18}$ and are commercially available from

- M/s Reliance Industries Ltd. Patalganga Maharashtra
- M/s Tamil nadu Petro Products Ltd. Madras
- Imported we purchase the same from local market at market rate.

This H.N.P/N.P/L.N.P/L.P 2030 is brought in tankers and unloaded in storage tank and with pump, is sent to Melter and heated H.N.P/N.P is sent in to jacketed reactor through chlorine header and from header to vaporizer wherein pressure and flow rates are measured and sent to reactor.

$CnHn+2Cl_2=CnHnCl_2+2HCl+Heat$.

1 MT HNP + 3.5MT of Chlorine +3.6 $H_2O$ = 2.6 Mt CPW + 5.4 MT HCl + 0.14 MT waste. 0.14 MT of 3.5 MT of $Cl_2$ is approx 1% of chlorine which is neutralized with sodium hypo and this sodium hypo have commercial value and sold in market.

HCl fumes goes to separator buffer S.N where vapor form of N.P/H.N.P is condensed and drained out for future use. HCl gas is passed on circulating water or dilutes HCl in graphite absorbers.

$HCl+H_2O=====HCl + Heat$.

Graphite absorbers are cooled with water and hot water is sent to cooling tower and is rescued. Gases from absorber are sent to bubbling tank. The diluted acid of bubbling tank is used as fresh refill for circulating tank. HCl is stored in HCl storage tank for sale. Gases from bubbling tank are sent to waste gas storage system and from waste gas storage to sodium hypo chlorite plant or to lime neutralization system. The reaction on reactor is exothermic and temperature is controlled by circulating water from cooling tower the temperature of process from 60°C to 120°C am dos gradually increased by controlling chlorine feed rate. CRW thus processed of 1.4 is clear by compressed air initially in reactor and subsequently in degasser. Epoxy plasticizer at rate of 8 Kg per Ton of CPW is added for Neutralization of remaining HCl fumes. CPW thus cleaned is packed in 250 Kg. PVC cans with weighing scale. Use of Epoxy Plasticizer depends on presence of untreated HCL Fumes.

The process of manufacture of Sodium Hypochlorite

The Hypochlorite, one of the strongest classes of bleaching agents is used in laundering and for pulp and textile bleaching. Commercial bleaching solution is prepared by passing chlorine gas through caustic soda solutions containing less than 20.5 % sodium hydroxide. Sodium chloride is salted out if caustic solution containing at most 15% available chlorine is used for industrial bleaching.

It is important to note that free caustic should always be present in the solution as it acts as stabilizer. It is also important to note the hypo chlorite solution should not contain heavy metals.

The hypochlorite solution should be stored at temperature below 30°C significant decomposition of the hypochlorite solution occurs above40°C.

## 1.2 Chemical Hazards identified at M/s. Swastika Chloroffin LLP

Identification of Hazardous Chemicals is done in accordance with The Manufacture, Storage and import of Hazardous Chemical Rules, 1989. Schedule-1, of the Rule provides a list of the Toxic and

Hazardous chemicals and the flammable chemicals. It defines the flammable chemicals based on the flashpoint and boiling point.

"Major accident hazards (MAH) installations" is defined as the isolated storage and industrial activity at a site handling (including transport through carrier or pipeline) of hazardous chemicals equal to or, in excess of the threshold quantities specified in Column-3 of Schedule-2 and 3 respectively.

Schedule-3 has classified hazardous substances in an operating plant into 5 groups and has provided the threshold quantities for application of above rules.

Group1 & 2 – Toxic substances
Group 3 – Highly reactive substances
Group 4 – Explosive substance
Group 5 – Flammable substances

The following **Table-1.0** shows the list of major chemicals stored onsite which have been identified as hazardous chemicals in The Manufacture, Storage and import of Hazardous Chemical Rules, 1989 and which are to be considered as Major accident hazards (MAH) installations.

## Hazard Identification Risk Assessment

1. Chlorine toners- 15 Nos. Each Capacity of 900 Kg

2. Pipeline of Chlorine from Grasim is AG, Length- 100m, Dia- 2inch

3. Total Day storage capacity of HCL at site will be Maximum 1 day, 5 No. HCL Tank (Each 40 Tonnes)

4. Sodium Hypochlorite

5. Chlorinated paraffin wax

## Fuel Oil and Chlorine

The identification of specific scenarios is based on the assessment of likely events and incidence of failures. In most of the cases stored quantities of liquid fuel and chemicals are considered in hazard identification.

**Table- 1.0: Hazardous Chemicals Handled onsite**

| S. No. | Chemical | Nature of | Storage | Threshold |
|---|---|---|---|---|

| | | Chemical (Schedule 1 & 3) | Quantity | quantity for MAH |
|---|---|---|---|---|
| 1. | Fuel Oil | Highly Flammable | 3750 KL* | 2500 tonnes |
| 2. | Chlorine | Toxic – Group 2 | 25 tonnes* | 10 tonnes |
| 3. | Hydrochloric Acid | Hazardous | 250 tonnes | Not considered |
| 4. | Sodium Hypochlorite | Hazardous | 24 tonnes | Not considered |

* To be considered as MAH

The chemicals which are stored more than the threshold quantities are considered for major accident hazard.

1. Fuel oil (LDO/HFO), used as supportive fuel in the boiler, and is classified as Highly Flammable liquid as its flash point remains within $30^{o}C$–$90^{o}C$. Its threshold quantity is 2500 tonnes.

2. Chlorine is a toxic gas and its MAH quantity is 25 tonnes. A substantial release will then form a vapour cloud. As the cloud travels under the influence of wind, it disperses and its concentration becomes further diluted and at some distance concentration becomes non-hazardous.

3. Hydrochloric Acid, sodium hypochlorite are hazardous chemicals but are not included in Schedule-3 for MAH.

**Explosion hazards can take place due to the following reasons also:**

**a) Bursting of Pipe Lines, Vessels**

- Water / Steam pipes due to high pressure/ temperature
- Gas lines and Acid lines.
- Acid/Alkali tanks
- Gas Cylinders
- Compressed air header
- Compressed air receivers
- Electrical Hazards
- Fire Hazards

**b) Failure scenario/Release of Liquid posing risk are listed below:**

- Spillage in Acid and alkali tanks
- Leak in Chlorine toners & 100m pipeline from Grasim Industries
- Spillage, Leak & Catastrophic Rupture in Fuel oil tanks in fuel oil handling section

## 2.0 Maximum Credible Accident (MCA) Analysis

Maximum Credible Accident Scenario involves identification of failure modes and scenarios.The MCA analysis involves ordering and ranking of various sections in terms of potential vulnerability. The data requirements for MCA analysis are:

- Flow diagram and P&I diagrams
- Detailed design parameters
- Physical and chemical properties of all the chemicals
- Plant layout
- Past accident data

### Fire and Explosion Index (FEI) & Toxicity Index (TI)

Fire and Explosion Index (FEI) is useful in identification of areas in which the potential risk reaches a certain level. It estimates the global risk associated with a process unit and classifies the units according to their general level of risk. FEI covers aspects related to the intrinsic hazard of materials, the quantities handled and operating conditions. This factor gives index value for the area which could be affected by an accident, the damage to property within the area and the working days lost due to accidents.

Degree of hazards based on FEI and TI is given in the following **Tables 2** and **3** respectively.

**Table 2**

**Degree of Hazards Based on FEI**

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

***Source:*** *Dow's Fire and Explosion Index Hazard Classification Guide, Seventh Edition, AIChE Technical Manual (1994)*

**Table 3**

**Degree of Hazards Based on TI**

| TI Range | Degree of Hazard |
|---|---|
| 0 – 5 | Light |
| 5 – 10 | Moderate |
| Above 10 | High |

Preventive and protective control measures are recommended based on degree of hazard. Therefore, FEI indicates the efforts to be taken to reduce risks for a particular unit. FEI and TI computed for various process equipments are presented
in **Table 4**

**Table 4**

**Fire and Explosion Index and Toxicity index**

| Sr. No. | Unit Name | FEI | Category |
|---|---|---|---|
| **Fire and Explosion Index** | | | |
| 1 | Oil Storage Tank | 15.1 | Light |
| **Toxicity index** | | | |
| 1 | Chlorine Tonner | 19.35 | High |
| 2 | Hydrochloric Acid storage | 13.25 | high |
| 3. | Sodium Hypochlorite | 12.1 | High |
| 4. | Chlorinated Paraffin Wax | 10.2 | High |

Consequence Analysis is the application of the mathematical, analytical and computer models (PHAST software) for calculation of the effects and damages subsequent to a hydrocarbon/toxic release Event.

PHAST & PHAST RISK Software is used to predict the physical behavior of hazardous incidents. The model uses below mentioned techniques to assess the consequences of identified scenarios:

- Modeling of discharge rates when Leaks develop in process equipment/pipe work.
- Modeling of the size & shape of the flammable/toxic gas clouds from releases in the atmosphere.
- Modeling of the flame and radiation field of the releases that are ignited and burn as pool fire.

## 2.1 Consequence Modelling

### Discharge Rate

The initial rate of release through a leak depends mainly on the pressure inside the equipment, size of the hole and phase of the release. The release rate decreases with time as the equipment depressurizes. This reduction depends mainly on the inventory and the action taken to isolate the leak and blow-down the equipment.

### Dispersion

Releases of gas into the open air form clouds whose dispersion is governed by the wind, by turbulence around the site, the density of the gas and initial momentum of the release. In case of flammable materials the sizes of these gas clouds above their Lower Flammable Limit (LFL) are important in determining whether the release will ignite. In this study, the results of dispersion modeling for flammable materials are presented LFL quantity.

### Pool Fire

A cylindrical shape of the pool fire is presumed. Pool-fire calculations are then carried out as part of an accidental scenario, e.g. in case a hydrocarbon liquid leak from a vessel leads to the formation of an ignitable liquid pool. First no ignition is assumed, and pool evaporation and dispersion calculations are being carried out. Subsequently late pool fires (ignition following spreading of liquid pool) are considered. If the release is bounded, the diameter is given by the size of the bund. If there is no bund, then the diameter is that which corresponds with a minimum pool thickness, set by the type of surface on which the pool is spreading.

While modeling cases of lighter hydrocarbons in the range of ATF wherein the rainout fraction have been minimal (not leading to pool formation) due to the horizontal direction of release, downward impingement has been considered for studying the effects of pool fire for consequence analysis only.

Pool fires occur when spilled hydrocarbons burn in the form of large diffusion flames. Calculating the incident flux to an observer involves four steps, namely

- Characterizing the flame geometry
- Estimation of the flame radiation properties
- Computation of the geometric view factors
- Estimation of flame attenuation coefficients and computation of geometric view factors between observer and flame.

The size of the flame will depend upon the spill surface and the thermo chemical properties of the spilled liquid. In particular, the diameter of the fire, the visible height of the flame, the tilt and drag of the flame etc. The radioactive output of the flame will depend upon the fire size, the extent of mixing with air and the flame temperature. Some fraction of the thermal radiation is absorbed by the carbon dioxide and water vapor in the intervening atmosphere. In addition, large hydrocarbon fires produce thick smoke which significantly obscure flame radiation.

The calculations for radiation damage distances start with estimation of the burning velocity:

$Y = 92.6\ e - 0.0043 T_b Mw 10^{-7}/(D \times 6)$

Where, y= burning velocity in m/s

Mw= molecular weight in kg/kg mol

$T_b$= normal boiling point

The next step involves calculation of the equivalent diameter for the spreading pool- this depends upon the duration of the spill (continuous, instantaneous, finite duration etc.). This is calculated using expressions like:

$D_{eq.} = 2(V/3.142y)^{1/2}$

Where $D_{eq.}$ Is the steady state diameter of the pool in m

V= liquid spill rate in $m^3/s$

Y= Liquid burning rate in m/s

In the absence of frictional resistance during spreading, the equilibrium diameter is reached over a time given by:

$T_{eq.}= 0.949\ D_{eq.}/(\Delta\ y\ X\ D_{eq.})^{1/3}$

The visible flame height is given by;

$H_{flame}= 42D_p\ ((BvD/D_a(gD_p)1/2)^{0.61}$

Where $H_{flame}$ = flame height in m

D= density in kg/$m^3$

$D_a$= air density in kg/$m^3$

g = gravitational acceleration or 9.81 m/$s^2$

The emissive power of a large turbulent fire is a function of the black body emissive power and the flame emissivity. The black body emissive power can be computed by Planck's law of radiation. The general equation used for the calculation is:

$E_P= -0.313T_b+117$

Where $E_p$ is the effective emissive power in kw/$m^2$

$T_b$= normal boiling point of the liquid in °F

Materials with a boiling point above 30 °F typically burn with sooty flames-the emissive power from the sooty section is about 20 kW /$m^2$. The incident flux at any given location is given by the equation:

$Q_{incident}$ = EP * t * $V_F$

Where, $Q_{incident}$ = incident flux in kw/$m^2$

t= transmitivity (a function of path length, relative humidity and flame temperature) often taken as 1 and the attenuation of thermal flux due to atmospheric absorption ignored.

$V_F$= geometric view factor

The view factor defines the fraction of the flame that is seen by a given observer.

$V_F$= 1.143 ($R_p$/X) 1.757

Where, X= distance from the flame center in m

$R_p$= pool radius in m

Based on the radiation received, the fatality levels are calculated from Probit equation, which for protected clothing is given by:

Pr.= -37.23 + 2.56 ln (t X $Q^{4/3}$)

Where Pr. = Probit No.

t= time in seconds

Q heat radiation in w/$m^2$

## Thermal Hazard Due to Pool Fire

Thermal radiation due to pool fire may cause various degree of burn on human body and process equipment. The following table details the damage caused by various thermal radiation intensity.

**Table 5: Effects due to incident radiation intensity**

| Incident Radiation (kW/$m^2$) | Type of Damage |
|---|---|
| 0.7 | Equivalent to Solar Radiation |
| 1.6 | No discomfort for long exposure |
| 4.0 | Sufficient to cause pain within 20 sec. Blistering of skin (first degree burns are likely) |
| 9.5 | Pain threshold reached after 8 sec. Second degree burns after 20 sec. |
| 12.5 | Minimum energy required for piloted ignition of wood, melting plastic tubing etc. |
| 25 | Minimum energy required to ignite wood at indefinitely long exposure |
| 37.5 | Sufficient to cause damage to process equipment |

**Table 6: Physiological Effects of Threshold Thermal Doses**

| Dose Threshold, KJ/$M^2$ | Effect |
|---|---|
| 375 | 3rd Degree Burn |
| 250 | 2nd Degree Burn |
| 125 | 1st Degree Burn |
| 65 | Threshold of pain, no reddening/blistering of skin. |

1st Degree Burn : Involve only epidermis, blister may occur; example - sun burn.

2nd Degree Burn : Involve whole of epidermis over the area of burn plus some portion of dermis.

3rd Degree Burn : Involve whole of epidermis and dermis; subcutaneous tissues may also be damaged.

Explosion may also occur due to release of natural gas through leakage. This will cause damage mainly to property.

## Toxic Release

The aim of the toxic risk study is to determine whether the operators in the plant, people occupied buildings and the public are likely to be affected by toxic substances. Toxic gas cloud e.g. chlorine, etc was undertaken to determine the extent of the toxic hazard created as the result of loss of containment of a toxic substance.

Standard System for the Identification of the Hazards of Materials for Emergency Response" is a standard maintained by the **U.S.-based National Fire Protection Association**. "**fire diamond"** used by emergency personnel to quickly and easily identify the risks posed by hazardous materials. The four divisions are typically color-coded with **red indicating flammability**, **blue indicating level of health hazard**, **yellow for chemical reactivity**, and **white containing codes for special hazards**. Each of health, flammability and reactivity is rated on a scale from 0 (no hazard) to 4 (severe risk).

The numeric values in the first column are designated in the standard by **"Degree of Hazard**" using numerals (0, 1, 2, 3, 4)

**Table 7: Physiological response to chlorine concentration**

| Physiological Response | Concentration equal to or greater than | |
|---|---|---|
| | ppm | $mg/m^3$ |
| Slight symptom after several hours. | 1.0 | 3.0 |
| Odour detectable | 3.0 – 3.5 | 9.0 – 10.0 |
| Maximum allowable for exposure of 0.5 to 1 hr. | 4 | 12 |
| Least amount causing immediate irritation to throat. | 10 – 15 | 30 – 45 |
| Cause coughing | 30 | 87 |
| Dangerous in about 30 minutes | 40 – 60 | 116 – 174 |

| | | |
|---|---|---|
| Lethal concentration for 50% of population after 30 minutes exposure | 500 | 1450 |
| Fatal in 30 min or less | 1000 | 2900 |
| Fatal in 10 minutes | 1800 | 5200 |

**Table 8: Pasquill-Giffard Atmospheric Stability class**

*** Class D & F are considered for modelling Worst case scenario*

| Sr. No. | Stability Class | Weather Conditions |
|---|---|---|
| 1. | A | Very unstable – sunny, light wind |
| 2. | A/B | Unstable - as with A only less sunny or more windy |
| 3. | B | Unstable - as with A/B only less sunny or more windy |
| 4. | B/C | Moderately unstable – moderate sunny and moderate wind |
| 5. | C | Moderately unstable – very windy / sunny or overcast / light wind |
| 6. | C/D | Moderate unstable – moderate sun and high wind |
| 7. | D | Neutral – little sun and high wind or overcast / windy night |
| 8. | E | Moderately stable – less overcast and less windy night |
| 9. | F | Stable – night with moderate clouds and light / moderate wind |
| 10. | G | Very stable – possibly fog |

## 2.2 Selected Worst-case Failure Cases for Consequence Analysis

**Table 9: Selected Worst Case Failure scenarios**

| Sl.No. | Failure Scenarios | Likely Consequences |
|---|---|---|
| **LDO** | NFPA classification of Chemicals | Nh= 1<br>Nf= 2<br>Nr= 0 |
| 1. | 25 and 50 mm leak in Oil storage Tank | Thermal radiation Flash Fire, Jet Fire, Pool Fire |
| 2. | Catastrophic failure of LDO storage tank | Thermal radiation, Flash Fire, Pool Fire |
| **Transformer Oil** | NFPA classification of Chemicals | Nh= 1<br>Nf= 1 |

| | | |
|---|---|---|
| | | Nr= 0 |
| 3. | 25 and 50 mm leak in Transformer Oil storage Tank | Thermal radiation Flash Fire, Jet Fire, Pool Fire |
| 4. | Catastrophic failure of Transformer Oil storage tank | Thermal radiation, Flash Fire, Pool Fire |
| **Chlorine** | NFPA classification of Chemicals | Nh=4<br>Nf=0<br>Nr= 0 |
| 11. | 5 mm leak in Chlorine Tonner for 10 PPM IDLH condition | Toxic Release |
| 12. | 5 mm leak in Chlorine Transfer Piping of 2" for 10 PPM IDLH condition | Toxic Release |
| 13. | Line Rupture in Chlorine Transfer Piping 2" for 10PPM IDLH condition | Toxic Release |

## 2.3 Consequence Analysis Results

Consequence analysis was carried out for identified selected failure cases given in **Table no 9**. Damage distances for the accidental release of hazardous materials have been computed at 2F, 3D and 5D weather conditions. In these conditions, 2, 3 and 5 are wind velocities in m/s and F and D are atmospheric stability classes. These weather conditions have been selected to accommodate worst case scenarios to get maximum effective distances. DNV based PHAST Micro 6.51 software has been used to carry out consequence analysis.

Consequence analysis quantifies vulnerable zones. For the selected accidental failure scenarios, after vulnerable zone is defined, measures to minimize damages caused. Results of the consequence analysis for the scenarios covered in this study are summarized in **Table no 10 to 14** given below**.** Major contributing Scenarios from Thermal Power Plant are given in **Fig. No. 1 to 14** below:

### Table 10: Flash Fire Consequence Analysis

| Scenario Considered | LFL Concentration (ppm) | Leak Size (mm) | Weather | LFL Distance (m) |
|---|---|---|---|---|
| Oil Storage | 8000 | 25 | 2F | 11.50 |

| Scenario Considered | LFL Concentration (ppm) | Leak Size (mm) | Weather | LFL Distance (m) |
|---|---|---|---|---|
| | | | 3D | 7.55 |
| | | | 5D | 4.64 |
| | | 50 | 2F | 17.55 |
| | | | 3D | 10.39 |
| | | | 5D | 9.02 |
| | | Catastrophic Rupture | 2F | 161.74 |
| | | | 3D | 111.94 |
| | | | 5D | 90.4 |
| | | | 3D | 20.77 |
| | | | 5D | 20.75 |
| | | Catastrophic Rupture | 2F | 15.42 |
| | | | 3D | 16.65 |
| | | | 5D | 19.29 |
| | | | 3D | 13.05 |
| | | | 5D | 12.89 |
| | | Catastrophic Rupture | 2F | 19.70 |
| | | | 3D | 24.08 |
| | | | 5D | 28.59 |

**Table 11: Jet Fire Consequence Analysis**

| Scenario Considered Leak | Leak Size (mm) | Weather | Damage Distance (m) for Various Heat Loads | | |
|---|---|---|---|---|---|
| | | | 37.5 kW/m² | 12.5 kW/m² | 4.0 kW/m² |

| Scenario Considered Leak | Leak Size (mm) | Weather | Damage Distance (m) for Various Heat Loads | | |
|---|---|---|---|---|---|
| | | | 37.5 kW/m$^2$ | 12.5 kW/m$^2$ | 4.0 kW/m$^2$ |
| Oil Storage | 25 | 2F | - | 2.66 | 3.93 |
| | | 3D | - | 2.31 | 3.64 |
| | | 5D | - | 2.07 | 3.39 |
| | 50 | 2F | 5.92 | 5.94 | 7.77 |
| | | 3D | 4.11 | 5.35 | 7.10 |
| | | 5D | 3.61 | 4.93 | 6.58 |

**Table 12: Pool Fire Consequence Analysis**

| Scenario Considered | Leak Size (mm) | Pool Radius (m) | Weather | Damage Distance (m) for Various Heat Loads | | |
|---|---|---|---|---|---|---|
| | | | | 37.5 kW/m$^2$ | 12.5 kW/m$^2$ | 4.0 kW/m$^2$ |
| | | | 3D | - | 23.09 | 57.81 |
| | | | 5D | - | 24.24 | 61.72 |
| | 50 | 30.15 | 2F | - | 33.48 | 76.01 |
| | | | 3D | - | 34.44 | 85.01 |
| | | | 5D | - | 35.61 | 91.01s |
| | Catastrophic Rupture | | 2F | - | 32.10 | 75.05 |
| | | | 3D | - | 33.18 | 84.54 |
| | | | 5D | - | 34.54 | 90.92 |

**Table 14: Toxic release Consequence Analysis**

| Scenario Considered | IDLH (ppm) | Leak Size (mm) | Weather | IDLH Distance (m) |
|---|---|---|---|---|
| Chlorine Tonner | 10 | 5 | 2F | 2479.28 |
| | | | 3D | 711.22 |
| | | | 5D | 579.61 |
| Chlorine Transfer Piping | 10 | 5 | 2F | 231.6 |
| | | | 3D | 70.32 |
| | | | 5D | 49.67 |
| | | Catastrophic Rupture | 2F | 250.61 |
| | | | 3D | 197.96 |
| | | | 5D | 146.59 |
| | | | 3D | 147.98 |
| | | | 5D | 133.48 |
| | | Catastrophic Rupture | 2F | 120.94 |
| | | | 3D | 83.60 |
| | | | 5D | 93.70 |

Ammonia_ catastrophic Rupture for Consequence Graph for IDLH Condition at different wind stability Class (2F,3D,5D)

## 2.0 Risk Evaluation

Risk is quantified in terms of probability of occurrence of hazardous event and magnitude of its consequences. The consequence modelling was carried out in order to assess the extent of damage by visualizing accidental release scenarios for various process equipments. The risk to the human due to accidental release scenarios is represented in two ways viz. individual risk and societal risk. Individual risk associated with the various equipments of Reliance Power Plant, Dahej has been evaluated by analysing various scenarios which are described in subsequent sections.

**Individual Risk**

The Individual Risk (IR) level is more specifically defined as the Individual Risk Per Annum (IRPA), which is the calculated annual risk loading to a specific individual or group of individuals. Clearly this depends on the amount of time in a year that the individual spends in different risk areas. The individual risk calculation takes account of the fact that people move from one place to another.

When calculating individual risk from major accident scenarios, it is normal to take account of protection by buildings. Individual risk is typically depicted as contour plots on overall plot plan of a facility, the risk level falls rapidly as one moves away from the source of the leak / epicentre of potential explosions.

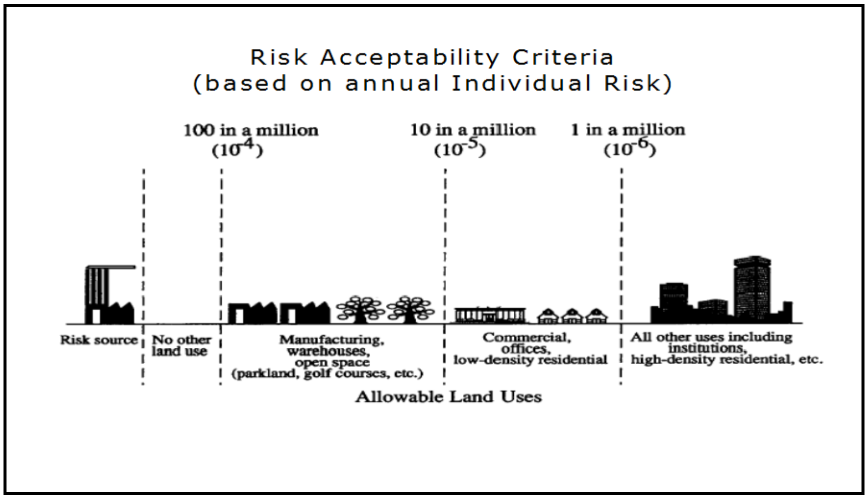

**Fig No. 15**

**Commonly Acceptable Individual Risks in Different Designated Land Zones**

**Societal Risk**

Societal risk is used in quantified risk assessment (QRA) studies and is depicted on a cumulative graph called an F/N curve. The horizontal axis is the number of potential fatalities, N. The vertical axis is the frequency per year that N or more potential fatalities could occur, F. This risk indicator is used by authorities as a measure for the social disruption in case of large accidents.

It is normal to take account of protection by buildings, and people's response. For large toxic release models, alarm and evacuation can be included. Because it is a cumulative curve, the curve always drops away with increasing N. Normally the F/N curve has a lower frequency cut-off at one in a billion (1 $x10^{-9}$ /yr). Regulators often split the graph into different regions, so that different actions have to be undertaken depending on where the F/N curve falls. Sometimes a maximum limit is placed on N (number of fatalities) possible for any event.

This type of curve is normal for plant type hazardous installations where a large group of people could be affected and their location is well established (housing estates, schools etc) relative to the event location (the plant). For pipelines however, because there is no single location for an event and the population affected varies along the pipeline route, this curve is not normally generated unless a large group of people can be affected over a reasonable distance.

**United Kingdom (Risk Acceptability criteria)**

In the UK the "Control of Major Accident Hazards" (COMAH) regulations are in line with the latest EU "Seveso-2" Directive. The regulations do not formally require a quantitative risk assessment, but the guidance notes make clear that in some circumstances quantification will help or could be asked for by the UK regulator - the Health and Safety Executive (HSE) - and this is often done in practice.

To advise planning authorities on developments around industrial installations, the UK HSE has been developing risk acceptance criteria over the years. A comprehensive treatment of the subject of tolerability of risk was given in a report titled "Reducing Risks Protecting People”. The report repeated the concept and criteria as argued by the Royal Society in 1983. It accepted the concept of tolerable Individual Risk as being the dividing line between what is just tolerable and intolerable and set the upper tolerable limit for workforce fatalities at $10^{-3}$/yr (1 in a thousand) for workers and $10^{-4}$/yr (1 in 10 thousand) for members of the public. A level at which risks might be broadly acceptable but not altogether negligible was set at $10^{-6}$/yr (1 in a million). The region in between would be controlled by the ALARP concept.

ALARP can be demonstrated in a variety of ways, depending on the severity of the worst case scenario. These are expressed in HSE guidance to Inspectors Consultation Draft September 2002.

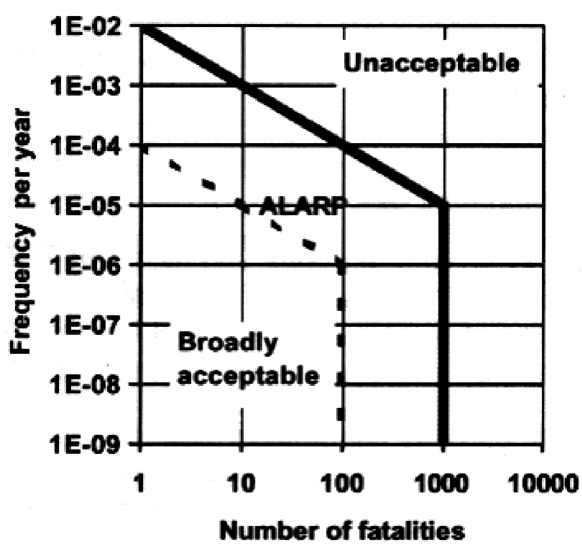


**Fig No. 16**

**United Kingdom Societal Risk Guidelines (risk to workforce and public).**

## 3.0 Results and Discussion

Above consequence modelling results shows that Impact Distances are well within Limits. Appropriate safety measures to control any hazardous situation will be installed to prevent loss of Life and Properties. **Fire fighting facilities and measures to control toxic release scenario will be installed onsite.**

Risk Level estimated for Proposed Project are given below in **Table No15** and **Fig No.** Results are well within limit set by HSE,U.K and are in the acceptable zone. **Hence the proposed Project No threat to Life and Loss of Property.**

### Table 15: Toxic release Consequence Analysis

| Sl No. | Risk type | Results | HSE U.K Acceptance criteria |
|---|---|---|---|
| 1. | Individual Risk | $8.274\text{x } 10^{-6}$/yr | Upper tolerable limit for workforce fatalities at $10^{-3}$/yr (1 in a thousand) for workers and $10^{-4}$/yr (1 in 10 thousand) for members of the public. |
| 2. | Societal Risk | $1.234\text{x } 10^{-5}$/yr | |

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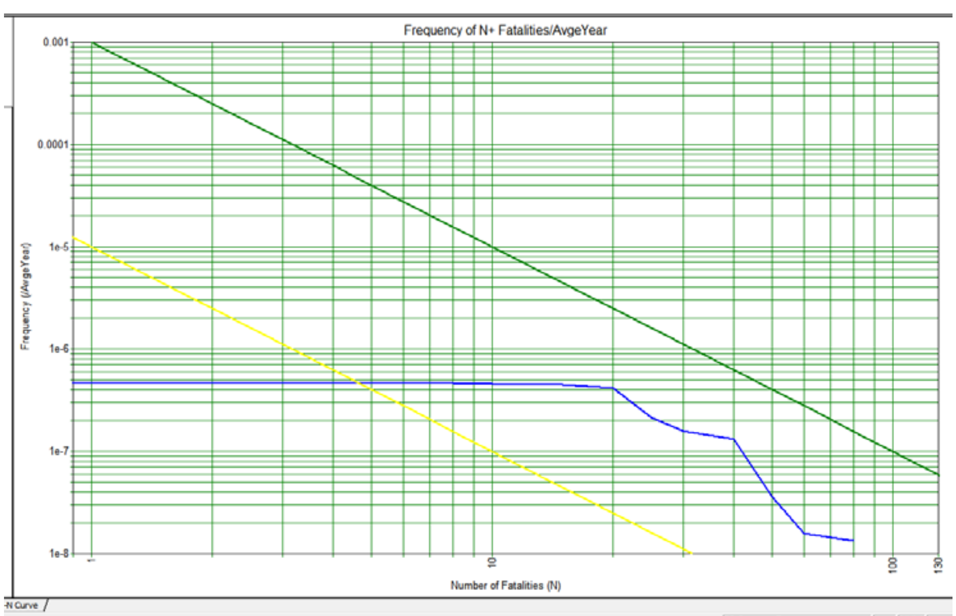

**Fig No. 17**

**Risk Level Vs No of Fatalities Graph**

## 3.0 General Mitigation Measures

- Fire is one of the major hazards, which can result from auxiliary fuel (LDO & Transformer Oil) storage tanks. The fire service facility shall be equipped with:
    - Smoke and fire detection alarm system
    - Water supply
    - Fire hydrant and nozzle installation
    - Foam system
    - Water fog and sprinkler system
    - Mobile Firefighting equipment
    - First aid appliances
- Smoke and fire detection, fire hydrant & nozzle installation etc. as indicated above shall be included as part of all major units at the proposed project.
- Periodic maintenance of all protective and safety equipment.
- Wind socks/wind cock should be installed at suitable height and with proper visibility to check the prevailing wind direction at the time of accident.
- Periodical training/awareness would be given to work force at the project as refresher courses to handle any emergency situation.
- Periodic mock drills should be conducted so as to check the alertness and efficiency of the Disaster Management Plan (DMP) and corresponding records should be maintained.
- Signboards including emergency phone numbers and no smoking signs should be installed at all appropriate locations.

- Plant would have adequate communication system.
- All major units/equipment shall be provided with smoke/fire detection and alarm system.
- All electrical equipments shall be provided with proper earthing. Earthed electrode shall be periodically tested and maintained.
- Emergency lighting shall be available at all critical locations including the operator's room to carry out safe shut down of the plant, ready identification of fire fighting facilities such as fire water pumps, fire alarm stations, etc.
- In addition to normal lighting each installation shall be equipped with emergency (AC) and critical (DC) lighting.
- All electrical equipments shall be free from carbon dust, oil deposits, grease, etc.
- Cable routing shall be planned away from heat sources, gas, water, oil, drain piping, air conditioning ducts, etc.
- Cable route markers shall be provided in the permanent way at the location of changes in the direction of cables and at cable joint locations.
- Chlorine detectors and Chlorine arresting kits would be provided at relevant locations.
- There would be necessary provision for emergency stop of critical equipments from control room in the event of major leak/flash fire at Plant.
- Clearly defined escape routes would be developed for the Station taking into account the impairment of escape by hazardous releases and sign boards be erected in places to guide personnel in case of an emergency.
- Well defined assembly point in safe locations would be identified for personnel in case of an emergency.
- Windsocks visible from all direction would be provided. This will assist people to escape in upwind or cross wind direction from flammable releases.

- There should be an SOP established for clarity of actions to be taken in case of fire/leak emergency.

## 3.3 Project Specific Mitigation Measures

### Chlorine Tonners and Above Ground Pipeline from Grasim Industries

General Recommendations

For chlorine tonners following control/containment measures are recommended.

- Auto chlorine leak absorption system would be provided to absorb the leaked chorine from the tonners/system.
- To prevent the large release of chlorine to atmosphere, monitoring and feedback facilities for early detection leaks and emergency shutdown shall be provided.
- There should be facilities in the form of water curtain for absorption of chlorine released during an emergency as chlorine is highly soluble in water.
- Flow control valves at key points would be installed to prevent excess chlorine flow from the tonner with multiple level safety per line.
- Provision for immediate evacuation of all personnel in case of accidental release of chlorine.
- Eye wash stations and emergency shower stations should be provided at appropriate locations especially in the vicinity of Chlorine storage and dosing facilities
- The stand by chlorine tonners shall be kept/stored at isolated covered warehouse at safe distance. It shall be provided with sufficient high (about 6 m) roof ventilation, chlorine detection and water spray system inside storage facility
- Conduct awareness programmes on regular basis in order to educate villagers around the project about the consequences of possible health hazards and their precautionary measures during accidental conditions

- In case of any tank on fire or fire in the vicinity, the cooling of adjoining tank should be resorted promptly in addition to tank on fire so that neighboring tanks does not give away.

- The night vision wind stocking be mounted on top of administrative building, main plant building and storage tanks so that people can move in upwind directions in the event of massive spillage or tank on fire.
- No machinery of vital importance like fire fighting pump house, Hydrant and Fuel oil pump house shall be placed out of radiation contours of 37.5 $kW/m^2$ heat intensity.
- Maintenance plays a vital role in proper upkeep of plant. One important function is the monitoring of equipment health, pipelines and machines. Adoption of system like thickness survey (including supports) maintenance practices will improve plant performance and safety.

## Specific Mitigations

- All the person handling chlorine are being trained at chemical alkalis plants.
- Air pollution control system is adopted so that ambient air pollution is not more than 3mg/nm3 permitted by pollution control board.
- Wind sock has been installed and workers are trained to go against the direction in case of accident.
- HNP storage tank has been kept at least 25 ft. away from chlorine header and reactor.
- Chlorine toners are kept under shed so that no exposure is made to any source of direct heat.
- All the equipments is being painted from time to time for any possible corrosion.
- Ammonia torch is kept ready for detection of any leakage of chlorine.
- Three oxygen cylinder type gas mask and one canister type masks is kept ready for handling chlorine leakage.
- Graphic block absorbers with neutralizers are installed for control of HCL fumes.
- Additional chlorine valve are being used along with use of each tonner in order to give 100% reliability from valve leak/damage.

- In case of fire, chlorine cylinders shall be removed immediately from fire zone to avoid explosion .in case of non-movement of cylinder due to any reason; water will be sprayed to keep cylinder cool.
- In case of chlorine leakage, the first step to be taken is to remove all persons not directly connected upwind (opposite to the direction of wind), and to a higher plane in the open and only trained personnel are allowed to attend leakage, with use of gas mask.
- Water should never be used on chlorine leakage.

  $H_2O+Cl_2 = HCl + Hocl$

  $Hocl ====HCl+H_2O$

- HCl is strong corrosion medium.
- In case of valve leak in tonner the tonner should be rolled, so that the valves are in vertical plane with leaking valve above.
- Emergency kit is kept consisting of gasket, yokes, hoods, clamps, studs, tie rod, wooden pegs, is kept ready for use during leakage.
- All persons operating chlorine process will be trained for use of emergency kits during leakage.
- To control large accidental spillage of liquid chlorine on the floor, chilled water is sprayed so that film of chlorine hydrate is formed thus reducing the rate of evaporation from spillage. Immediate steps will be taken to neutralize spilled chlorine with lime/caustic soda.
- Following first aid measures are provided:

  i. In case of chlorine gas inhalation the patient should immediately remove to an open area where fresh air is available. Clothes are to be loosened and shoes head removed. If breathing has not ceased, the patient should be placed on his back with head and back elevated, and kept warm. Rest in essential. If breathing has apparently ceased, artificial respiration should be given immediately. Oxygen shall be given, butter milk, lime juice, cough syrup shall be given.

ii. Tablets Astemaz and Dermonorm shall be given as first measures.

iii. If eyes have been affected 2 or 3 drops of 0.5% solution of Pontocaine or Xylocaine solution shall be instilled into eyes.

iv. In case of effect on skin, area shall be washed with soap and water and water sprayed quickly.

- For storing more than five tonners, storage license from Dy. Chief Controller of explosive, is to be obtained. The firm will obtain such license.

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