RISK ASSESSMENT STUDY REPORT

FOR

M/s. SHREY INDUSTRIES

Survey No. 111 & 112, Plot No. 7 & 8, Village: Dhanot, Ta: Kalol,

Dist: Gandhinagar (Gujarat)

PREPARED BY

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CHAPTER: 1

INTRODUCTION

M/s. SHREY INDUSTRIES is a Proposed manufacturing unit located at Survey No. 111 & 112, Plot No. 7 & 8, Village: Dhanot, Ta: Kalol, Dist: Gandhinagar (Gujarat). In their proposed unit, they will manufacture Pigment Green 7 @ 100 MT/M.

Considering scale of unit and its categorization, according to EIA notification dated 14th September 2006, by Ministry of Environment & Forest (MoEF), Government of India, their proposed manufacturing activity is falls under Synthetic Organic Chemicals – Schedule 5(f) & cat -A. For that unit needs Environmental clearance from Ministry of Environment Forest Climate Change.

The Risk Assessment with following emphasis is required to be carried out:

Purpose

The purpose of this risk assessment is to evaluate the adequacy of the unit for production of pigment green 7 and usage of raw materials. Products have application as raw material in chemical industries and textile Industries for printing and dyeing. This risk assessment provides a structured qualitative assessment of the operational environment. It addresses sensitivity, threats, vulnerabilities, risks and safeguards. The assessment recommends cost-effective safeguards to mitigate threats and associated exploitable vulnerabilities.

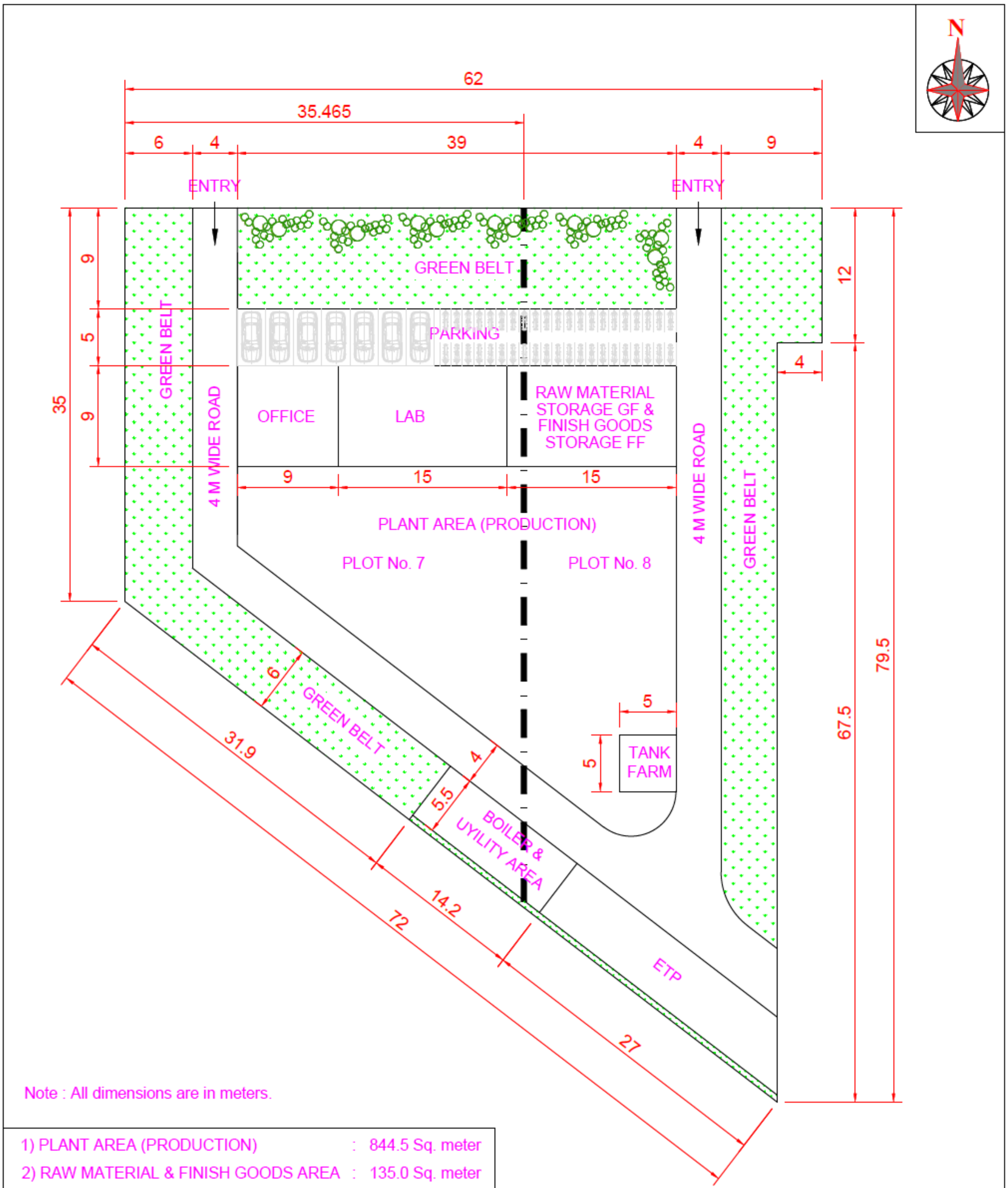
Scope

The scope of this risk assessment assessed the system's use of resources and controls (implemented or planned) to eliminate and/or manage vulnerabilities exploitable. This Risk Assessment Report evaluates the confidentiality (protection from unauthorized disclosure of system and data information), integrity (protection from improper modification of information), and availability (loss of system access) of the system. Recommended security safeguards will allow management to make decisions about security-related initiatives.

Geographical Information of Project Site

Sr. No.	Description	Information
1	Latitude	23^{o}18’13.27” N (23.303687)
2	Longitude	72^{o}25’38.61” E (72.427391)
3	Plot. No.	Plot No. 7 & 8, Survey No: 111 & 112
5	Village	Dhanot
5	Ta	Kalol
6	Dist	Gandhinagar
7	State	Gujarat

Layout Plan:



Note : All dimensions are in meters.

1) PLANT AREA (PRODUCTION)	:	844.5 Sq. meter
2) RAW MATERIAL & FINISH GOODS AREA	:	135.0 Sq. meter
3) LAB AREA	:	135.0 Sq. meter
4) OFFICE AREA	:	81.0 Sq. meter
5) BOILER & UYILITY AREA	:	78.0 Sq. meter
6) ETP AREA	:	135.0 Sq. meter
7) PARKING AREA	:	195.0 Sq. meter
8) GREEN BELT AREA	:	1121.0 Sq. meter
9) INTERNAL ROAD AREA	:	641.5 Sq. meter
TOTAL AREA	:	3366.0 Sq. meter

SHREY INDUSTRIES
PLOT No. 7 & 8
VILLAGE : DHANOT,
TALUKA : KALOL,
DISTRICT : GANDHINAGAR,
STATE : GUJARAT.

Location Map:

CHAPTER: 2

RISK ASSESSMENT PROCESS

RISK ASSESSMENT

Identification analysis and assessment of hazard and risk are very useful in providing information to risk management. It provides basis for what should be type and capacity of its on-site and off-site emergency plan also what types of safety measures are required. Risk and consequence analysis is carried out considering storage and handling of various hazardous raw materials, intermediates and product as well as manufacturing process.

This section details the risk assessment process performed during this effort. The process is divided into pre-assessment, assessment, and post assessment phases.

PHASE I – PRE-ASSESSMENT

Step 1: Define the Nature of the Risk Assessment

This initial risk assessment provides an independent review to help Centers for Disease Control and Prevention (CDC) determine the appropriate level of security required for the system to support the development of a System Security Plan for dyes and dye intermediate plant. The risk assessment is based on interviews, documentation and, as necessary, some automated technical review.

Step 2: Data Collection

The data collection phase included identifying and interviewing key personnel within the organization and conducting document reviews. Interviews focused on the operating environment. Document reviews provided the risk assessment team with the basis on which to evaluate compliance with policy and procedure.

Step 3: Templates

The following templates were used by the risk assessment team and are Included in the appendices:

- **Security Baseline Worksheet:**
  Completed by the analysts using information extracted from questionnaires and interviews.
- **Risk Calculation Worksheet:**
  Converts the raw vulnerabilities into risks based on the following methodology:
- **Risk Mitigation Worksheet:**
  Lists the risks and the associated recommended controls to mitigate these risks for the Business Steward to review.

PHASE II – ASSESSMENT

Step 1: Document Review

The assessment phase began with the review of documents provided by the members of the various pigment manufacturing system team. Detailed interviews with members of the pigment manufacturing system team allowed completion of the system questionnaire and identification of specific threats inadequately identified in the Enterprise Threat Statement.

Step 2: System Characterization

In this step, the analyst defined the boundaries of the IT system, along with the resources that constitute the system, its connectivity, and any other elements necessary to describe the system. Dependencies were clarified. Sensitivity of the system and data was discussed in the final section of the characterization.

Step 3: Threat Identification

Through the interview process, it also identified "most likely" system and location-specific threats.

Step 4: Vulnerability Identification

In this step, the risk assessment team developed a list of system vulnerabilities (flaws or weaknesses) that could be exploited by the potential threat vectors.

Step 5: Risk Determination (Calculation/Valuation)

In this step, the risk assessment team determined the degree of risk to the system. In some cases, a series of vulnerabilities combined to create the risk. In other cases, a single vulnerability created the risk. The determination of risk for a particular threat source was expressed as a function of the following:

- Likelihood Determination:
- The following governing factors were considered when calculating the likelihood of the probability that a potential vulnerability might be exploited in the context of the associated threat environment:
- Threat source motivation and capability
- Nature of the vulnerability
- Existence and effectiveness of current controls

The following table defines the likelihood determinations.

Table1. Likelihood Definition

Level	Likelihood Definition
High	The threat source is highly motivated and sufficiently capable, and controls to prevent the vulnerability from being exercised are ineffective.
Moderate	The threat source is motivated and capable, but controls are place that may impede successful exercise of the vulnerability.
Low	The threat source lacks motivation or capability, or controls are in place to prevent, or at least significantly impede, the vulnerability from being exercised.

Impact Analysis:

The next major step in measuring level of risk was to determine the adverse impact resulting from successful exploitation of vulnerability. The adverse impact of a security event can be described in terms of loss or degradation of any, or a combination of any, of the following three security goals:

- Loss of Confidentiality – Impact of unauthorized disclosure of sensitive information (e.g., Privacy Act).
- Loss of Integrity – Impact if system or data integrity is lost by unauthorized changes to the data or system.
- Loss of Availability – Impact to system functionality and operational effectiveness.

Table 2. Impact Definition

Magnitude of Impact	Impact Definition
High	Exercise of the vulnerability (1) may result in the highly costly loss of major tangible assets or resources; (2) may significantly violate, harm, or impede an organization's mission, reputation, or interest; or (3) may result in human death or serious injury.
Moderate	Exercise of the vulnerability (1) may result in the costly loss of tangible assets or resources; (2) may violate, harm or impeded an organization's mission, reputation, or interest; or (3) may result in human injury.
Low	Exercise of the vulnerability (1) may result tangible assets or resources; (2) may organization's mission, reputation, or interest. in the loss of some noticeably affect an

- **Risk Determination:**
  The following were used to assess the level of risk to the IT system:
  - The likelihood of a given threat source's attempting to exercise a given vulnerability.

- The magnitude of the impact should a threat-source successfully exercise the vulnerability.
- The adequacy of planned or existing security controls for reducing or eliminating risk.

The following table provides a definition for the risk levels. These levels represent the degree or level of risk to which an IT system, facility, or procedure might be exposed if a given vulnerability were exercised.

Table 3. Risk Level Definition

Magnitude of Impact	Risk Level Definition
High	There is a strong need for corrective measures. An existing system may continue to operate, but a corrective action plan must be put in place as soon as possible.
Moderate	Corrective actions are needed and a plan must be developed to incorporate these actions within a reasonable period of time.
Low	The system's Authorizing Official must determine whether corrective actions are still required or decide to accept the risk.

Step 6: Risk Mitigation Recommendations:

During this step of the process, controls that could mitigate or eliminate the identified risks, as appropriate to the organization's operations, were provided. The goal of the recommended controls is to reduce the level of risk to the IT system and its data to an acceptable level. The risk assessment team considered the following factors when recommending controls and alternative solutions to minimize or eliminate identified risks:

- Sensitivity of the data and the system
- Effectiveness of recommended options
- Legislation and regulations
- Organizational policy
- Operational impact
- Safety and reliability

PHASE III – POST ASSESSMENT

Risk Mitigation

The elimination of all risk is usually impractical, senior management and business stewards should assess control recommendations, determine the acceptable level of residual risk, and implement those mitigations with the most appropriate, effective, and highest payback.

CHAPTER: 3

BASIC ENVIRONMENT

Details of Products:

LIST OF PROPOSED PRODUCT

Sr. No.	Product Name	Chemical Name/ Other Name/ C.I. Name	CAS No.	Quantity (MT/Month)
1.	Pigment Green 7	Phthalocyanine Green	1328-53-6	100

PACKING AND FINAL APPLICATION OF PRODUCT

Sr. No.	Name of Product	CAS No.	Type of Packing	Final application of product
1.	Pigment Green 7	1328-53-6	HDPE Bags packing of 25 Kg/50 Kg With inner liner & 500 kg jumbo bags	In chemical industries and textile Industries for printing and dyeing.

DETAILS OF RAW MATERIALS

Sr. No.	Name of Raw Material	Quantity	
		MT/MT	MT/Month
1.	Aluminum Chloride	1.825	182.5
2.	Cupric Chloride	0.080	8.000
3.	Salt	0.397	39.70
4.	Copper phthalocynine blue	0.555	55.50
5.	Chlorine	1.270	127.0
6.	Mono Chloro Benzene Solvent	0.060	6.000
7.	Emulsifier	0.040	4.000
8.	Caustic flakes	0.079	7.900

Source: Chemical Mfg. Units located in Ahmedabad, Ankleshwar, Vapi, Vadodara etc, various Traders and Export from other Countries.

PHYSICAL FORM AND STORAGE OF RAW MATERIAL FOR PROPOSED PRODUCTS:

Sr. No	Product	Physical & Chemical Composition			B.P.	F.P.	LEL	TLV,	LD_{50} mg/kg	Sp.Gr. (Water=1) at	V.D. at (air=1)	Odour Threshold,	Solubility in Water
		Chemical Formula	State	MW	°C	°C		ppm or mg/nm^3				ppm, mg/Nm^3	
B	**Raw Materials**												
1.	Aluminum Chloride	$AlCl_3$	Solid	133	NA	NA	NA	NA	3805	2.44	NA	NA	NA
2.	CPC Blue	$C_{32}H_{16}CuN_8$	Solid	576	NA	NA	NA	NA	NA	1.5	NA	NA	Insoluble
3.	Chlorine	Cl_2	Gas	71	-34	NA	NA	STEL:2.9	293	NA	2.5	Pungent-Suffocating	7.41
4.	Caustic flakes	NaOH	Solid	40	1388	NA	NA	STEL: 2	NA	2.13	NA	NA	soluble
5.	Monochloro Benzene	C_6H_5Cl	Liquid	112	132	29.44	NA	NA	1110	1.10	3.88	0.2	Slightly Soluble

CHAPTER: 4

STORAGE AND HANDLING OF HAZARDOUS CHEMICALS

The safety precautions to be taken to prevent an accident are detailed in 'Material Safety Data Sheets'. The details of storage of Hazardous chemicals along with measures taken during storage are given in Table.

HAZARDOUS CHEMICALS

Details of raw material, which are termed as Hazardous Chemicals as per Manufacture, Storage and Import of Hazardous Chemical (Amendment) Rules 2000 are given in the **below table.**

TABLE
DETAILS OF HAZARDOUS CHEMICALS

Hazardous Chemicals	Reference The Manufacturer, storage & Import of Hazardous chemical Rules 1989	Maximum Quantity to be Stored at a time (MT)	Threshold Storage quantity in MT as per schedule 3 for application Rules 10-12
Chlorine	Sr. No. 119 (Part II, Schedule 1 of MSIHCR, 1989)	20.0	25
Aluminium Chloride	Sr. No. 22 (Part II, Schedule 1 of MSIHCR, 1989)	40.0	Not listed
Sodium Hydroxide	Sr. No. 571 (Part II, Schedule 1 of MSIHCR, 1989)	2.0	Not listed

SAFETY PRECAUTIONS DURING STORAGE OF CHEMICALS

To prevent any spillage, accident and impacts of human health for safety measure will be taken while handling the raw material and products:

Occupational control measures for no health hazard to the worker and to keep the risk of accidents to a minimum from our manufacturing activities.

Mitigatory measures:

For the proposed project, company will make following arrangement within the factory premises for the different hazards:

Storage & Handling of Hazardous Chemicals:

- Company will do planning to stock all the necessary material as minimum as possible.
- All containers with hazardous chemicals have labels indicating the contents and warning of the hazard.
- Necessary information on safe handling and first aid measures and antidotes of major hazardous material will be available on the label.
- Workers dealing with hazardous chemicals will be trained on health risks and safe handling.
- Exposure to hazardous chemicals will be minimized.
- Liquid Hazardous chemicals will be transferred in closed piping system.
- Separate storage section will be provided for storage of hazardous and non-hazardous raw materials.

Vessel and other Equipment related:

- Checking of process vessels and equipment is carried out regularly.
- Records related to maintenance and its planning schedule is maintained.

Fire related:

- Overhead water storage tank with adequate capacity is provided to ensure 24 hr. supply.
- Fire water tank with sufficient capacity of 100 KL (02 Nos.) will be provided with fire pump (02 Nos.)
- Fire hydrant system will be provided.
- Sprinkler system will be provided at raw material storage area and tank farm area.
- Fire extinguisher will be provided at production plant as per the requirement. Contact numbers of nearest fire agency will be provided.
- Unit will appoint qualified and trained fire personnel having qualification like B.Sc or Diploma in Fire and Safety.

Electrical related:

- All electrical fitting and motors in the storage areas will be flameproof.
- Checking of all earthings, wiring & connection will be carried out regularly.
- Proper earthing will be provided at all equipments and will be provided for additional equipment. Adequate Nos. of earth pits will be provided.

Safety related:

- Adequate types of personal protective equipment will be provided and also safety training will be provided to workers.
- Emergency showers and eye wash stations will be available at the worksite.
- Arrangement for 24 hr. medical facilities by contact with nearest health care centre/ hospital.
- Pre-employment medical check-up and annual medical check-up will be carried out and its records will be maintained properly.

TABLE

ANTIDOTES OF CHEMICALS

Sr. No.	Name of Hazardous Chemical	Name of Antidote
1.	Sodium Hydroxide	• Wash with plenty of water if eyes or skin is affected. • Do not give chemical antidotes because it increases heat and injury with reaction. Do not induce vomiting.
2.	Chlorine	• There is no antidote for chlorine poisoning; management is supportive after evacuating people from the site of exposure and flushing exposed tissues. For lung damage caused by inhalation, oxygen and bronchodilators may be administered.
3.	Aluminium Chloride	• Remove contaminated clothing and shoes. Flush affected areas with plenty of water. If in eyes, hold eyelids open and flush with plenty of water. If swallowed and victim is conscious, have victim drink water or milk. Do not induce vomiting.

CHAPTER: 5

HEALTH & SAFETY MEASURES

For handling hazardous chemicals and to take care of employees' health, M/s. SHREY INDUSTRIES shall adopt a practice of preventive and predictive maintenance looking to the nature of hazardous chemicals being handled / processed. All the equipments in the plant areas shall be inspected/ tested by an outside agency.

The various safety equipments like breathing apparatus and critical instrumentation provided on various equipments will be inspected and tested frequently to ensure their operability all the time. Besides, all the first aid, fire fighting devices shall also be inspected, tested and maintained by a competent third party and kept all the time in ready to use condition.

Health of all the employees in plant area shall regularly monitor by outside physician. If any abnormality shall found necessary treatment shall be given. Necessary history cards, records will be maintained and up-dated time to time.

Some of the safety measures shall carry out by M/s. SHREY INDUSTRIES to ensure prevention of occupational hazards is delineated below for the proposed activity.

- Flameproof equipments and fittings will be provided for handling of hazardous chemicals.
- All pump motors shall be earthed.
- Road tanker earthing lines shall provide near the unloading pumps.
- Independent dykes will provide for hazardous chemicals storage to contain leakages. Floors of the dyke area shall of impervious finish.
- Housekeeping of the plant shall as per prescribed norms. Floors, platforms, staircases, passages will be kept free of any obstruction.
- All hazardous operations shall explain to the workers. They will periodically train on the hazardous processes.
- Dedicated supply of firewater shall available in the plant.
- Only authorized persons shall be allowed inside the plant.
- All instrument and safety devices will be checked and calibrated during installation. They will also be calibrated, checked at a frequent interval. Calibration records shall maintain.
- All electrical equipments will be installed as per prescribed standards.
- All the equipments of the plant shall periodically test as per standard and results shall document. All equipments undergo preventive maintenance schedule.
- The area will fence to isolate the same from all other departments.

- Proper Earthing will be provided to each storage area. Also earthing would be taken care during solvent transfer from tanker into the underground vessel.
- Flame arrestors shall provide.
- Flameproof pumps & motors shall provide for solvent transfer.
- In addition to fire hydrant system, nos. of fire extinguishers will be installed at different locations within premises.
- Adequate ventilation arrangement shall provide for safe and better working in the plant as per the standard.
- Process, equipments, plant involving serious fire hazards are designed as per prescribed guideline.
- Sufficient access for firefighting shall provide in the plant.
- Protection against lightning will be taken care in the plant.
- Precautions against ignition will be taken.

CHAPTER: 6

OCCUPATIONAL HEALTH SCHEME FOR THE WORKERS

M/s. SHREY INDUSTRIES shall carry out following occupational health scheme for workers;

- Personal protective equipment such as safety shoes, safety goggles, hand gloves, gum boots, safety helmet, air line mask, Breathing Apparatus set kit have been given to each workers & staff and additional PPE's are kept in all related area, Fire fighting facilities, etc.
- Safety awareness training programmers are arranged regularly for staff & contractor workers working in the factory premises.
- On site – Off site emergency plan shall be available.
- Medical Examination as per GFR guidelines
- Work Permit system procedure shall be adopted.

CHAPTER: 7

RISK REDUCTION MEASURES

TRAINING AND EDUCATION OF EMPLOYEES:

Safety awareness training programmers are arranged regularly and safety-training programme are also arranged for workers & staff working in the factory premises.

M/s. SHREY INDUSTRIES shall give training on the following subjects;

- Accident Prevention Technique
- Basic fire fighting
- Use of Respiration PPE
- Handling of Hazardous chemicals
- First Aid program
- Breathing Apparatus practical programme
- General safety regulation
- Work Permit system
- Electrical safety
- On site emergency plan training
- MSDS Awareness

Once in a month workmen shall be grouped together & practical classes shall be held to train them how to operate various types of fire extinguisher to wear the mask, SCBA apparatus, use of cylinder handling kits. Fire drill is also conducted regularly. Personal protective equipment such as safety shoes, safety goggles, hand gloves, gum boots, safety helmet have been given to each workers & staff.

RISK REDUCTION MEASURES:

Design:

- Plant operator and staffs shall be selected well experience and qualified for chemical plant operation.
- All key personals shall be trained for emergency handling procedures and regular Mock Drills will be conducted on various scenarios.

- At design stage adequate care shall be taken for design, selection, fabrication, erection and commissioning of facilities and other equipment piping, pipe fittings, electrical equipment etc.

Safety at Pumps:

- Required outlet valve and NRV provided on pump outlet.
- Modular fire extinguisher shall be provided near of most of pumps.
- FLP type and mechanical seal type pump will be installed for flammable chemicals.

Safety at Pipelines:

- Jumper connections on flanges to prevent build up of static electricity charge.
- Proper supports and clamping are provided.
- Double earthing provided to all electrical motors.
- Color code as per IS standard will be maintained.

Safety during Operation & maintenance:

- Periodic testing of hoses for leakages and continuity.
- Earthing of all plant equipment and earthing of all vehicles of vehicles under unloading operation.
- Annual testing of all safety relief valves.
- Planned preventive maintenance of different equipment of their safety and reliable operations.
- Strict compliance of safety work permits system.
- Proper maintenance of earth pits.
- Periodic training and refresher courses to train the staff in safety, fire fighting and first aid.

CHAPTER: 8

FIRE FIGHTING SYSTEM

M/s. SHREY INDUSTRIES will take into consideration fire prevention measures during the project planning to avoid any outbreak of fire. But looking to the hazardous nature of process and the chemicals that are handled and processed, the chances of outbreak of fire cannot be totally ignored. Hence to tackle such a situation a good well laid fire protection system will be provided in the factory.

The unit will provide fire extinguishers based on probability and type of fire hazards at strategic locations. The unit will install approximately 25 fire extinguishers (Dry powder type) to tackle the fire hazards of Class A, B & C at different levels of the plant.

The unit has also decided to provide fire protection arrangements in the form of fixed water spray system (1 No.) and fire hydrant systems (1 Nos.) to tackle any fire emergency arising due to storage of chemicals.

Fire related:

- Overhead water storage tank with adequate capacity is provided to ensure 24 hr. supply.
- Fire water tank with sufficient capacity of 100 KL (02 Nos.) will be provided with fire pump (02 Nos.)
- Fire hydrant system will be provided.
- Sprinkler system will be provided at raw material storage area and tank farm area.
- Fire extinguisher will be provided at production plant as per the requirement. Contact numbers of nearest fire agency will be provided.
- Unit will appoint qualified and trained fire personnel having qualification like B.Sc or Diploma in Fire and Safety.

CHAPTER: 9

HAZARDS IDENTIFICATION, MAJOR HAZARDS & DAMAGE CRITERIA

HAZARDS IDENTIFICATION:

Hazard is defined as a chemical or physical condition that has a potential of causing damage to the people, property or the environment. Hazard identification is the first step in the risk analysis and entails the process of collecting information on:

- The types and quantities of hazardous substances stored and handled,
- The location of storage tanks / Areas & other facilities,
- Potential hazards associated with the spillage and release of hazardous Chemicals.

Hazard is the associated term with material, which is a measure or the likely hood of the damage to human working with, or studying the material in question. The potential hazard and major risks associated with the plant will be identified using Hazard & operability study (HAZOP).

MAJOR HAZARDS:

A brief description of the following hazards generally encountered in handling hazardous chemicals is given in the section.

- Pool Evaporation
- Vapor Cloud Explosion
- Vapor Cloud Dispersion
- Pool Fire
- Jet Fire
- BLEVE
- Toxic Release

Pool Evaporation

If the fluid, which escapes from containment, is a liquid, then vaporization must occur before a vapor cloud is formed. The rate at which vaporization takes place determines the formation of such a vapor clouds.

Vaporization scenarios

Vaporization can occur when there is a leak in any of the following situations:

a) A liquid at atmospheric temperature and pressure.

b) A liquid under pressure and above normal boiling point. The rates of vaporization of the liquid are different for each of the two cases. In the case

- The liquid after spillage is approximately at equilibrium and evaporates relativity slowly.
- In the case, the liquid flashes off when released, and the liquid remaining then undergoes slow evaporation.

***(I)* Evaporation of a liquid at atmospheric temperature and pressure.**

Evaporation from a pool of liquid is essentially a mass transfer process that depends on the vapor pressure of the liquid, wind velocity across the surface of the pool and ambient weather condition.

A spillage of this kind constitutes a steady continuous source of vapor. Unless the rate of evaporation due to the combination of vapor pressure and wind velocity is high enough, it is usually assumed that the heat transfer from the air and the ground is sufficient to provide the latent heat of vaporization.

(II) Evaporation of a liquid under pressure and above normal boiling point

When a pressurized liquid is released from containment a portion flashes off. This heat is obtained by cooling the remaining liquid to its boiling point thus reaching a state of equilibrium from the high in equilibrium prevalent immediately on loss of containment. In practice, it frequently happens that there is a significant amount of spray formation caused by the sudden release of pressure and the violent boiling of liquid. This spray vaporizes rapidly by taking heat for vaporization from air. This spray liquid formation is assumed to equal to the gas fraction generated by flash. The proportion of liquid airborne is thus considerably high. Following flashing, the residual liquid is at its boiling point. Vaporization then continuous by gaining heat from surrounding as an essentially heat or mass transfer limited process. This secondary stage of rate limited vaporization is usually relatively less important compared with the flash off, particularly with respect to formation of flammable gas clouds.

Vapor Cloud dispersion

Following a continuous leak and formation of gas cloud, if cloud does not ignite it undergoes atmospheric dispersion in accordance with the prevalent wind direction, speed and stability category. The objective of carrying out analysis of cloud dispersion is twofold. First, it provides the distance (from the leak) at which the concentration of flammable material falls below the lower flammability limit (LEL). Second it provides the concentration of the toxic substance to which people may be exposed for short time, at varying distance (from the leak).

Vapor cloud Explosion

Release of energy in a rapid and uncontrolled manner gives rise to explosion. Identified locations having explosion hazards shall in tank farm and storage area (warehouse). Extra care shall be taken by providing rupture disc, Pressure release valve, and temperature controller.

Explosion is a sudden and violent- release of energy which may be in the form of physical energy or chemical energy. In case where a major leak continues from some time without ignition a substantial mass of the gas from a vapor of cloud which on finding a source of ignition may result in an vapor cloud explosion (VCE) before a cloud is diluted to the concentration below the lower explosion limit in air. The explosion will cause overpressure resulting in to damage to the surrounding area.

Pool fire

Since the Stone Age term 'fire' is associated with fear. It is very dangerous if occurs in uncontrolled manner. It should be clearly understood that when a liquid is used having flash point below the normal ambient temperature, it could, in suitable circumstances, liberate a sufficient quantity of vapor to give rise to flammable mixtures with air.

Following an accidental release, chemicals will form either a confined pool within the bund area or an unconfined pool. Should the vapor above the pool ignite, the liquid will burn as a pool fire. The pool fire will result in thermal radiation. It cloud also damage all the storage tanks within the confined area of the dyke. In the present study, impact distances for various scenarios have been calculated.

Jet fire

After a minor or major loss of containment following hardware failure, chemicals which are stored under high pressure would escape as liquid/ gas spray or jet which undergoes flashing evaporation and forms a dense flammable gas could in the air. The cloud, which initially moves forward in the spatial direction of the spray till the kinetic energy, is lost and gravity slumping of cloud occurs if the gas is heavier than the air. Should the flammable jet ignite very soon after development of leak? A jet fire will commence. The jet fire could damage the neighboring tanks by direct flame impingement. It would also cause thermal radiation in the surrounding area.

Fire Ball / BLEVE

Any fire in the vicinity of storage tank containing a liquefied gas may cause Boiling Expanding Vapor Explosion (BLEVE). Due to simultaneous increase of pressure as well as weakening of the material of the vessel because of a fire in the vicinity the tank. It may fail resulting in release of the entire inventory suddenly and result in a BLEVE and fireball. BLEVE results in serious thermal radiation to the plant equipment and surroundings. Damage may also result to the debris of the shattered vessel being thrown about.

The major hazards in the M/s. BHIMANI DYE CHEM INDUSTRIES are described below.

- Toxic hazard due to leakage of hazardous chemicals.
- Fire hazard due to leakage of flammable chemicals.
- Electrical hazards due to the electrical major equipment/ machinery, operations, welding, motors, heavy lift devices, cabling, human intervention (short circuit possibility), maintenance work (due to machinery breakdown etc.), plant lighting related electrical hazards.
- Possibility of human injury due to working with mechanical machines, manual handling etc.
- Possibility of injury during chemicals handled, during operations and due to intoxication.
- Major dropped objects hazard due to large number of physical handling steps / operations involved with crane/ overhead lifting/ hoisting equipment.
- Fires in any part of the plant working areas – there is a possibility of rapid escalation if it is not brought under control quickly.

Toxic hazards

Toxic substances affect in three ways by ingestion, absorption & inhalation. Adequate provision of safety along with personal protective equipment will be made, breathing apparatus and emergency kit shall be provided at various locations of the installation.

Corrosion hazards

Corrosion is a chemical reaction-taking place at the surface of metal. Corrosive chemicals have their typical hazard when it comes in contact with human tissues. Most corrosive substances will produce chemical burns, while certain chemical produce deep ulceration. Other has detailing effect on skin and may cause dermatitis. This has also adverse effects on weakening the strength of material in contact.

M/s. SHREY INDUSTRIES shall take due care to overcome the hazard. The complete structure of the manufacturing area shall be painted with special type of anticorrosive paint. Good quality materials will be used for transferring corrosives. Regular thickness testing of equipment, pipelines etc. shall carry out to have the exact picture of effect of corrosion.

Biological hazards

Effluent treatment process involves the biological activities so biological hazard's cannot be eliminated. The way of biological hazards is by hand to mouth contact during eating, drinking or by wiping the face with contaminated hands or gloves or by licking splashes from the skin or by breathing them in, as dust, aerosol or mist. The major source of biological hazard on site is biological sludge drying bed, filter press, biological storage sump etc. Practically, complete elimination of biological hazard cannot be possible but it will be reduce by adopting the safe practice guards.

DAMAGE CRITERIA:

Damage estimates due to thermal radiations and overpressure have been arrived at by taking in to consideration the published literature on the subject. The consequences can then be visualized by the superimposing the damage effects zones on the plan site and identifying the elements within the project site as well as in the neighboring environment, which might be adversely affected, should one or more hazards materialize in real life.

In consequence analysis, use is made of a number of calculation models to estimate the physical effects of an accident (spill of hazardous material) and to predict the damage (lethality, injury, material destruction) of the effects. The calculations can roughly be divided in three major groups:

a) Determination of the source strength parameters;
b) Determination of the consequential effects;
c) Determination of the damage or damage distances.

The basic physical effect models consist of the following.

Source strength parameters

* Calculation of the outflow of liquid, vapour or gas out of a vessel or a pipe, in case of rupture. Also two-phase outflow can be calculated.
* Calculation, in case of liquid outflow, of the instantaneous flash evaporation and of the dimensions of the remaining liquid pool.
* Calculation of the evaporation rate, as a function of volatility of the material, pool dimensions and wind velocity.
* Source strength equals pump capacities, etc. in some cases.

Consequential effects

* Dispersion of gaseous material in the atmosphere as a function of source strength, relative density of the gas, weather conditions and topographical situation of the surrounding area.
* Intensity of heat radiation [in kW/ m^2] due to a fire or a BLEVE, as a function of the distance to the source.
* Energy of vapour cloud explosions [in N/m^2], as a function of the distance to the distance of the exploding cloud.
* Concentration of gaseous material in the atmosphere, due to the dispersion of evaporated chemical. The latter can be either explosive or toxic.

It may be obvious, that the types of models that must be used in a specific risk study strongly depend upon the type of material involved:

- Gas, vapour, liquid, solid
- Inflammable, explosive, toxic, toxic combustion products
- Stored at high/low temperatures or pressure
- Controlled outflow (pump capacity) or catastrophic failure?

Selection of Damage Criteria

The damage criteria give the relation between extent of the physical effects (exposure) and the percentage of the people that will be killed or injured due to those effects. The knowledge about these relations depends strongly on the nature of the exposure. For instance, much more is known about the damage caused by heat radiation, than about the damage due to toxic exposure, and for these toxic effects, the knowledge differs strongly between different materials.

In Consequence Analysis studies, in principle three types of exposure to hazardous effects are distinguished:

1. Heat radiation, from a jet, pool fire, a flash fire or a BLEVE.
2. Explosion
3. Toxic effects, from toxic materials or toxic combustion products.

In the next three paragraphs, the chosen damage criteria are given and explained.

Heat Radiation

The consequence caused by exposure to heat radiation is a function of:

- The radiation energy onto the human body [kW/m^2];
- The exposure duration [sec];
- The protection of the skin tissue (clothed or naked body).
- The limits for 1% of the exposed people to be killed due to heat radiation, and for second-degree burns are given in the table herein:

Damages to Human Life Due to Heat Radiation

Exposure Duration	Radiation for 1% lethality (kW/m^2)	Radiation for 2nd degree burns (kW/m^2)	Radiation for first degree burns, (kW/m^2)
10 Sec	21.2	16	12.5
30 Sec	9.3	7.0	4.0

Since in practical situations, only the own employees will be exposed to heat radiation in case of a fire, it is reasonable to assume the protection by clothing. It can be assumed that people would be able to find a cover or a shield against thermal radiation in 10 sec. time. Furthermore, 100% lethality may be assumed for all people suffering from direct contact with flames, such as the pool fire, a flash fire or a jet flame. The effects due to relatively lesser incident radiation intensity are given below.

Effects Due To Incident Radiation Intensity

RADIATION KW/m^2	DAMAGE TO EQUIPMENT	DAMAGE TO PEOPLE
0.7		Equivalent to Solar Radiation
1.2	Solar heat at noon	
1.6	***	No discomfort for long exposure , Minimum level of pain threshold
2.0	PVC insulated cables damaged	***
4.0	***	Causes pain if duration is longer than 20 secs. But blistering is unlikely.
6.4	***	Pain threshold reached after 8 secs. Second degree burns after 20 secs.
9.5	Minimum energy to ignite wood	Minimum energy required for piloted ignition of wood, melting plastic tubing etc. Pain threshold reached after 8 sec. second degree burns after 20 sec. 1% lethality in one minute.
12.5	With a flame; Melts plastic tubing.	First degree burns in 10 secs.
16.0	***	Severe burns after 5 secs.
25.0	Minimum energy to ignite wood at identifying long exposure without a flame.	100% lethality in 1 minute. Significant injury in 10 secs.
37.5	Severe damage to plant	100% lethality in 1 minute. 50% lethality in 20 secs. 1% lethality in 10 secs.

Explosion

In case of vapour cloud explosion, two physical effects may occur:

* a flash fire over the whole length of the explosive gas cloud;
* a blast wave, with typical peak overpressures circular around ignition source.

As explained above, 100% lethality is assumed for all people who are present within the cloud proper.

For the blast wave, the lethality criterion is based on:

* A peak overpressure of 0.1 bar will cause serious damage to 10% of the housing/structures.
* Falling fragments will kill one of each eight persons in the destroyed buildings.

The following damage criteria may be distinguished with respect to the peak overpressures resulting from a blast wave:

FATAL RADIATION EXPOSURE LEVELS:

RADIATION	**FATALITY**		
LEVEL			
kW/m2	**1%**	**50%**	**99%**
	EXPOSURE IN SECONDS		
4.0	150	370	930
12.5	30	80	200
37.5	8	20	50

Damage Due To Overpressures

Peak Overpressure	Damage Type
0.83 bar	Total Destruction
0.30 bar	Heavy Damage
0.10 bar	Moderate Damage
0.03 bar	Significant Damage
0.01 bar	Minor Damage

OVER PRESSURE mbar	MECHANICAL DAMAGE TO EQUIPMENTS	DAMAGE TO PEOPLE
300	Heavy damage to plant & structure	1% death from lung damage >50% eardrum damage >50% serious wounds from flying objects
100	Repairable damage	>1% eardrum damage >1% serious wounds flying objects from
30	Major glass damage	Slight injury from flying glass
10	10% glass damage	***

From this it may be concluded that p = 0.17 E+5 pa corresponds approximately with 1% lethality. Furthermore it is assumed that everyone inside an area in which the peak overpressure is greater than 0.17 E+5 pa will be wounded by mechanical damage. For the gas cloud explosion this will be inside a circle with the ignition source as its centre.

Intoxication

The consequences from inhalation of a toxic vapour/gas are determined by the toxic dose.
This dose D is basically determined by:

- Concentration of the vapour in air;
- Exposure duration.

Furthermore, of course, the breathing rates of the victim, as well as the specific toxic mechanism unto the metabolism play an important role.

The dose is defined as $D = C^n.t$, with:

C = concentration of the toxic vapour, in [ppm] or [mg/m^3];

t = Exposure duration, in [sec] or [min];

n = exponent, mostly > 1.0; this exponent takes into account the fact that a high concentration over a short period results in more serious injury than a low concentration over a relatively longer period of exposure. The value of n should be greater than zero but less than 5.

The given definition for D only holds if the concentration is more or less constant over the exposure time; this may be the case for a (semi) continuous source. In case of an instantaneous source, the concentration varies with time; the dose D must be calculated with an integral equation:

$$D = \int C^n.dt$$

For a number of toxic materials, so-called Vulnerability Models (V.M.) have been developed. The general equation for a V.M. (probit function) is:

$$Pr = a + b.\ln (C^n.t), \text{ with}$$

Pr = probit number, being a representation of the percentage of people suffering a certain kind of damage, for instance lethality

Pr = 2.67 means 1% of the population;
Pr = 5.00 means 50% of the population;
a and b material dependent numbers;

$C^n.t$ = dose D, as explained above.
The values for a and b are mostly derived from experiments with animals; occasionally, however, also human toxicity factors have been derived from accidents in past. In case only animal experiments are available, the inhalation experiments with rats seem to be best applicable for predicting the damage to people from acute intoxication. Although much research in this field have been done over the past decades, only for a limited number of toxic materials consequence models have been developed. Often only quite scarce information is available to predict the damage from an acute toxic exposition. Data transformation from oral intoxication data to inhalation toxicity criteria is sometimes necessary. Generally, in safety evaluations pessimistic assumptions are applied in these transformation calculations. The calculated damage (distance) may be regarded as a maximum. For the purposes of a response to a major incident, the IDLH value level has been chosen for the 'wounded' criteria. This type of injury will require medical attention.

Toxic Effects:

The effect of exposure to a toxic substance depends upon the duration of exposure and the concentration of the toxic substance. Short-term exposures to high concentration give Acute Effects while long term exposures to low concentrations result in Chronic Effects.

Only Acute Effects are considered under hazard analysis, since they are likely credible scenarios. These effects are:

a) Irritation (respiratory system skin, eyes)
b) Narcosis (nervous system)
c) Asphyxiation (oxygen deficiency)
d) System damage (blood organs)

Following are some of the common terms used to express toxicity of materials:

TLV: Threshold Limit Value – is the permitted level of exposure for a given period on a weighted average basis (usually 8 hrs.for 5 days in a week).
STEL: it is permitted Short Time Exposure Limit usually for a 15-minute exposure.
IDLH: Immediately Dangerous To Life & Health
LC50: Lethal Concentration Low
TC50: Toxic Concentration Low

CHAPTER: 10

CONSEQUENCE ANALYSIS & RISK ANALYSIS

CONSEQUENCE ANALYSIS

In a plant handling hazardous chemicals, the main hazard arises due to storage, handling & use of these chemicals. If these chemicals are released into the atmosphere, they may cause damage due to resulting fires or vapour clouds. Blast Overpressures depend upon the reactivity class of material between two explosive limits.

Operating Parameters

Potential vapour release for the same material depends significantly on the operating conditions. Especially for any liquefied gas, the operating conditions are very critical to assess the damage potential. If we take up an example of ammonia, if it is stored at ambient temperature, say about 28^{o}C, and then the vapour release potential of the inventory is much higher as compared to the case if it is stored at 0^{o}C.

Inventory

Inventory Analysis is commonly used in understanding the relative hazards and short listing of release scenarios. Inventory plays an important role in regard to the potential hazard. Larger the inventory of a vessel or a system, larger the quantity of potential release. The potential vapour release (source strength) depends upon the quantity of liquid release, the properties of the materials and the operating conditions (pressure, temperature). If all these influencing parameters are combined into a matrix and vapour source strength estimated for each release case, a ranking should become a credible exercise.

Loss of Containment

Plant inventory can get discharged to Environment due to Loss of Containment. Certain features of materials to be handled at the plant need to the clearly understood to firstly list out all significant release cases and then to short list release scenarios for a detailed examination. Liquid release can be either instantaneous or continuous. Failure of a vessel leading to an instantaneous outflow assumes the sudden appearance of such a major crack that practically all of the contents above the crack shall be released in a very short time. The more likely event is the case of liquid release from a hole in a pipe connected to the vessel. The flow rate is depending on the size of the hole as well as on the pressure, which was present, in front of the hole, prior to the accident. Such pressure is basically dependent on the pressure in the vessel.

The vaporisation of released liquid depends on the vapour pressure and weather conditions. Such consideration and others have been kept in mind both during the initial listing as well as during the short listing procedure. In the study, Maximum Credible Loss accident methodology is to be used, therefore, the largest potential hazard inventories have been considered for consequence estimation.

MAXIMUM CREDIBLE LOSS ACCIDENT SCENARIOS

A Maximum Credible Accident (MCA) can be characterised as the worst credible accident. In other words: an accident in an activity, resulting in the maximum consequence distance that is still believed to be possible. A MCA-analysis does not include a quantification of the probability of occurrence of the accident. Another aspect, in which the pessimistic approach of MCA studies appears, is the atmospheric condition that is used for dispersion calculations.

The Maximum Credible Loss (MCL) scenarios have been developed for the Facility. The MCL cases considered, attempt to include the worst "Credible" incidents- what constitutes a credible incident is always subjective. Nevertheless, guidelines have evolved over the years and based on basic engineering judgement, the cases have been found to be credible and modelling for assessing vulnerability zones is prepared accordingly. Only catastrophic cases have been considered and not partial or small failures (as is the case in Quantitative Risk Assessment where contributions from low frequency - high outcome effect as well as high frequency - low outcome events are distinguished). The objective of the study is emergency planning, hence only holistic & conservative assumptions are used for obvious reasons. Hence though the outcomes may look pessimistic, the planning for emergency concept should be borne in mind whilst interpreting the results.

CONSEQUENCE ANALYSIS CALCULATIONS

The Consequence Analysis has been done for selected scenarios. This has been done for weather conditions having wind speed 3 m/s. In Consequence Analysis, geographical location of the source of potential release plays an important role. Consideration of a large number of scenarios in the same geographical location serves little purpose if the dominant scenario has been identified and duly considered.

6.7.3.1 SOFTWARE USED FOR CALCULATIONS

Aloha 5.1.1.2 is the most comprehensive software available for performing Process Hazard Analysis (PHA), Quantitative Risk Assessment (QRA) and Financial Risk Analysis (FRA). Our extensively validated software for consequence and risk analysis is used by governments and industry helping them to comply with local safety regulation and their own corporate best practice. **Aloha 5.1.1.2** contains all the discharge, dispersion, effects and risk models you will need to accurately assess all your major hazards and associated risks.

Aloha 5.1.1.2 Consequence provides you with comprehensive hazard analysis facilities to examine the progress of a potential incident from the initial release to its far-field effects.

6.7.4 SCENARIOS

Table : 6.5
Possible Accident scenarios at M/s. Shrey industries

Sr. No.	Name of Raw Material	CAS No.	Physical Form	Container Type	Maximum Storage at a time (MT)
1.	Mono Chloro Benzene	108-90-7	Liquid	HDPE/MS Drum	2
2.	Chlorine	7782-50-5	Gas	Cylinder	18

1. **Leakages of** Mono Chloro Benzene from drum: 2.0 MT.

Flammable Area of vapour Cloud : MCB

SITE DATA:

Location: M/S. SHREY INDUSTRIES, INDIA

Building Air Exchanges Per Hour: 0.53 (unsheltered double storied)

Time: April 18, 2019 1056 hours ST (using computer's clock)

CHEMICAL DATA:

Chemical Name: CHLOROBENZENE

CAS Number: 108-90-7 Molecular Weight: 112.56 g/mol

AEGL-1 (60 min): 10 ppm AEGL-2 (60 min): 150 ppm AEGL-3 (60 min): 400 ppm

IDLH: 1000 ppm LEL: 13000 ppm UEL: 96000 ppm

Ambient Boiling Point: 131.5° C

Vapor Pressure at Ambient Temperature: 0.017 atm

Ambient Saturation Concentration: 17,609 ppm or 1.76%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)

Wind: 4.09 meters/second from E at 3 meters

Ground Roughness: open country Cloud Cover: 5 tenths

Air Temperature: 27° C Stability Class: D

No Inversion Height Relative Humidity: 50%

SOURCE STRENGTH:

Direct Source: 2000 kilograms/min Source Height: 0

Release Duration: 60 minutes

Release Rate: 2,000 kilograms/min

Total Amount Released: 120,000 kilograms

THREAT ZONE:

Threat Modeled: Flammable Area of Vapor Cloud

Model Run: Heavy Gas

Red : 124 meters --- (7800 ppm = 60% LEL = Flame Pockets)

Yellow: 353 meters --- (1300 ppm = 10% LEL)

Yellow Threat Zone 1300 ppm = 10% LEL

Time: April 18, 2019 1056 hours ST
Chemical Name: CHLOROBENZENE
Wind: 4.09 meters/second from E at 3 meters

THREAT ZONE:
Red : 124 meters --- (7800 ppm = 60% LEL = Flame Pockets)
Yellow: 353 meters --- (1300 ppm = 10% LEL)

Model: ALOHA Flammable Area of Vapor Cloud

Toxic Threat Zone for MCB :

SITE DATA:

Location: M/S. SHREY INDUSTRIES, INDIA

Building Air Exchanges Per Hour: 0.53 (unsheltered double storied)

Time: April 18, 2019 1056 hours ST (using computer's clock)

CHEMICAL DATA:

Chemical Name: CHLOROBENZENE

CAS Number: 108-90-7 Molecular Weight: 112.56 g/mol

AEGL-1 (60 min): 10 ppm AEGL-2 (60 min): 150 ppm AEGL-3 (60 min): 400 ppm

IDLH: 1000 ppm LEL: 13000 ppm UEL: 96000 ppm

Ambient Boiling Point: 131.5° C

Vapor Pressure at Ambient Temperature: 0.017 atm

Ambient Saturation Concentration: 17,609 ppm or 1.76%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)

Wind: 4.09 meters/second from E at 3 meters

Ground Roughness: open country Cloud Cover: 5 tenths

Air Temperature: 27° C Stability Class: D

No Inversion Height Relative Humidity: 50%

SOURCE STRENGTH:

Direct Source: 2000 kilograms/min Source Height: 0

Release Duration: 60 minutes

Release Rate: 2,000 kilograms/min

Total Amount Released: 120,000 kilograms

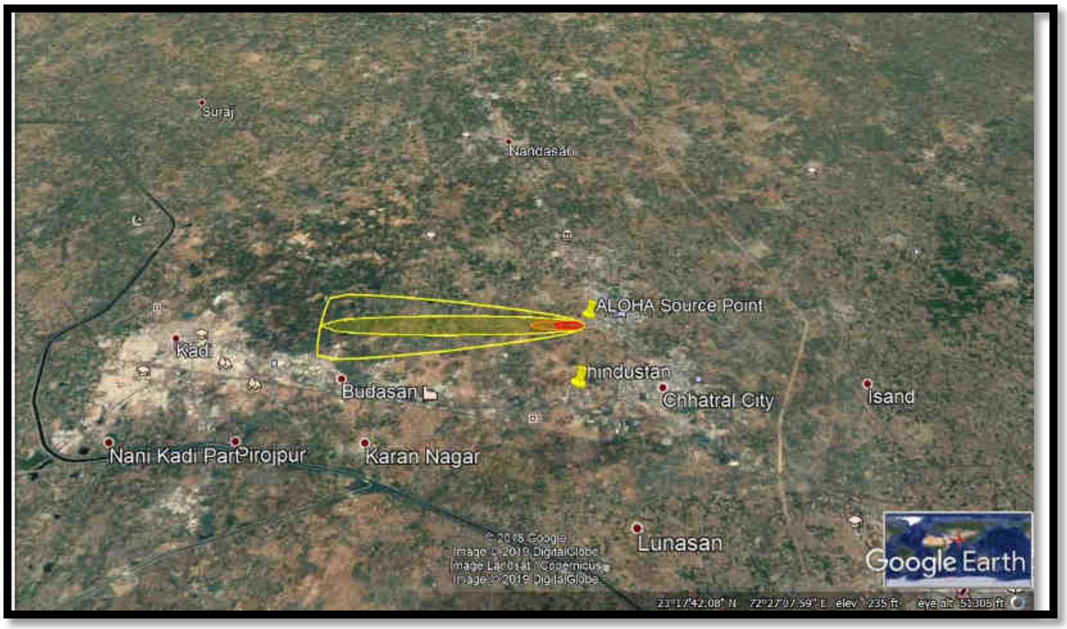
THREAT ZONE:

Model Run: Heavy Gas

Red : 722 meters --- (400 ppm = AEGL-3 [60 min])

Orange: 1.3 kilometers --- (150 ppm = AEGL-2 [60 min])

Yellow: 6.5 kilometers --- (10 ppm = AEGL-1 [60 min])



Yellow Wind Direction Confidence Lines 10 ppm = AEGL-1 (60 min)

Time: April 18, 2019 1056 hours ST

Chemical Name: CHLOROBENZENE

Wind: 4.09 meters/second from E at 3 meters

THREAT ZONE:

Red : 722 meters --- (400 ppm = AEGL-3 [60 min])

Orange: 1.3 kilometers --- (150 ppm = AEGL-2 [60 min])

Yellow: 6.5 kilometers --- (10 ppm = AEGL-1 [60 min])

Model: ALOHA Heavy Gas

2. Leakages of Chlorine from Cylinder: 18.0 MT.

SITE DATA:

Location: M/S. SHREY INDUSTRIES, INDIA

Building Air Exchanges Per Hour: 0.53 (unsheltered double storied)

Time: April 18, 2019 1056 hours ST (using computer's clock)

CHEMICAL DATA:

Chemical Name: CHLORINE

CAS Number: 7782-50-5 Molecular Weight: 70.91 g/mol

AEGL-1 (60 min): 0.5 ppm AEGL-2 (60 min): 2 ppm AEGL-3 (60 min): 20 ppm

IDLH: 10 ppm

Ambient Boiling Point: -34.2° C

Vapor Pressure at Ambient Temperature: greater than 1 atm

Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)

Wind: 4.09 meters/second from E at 3 meters

Ground Roughness: open country Cloud Cover: 5 tenths

Air Temperature: 27° C Stability Class: D

No Inversion Height Relative Humidity: 50%

SOURCE STRENGTH:

Direct Source: 18000 kilograms/min Source Height: 0

Release Duration: 60 minutes

Release Rate: 18,000 kilograms/min

Total Amount Released: 1,080,000 kilograms

Note: This chemical may flash boil and/or result in two phase flow.

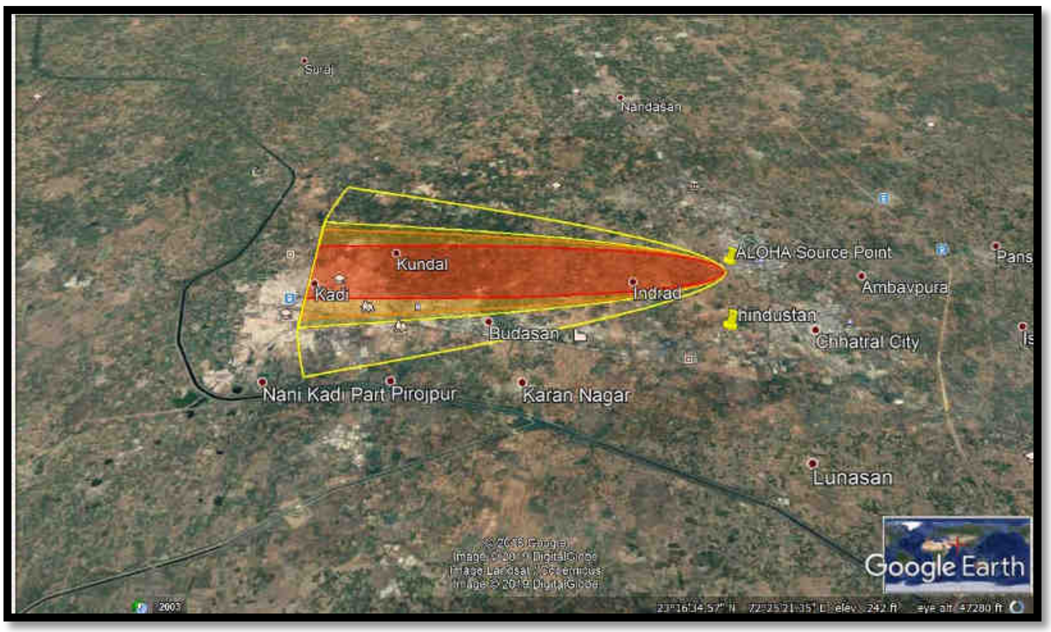
THREAT ZONE:

Model Run: Heavy Gas

Red : greater than 10 kilometers --- (20 ppm = AEGL-3 [60 min])

Orange: greater than 10 kilometers --- (2 ppm = AEGL-2 [60 min])

Yellow: greater than 10 kilometers --- (0.5 ppm = AEGL-1 [60 min])



Red Threat Zone 20 ppm = AEGL-3 (60 min)

Time: April 18, 2019 1056 hours ST

Chemical Name: CHLORINE

Wind: 4.09 meters/second from E at 3 meters

THREAT ZONE:

Red : greater than 10 kilometers --- (20 ppm = AEGL-3 [60 min])

Orange: greater than 10 kilometers --- (2 ppm = AEGL-2 [60 min])

Yellow: greater than 10 kilometers --- (0.5 ppm = AEGL-1 [60 min])

Model: ALOHA Heavy Gas

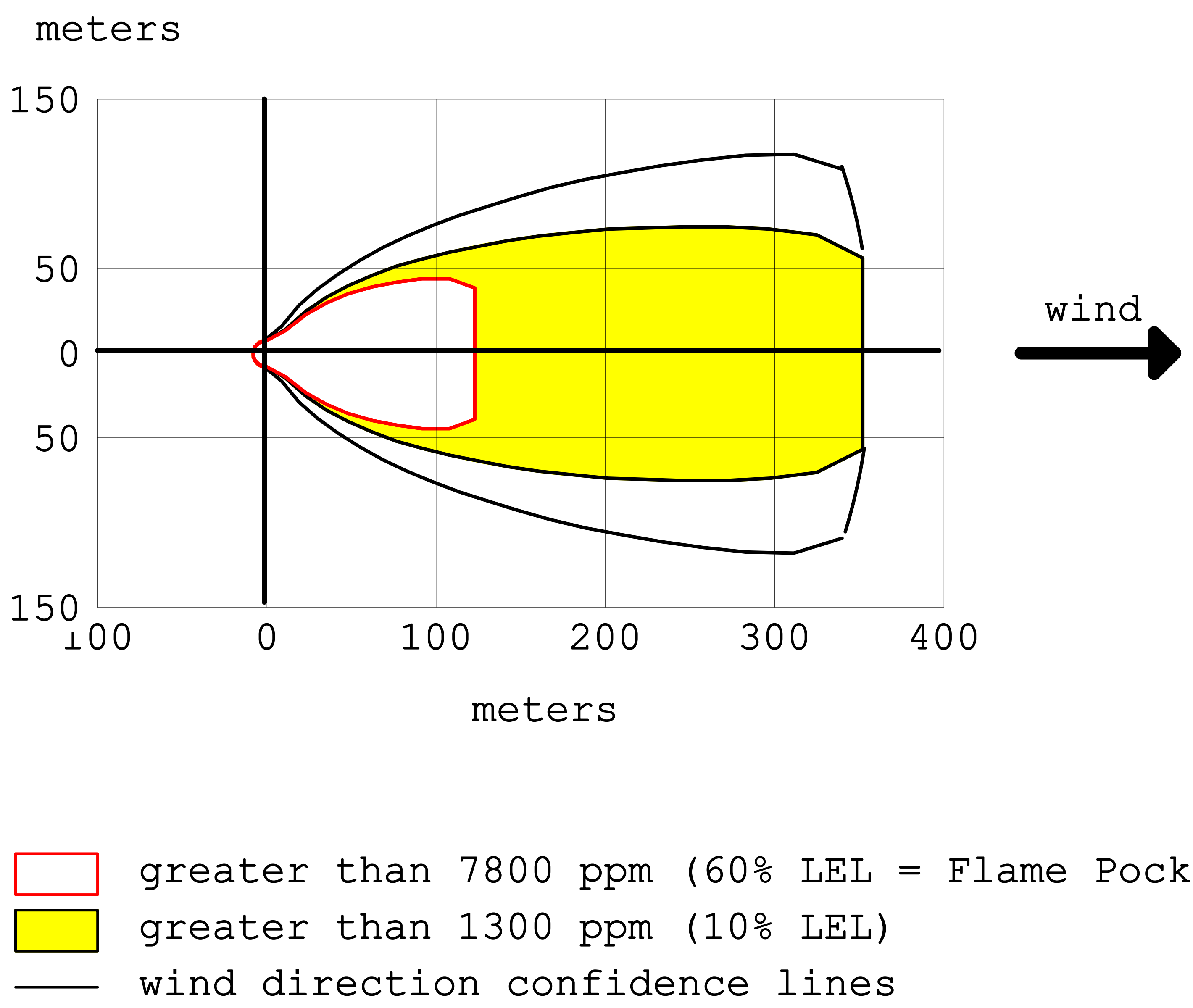
Flammable Threat Zone ALOHA® 5.4.7

```
Time: April 18, 2019  1056 hours ST (using computer's clock)

Chemical Name: CHLOROBENZENE

Wind: 4.09 meters/second from E at 3 meters

THREAT ZONE:
   Threat Modeled: Flammable Area of Vapor Cloud
   Model Run: Heavy Gas
   Red    : 124 meters --- (7800 ppm = 60% LEL = Flame Pockets)
   Yellow: 353 meters --- (1300 ppm = 10% LEL)
```



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SITE DATA:
  Location: M/S. SHREY INDUSTRIES, INDIA
  Building Air Exchanges Per Hour: 0.53 (unsheltered double storied)
  Time: April 18, 2019  1056 hours ST (using computer's clock)

CHEMICAL DATA:
  Chemical Name: CHLOROBENZENE
  CAS Number: 108-90-7                  Molecular Weight: 112.56 g/mol
  AEGL-1 (60 min): 10 ppm   AEGL-2 (60 min): 150 ppm   AEGL-3 (60 min): 400
ppm
  IDLH: 1000 ppm     LEL: 13000 ppm      UEL: 96000 ppm
  Ambient Boiling Point: 131.5° C
  Vapor Pressure at Ambient Temperature: 0.017 atm
  Ambient Saturation Concentration: 17,609 ppm or 1.76%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 4.09 meters/second from E at 3 meters
  Ground Roughness: open country        Cloud Cover: 5 tenths
  Air Temperature: 27° C                Stability Class: D
  No Inversion Height                   Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 2000 kilograms/min     Source Height: 0
  Release Duration: 60 minutes
  Release Rate: 2,000 kilograms/min
  Total Amount Released: 120,000 kilograms

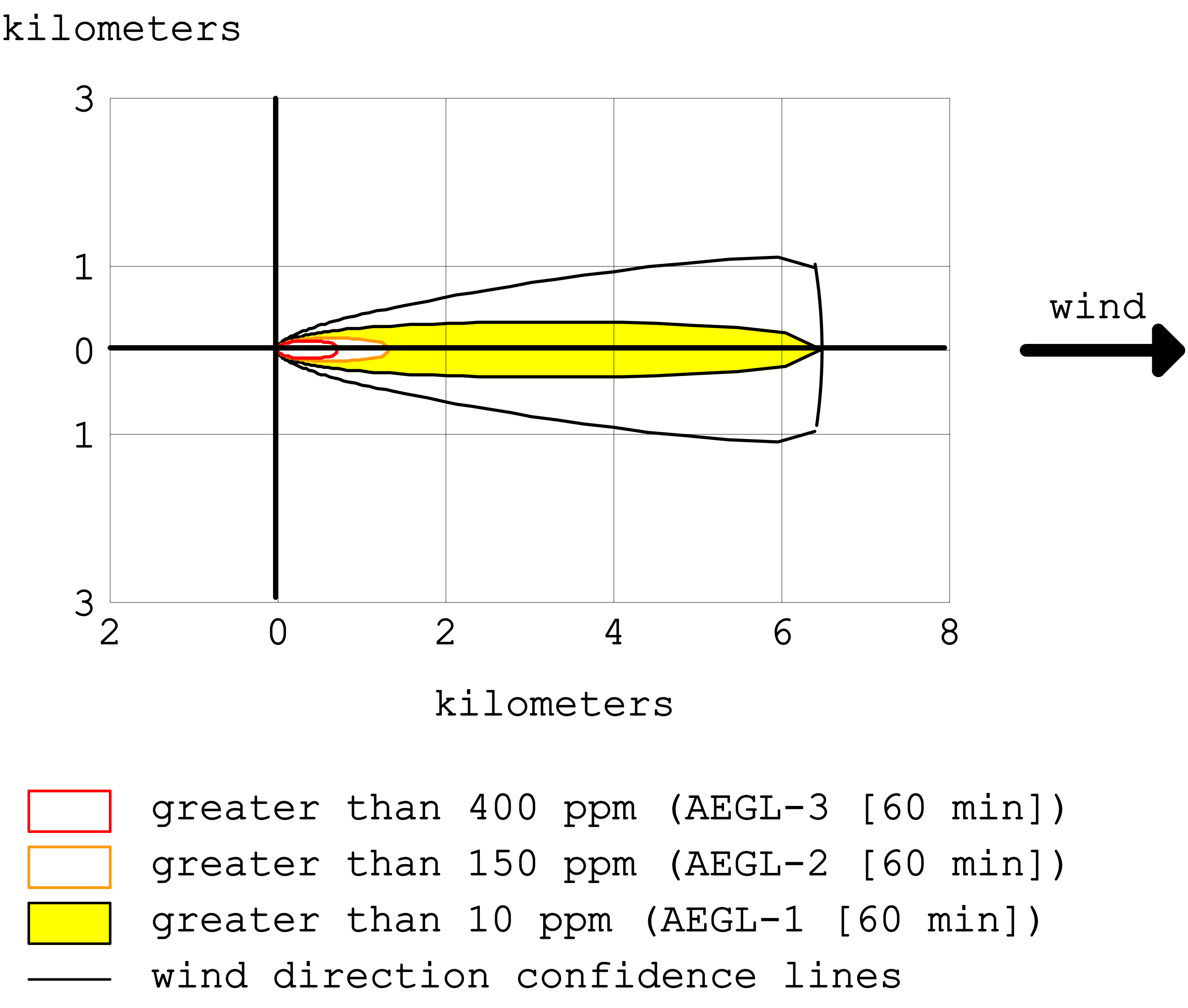
THREAT ZONE:
  Threat Modeled: Flammable Area of Vapor Cloud
  Model Run: Heavy Gas
  Red   : 124 meters --- (7800 ppm = 60% LEL = Flame Pockets)
  Yellow: 353 meters --- (1300 ppm = 10% LEL)
```

```
Time: April 18, 2019  1056 hours ST (using computer's clock)

Chemical Name: CHLOROBENZENE

Wind: 4.09 meters/second from E at 3 meters

THREAT ZONE:
  Model Run: Heavy Gas
  Red    : 722 meters --- (400 ppm = AEGL-3 [60 min])
  Orange: 1.3 kilometers --- (150 ppm = AEGL-2 [60 min])
  Yellow: 6.5 kilometers --- (10 ppm = AEGL-1 [60 min])
```



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SITE DATA:
  Location: M/S. SHREY INDUSTRIES, INDIA
  Building Air Exchanges Per Hour: 0.53 (unsheltered double storied)
  Time: April 18, 2019  1056 hours ST (using computer's clock)

CHEMICAL DATA:
  Chemical Name: CHLOROBENZENE
  CAS Number: 108-90-7                  Molecular Weight: 112.56 g/mol
  AEGL-1 (60 min): 10 ppm   AEGL-2 (60 min): 150 ppm   AEGL-3 (60 min): 400
ppm
  IDLH: 1000 ppm     LEL: 13000 ppm      UEL: 96000 ppm
  Ambient Boiling Point: 131.5° C
  Vapor Pressure at Ambient Temperature: 0.017 atm
  Ambient Saturation Concentration: 17,609 ppm or 1.76%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 4.09 meters/second from E at 3 meters
  Ground Roughness: open country        Cloud Cover: 5 tenths
  Air Temperature: 27° C                Stability Class: D
  No Inversion Height                   Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 2000 kilograms/min      Source Height: 0
  Release Duration: 60 minutes
  Release Rate: 2,000 kilograms/min
  Total Amount Released: 120,000 kilograms

THREAT ZONE:
  Model Run: Heavy Gas
  Red   : 722 meters --- (400 ppm = AEGL-3 [60 min])
  Orange: 1.3 kilometers --- (150 ppm = AEGL-2 [60 min])
  Yellow: 6.5 kilometers --- (10 ppm = AEGL-1 [60 min])
```

Toxic Threat Zone

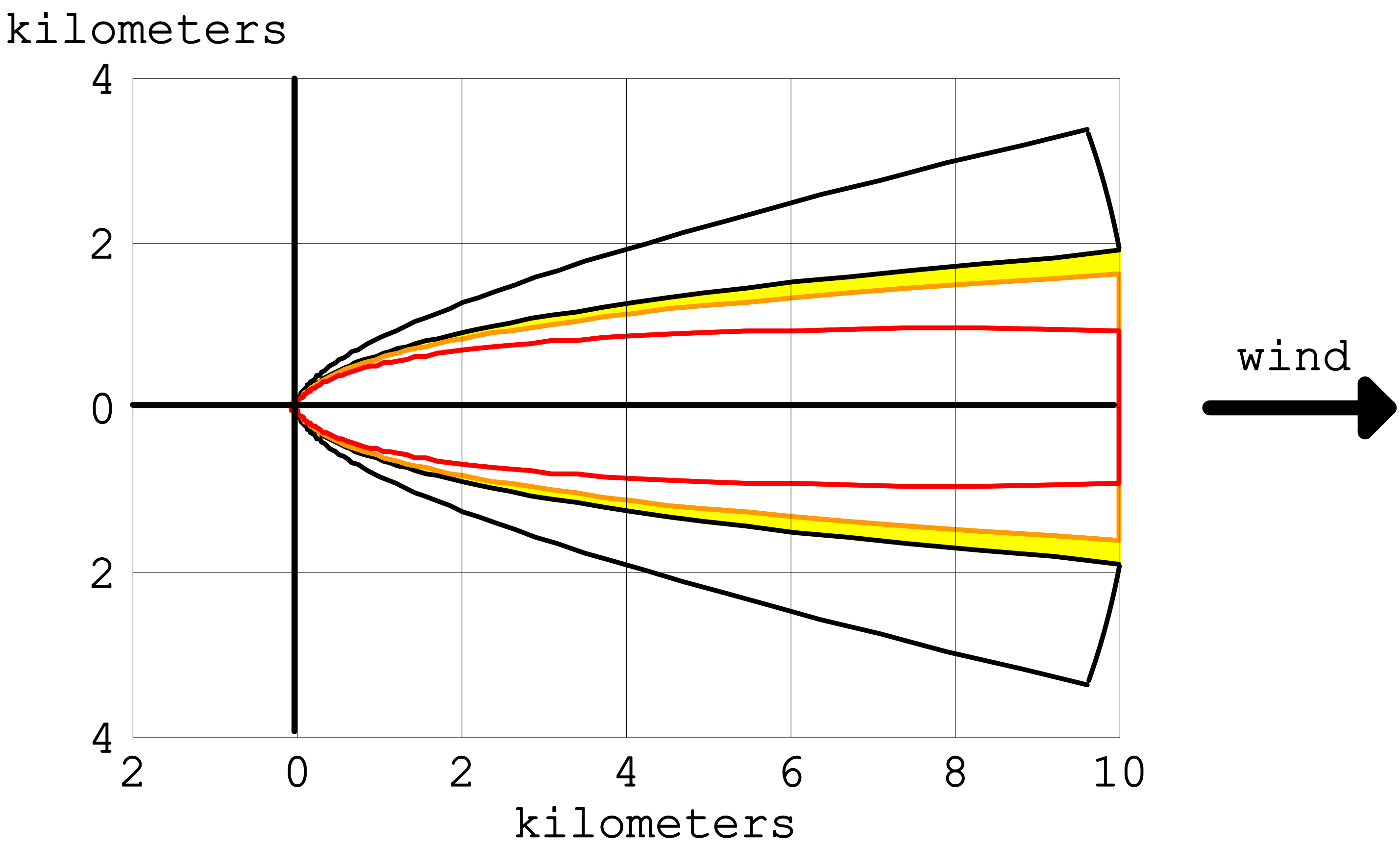
ALOHA® 5.4.7

Time: April 18, 2019 1056 hours ST (using computer's clock)

Chemical Name: CHLORINE

Wind: 4.09 meters/second from E at 3 meters

THREAT ZONE:
  Model Run: Heavy Gas
  Red   : greater than 10 kilometers --- (20 ppm = AEGL-3 [60 min])
  Orange: greater than 10 kilometers --- (2 ppm = AEGL-2 [60 min])
  Yellow: greater than 10 kilometers --- (0.5 ppm = AEGL-1 [60 min])



greater than 20 ppm (AEGL-3 [60 min])

greater than 2 ppm (AEGL-2 [60 min])

greater than 0.5 ppm (AEGL-1 [60 min])

wind direction confidence lines

Note: Threat zone picture is truncated at the 10 km

```
SITE DATA:
  Location: M/S. SHREY INDUSTRIES, INDIA
  Building Air Exchanges Per Hour: 0.53 (unsheltered double storied)
  Time: April 18, 2019  1056 hours ST (using computer's clock)

CHEMICAL DATA:
  Chemical Name: CHLORINE
  CAS Number: 7782-50-5                  Molecular Weight: 70.91 g/mol
  AEGL-1 (60 min): 0.5 ppm   AEGL-2 (60 min): 2 ppm   AEGL-3 (60 min): 20 ppm
  IDLH: 10 ppm
  Ambient Boiling Point: -34.2° C
  Vapor Pressure at Ambient Temperature: greater than 1 atm
  Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 4.09 meters/second from E at 3 meters
  Ground Roughness: open country         Cloud Cover: 5 tenths
  Air Temperature: 27° C                 Stability Class: D
  No Inversion Height                    Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 18000 kilograms/min     Source Height: 0
  Release Duration: 60 minutes
  Release Rate: 18,000 kilograms/min
  Total Amount Released: 1,080,000 kilograms
  Note: This chemical may flash boil and/or result in two phase flow.

THREAT ZONE:
  Model Run: Heavy Gas
  Red   : greater than 10 kilometers --- (20 ppm = AEGL-3 [60 min])
  Orange: greater than 10 kilometers --- (2 ppm = AEGL-2 [60 min])
  Yellow: greater than 10 kilometers --- (0.5 ppm = AEGL-1 [60 min])
```