ANNEXURE 7.1

RISK ASSESSMENT STUDY

A PART OF

ENVIRONMENTAL IMPACT ASSESSMENT REPORT

FOR PROPOSED BULK DRUGS MANUFACTURING UNIT

OF

M/s. FR CHEM PVT. LTD.

TO BE SET UP AT

Survey No. 47/1, 47/2, 47/3, 47/4, 47/5
Village: Lakshmipura (Nandasan), Taluka: Kadi,
District: Mehsana - 382 715, Gujarat

INDEX

LIST OF TABLES

LIST OF ANNEXURES

1. Introduction:

M/s. FR Chem Pvt. Ltd. to be set up at Survey No.: 47/1, 47/2, 47/3, 47/4, 47/5, Village: Lakshmipura, Nandasan, Taluka- Kadi, and District: Mahesana, Gujarat proposes to manufacture 10 cellulose based bulk drugs – excipients.

In order to assess the risk associated with the proposed project, **M/s. FR Chem** have entrusted **M/s. Anand Consultants, Ahmedabad** to carry out Risk Assessment Study.

The purpose of this study includes identification and assessment of potential hazards & risks arising from the proposed activities connected to the manufacturing marketing terminal that requires management to comply with regulatory requirements; and to reduce or eliminate to As Low As Reasonably Practical (ALARP) in terms of risk to environment, human health, risk of injury/damage to plant, equipment and business interruptions etc.

2. Objective:

- To understand the Maximum Credible Accident Scenarios.
- To develop systems for preventing, controlling and containing the frequency and consequences of such major effects of emergencies and based on the same to prepare Disaster Management Plan.

3. Methodology:

- Collection of data/information with respect to facility, process, hazardous chemicals etc.
- Collection of meteorological data through **Automatic Weather Monitoring System**.
- Identification of hazardous chemicals as per the **Manufacture, Storage and Import of Hazardous Chemicals** (MSIHC) Amendment Rules 2000
- Screening of hazardous nature of each chemical and confirmation with Fire Diamond.
- Tabulation of chemical as well as physical properties and storage details for each hazardous chemical.
- Identification of hazard associated with each chemical.
- Identification of release type and determine release rates.
- Simulation of each identified hazardous chemical for consequence analysis using **ALOHA** (Areal Locations of Hazardous Atmospheres) software.

4. Hazards and Damage Criteria with respect to the Project:

4.1 Major Hazards:

A brief description of possible major hazards is discussed as follows:

Jet Fire:

A jet fire, also referred to as a flame jet, occurs when a flammable chemical is rapidly released from an opening in a container and immediately catches on fire -- much like the flame from a blowtorch. Thermal radiation is the primary hazard associated with a jet fire. Other potential jet fire hazards include smoke, toxic byproducts from the fire, and secondary fires and explosions in the surrounding area. In some cases, heat from the jet fire may weaken the tank and cause it to fail completely -- in which case, a BLEVE may occur.

BLEVE:

BLEVE stands for Boiling Liquid Expanding Vapor Explosion. BLEVEs typically occur in closed storage tanks that contain a liquefied gas, usually a gas that has been liquefied under pressure. A gas can be liquefied by either cooling (refrigerating) it to a temperature below its boiling point or by storing it at a high pressure.

Propane is an example of a chemical that has been involved in many BLEVE accidents. Most propane tanks contain liquid propane. These tanks are neither insulated nor refrigerated, so the tank contents are at ambient temperature. Since the ambient temperature is almost always significantly above propane's boiling point of - 43.7 degrees F, the tanks are highly pressurized.

A common BLEVE scenario happens when a container of liquefied gas is heated by fire, increasing the pressure within the container until the tank ruptures and fails. When the container fails, the chemical is released in an explosion. If the chemical is above its boiling point when the container fails, some or all of the liquid will flash-boil -- that is, instantaneously become a gas. If the chemical is flammable, a burning gas cloud called a fireball may occur if a significant amount of the chemical flash-boils. ALOHA assumes that any liquid not consumed in the fireball will form a Pool Fire.

ALOHA estimates the thermal radiation hazard from a fireball and/or a pool fire. Other potential BLEVE hazards include overpressure, hazardous fragments, smoke, and toxic byproducts from the fire (although ALOHA does not model these hazards).

Flash Fire:

When a flammable vapor cloud encounters an ignition source, the cloud can catch fire and burn rapidly in what is called a flash fire. The part of the cloud where the concentration is in the flammable range, between the **Lower and Upper Explosive Limits** (LEL and UEL), will burn rapidly because that portion of the cloud is already pre-mixed to the right mixture of fuel and air for burning to occur. Following the rapid burning, the part of the cloud where the fuel-air concentration is above the UEL may continue to slowly burn as air mixes with the cloud.

Possible hazards associated with a flash fire include thermal radiation, smoke and toxic byproducts from the fire.

Vapor Cloud Explosion:

When a flammable chemical is released into the atmosphere, it forms a vapor cloud that will disperse as it travels downwind. If the cloud encounters an ignition source, the parts of the cloud where the concentration is within the flammable range (between the Lower and Upper Explosive Limits) will burn. The speed at which the flame front moves through the cloud determines whether it is a deflagration or a detonation. In some situations, the cloud will burn so fast that it creates an explosive force (blast wave).

The severity of a vapor cloud explosion depends on the chemical, the cloud size at the time of ignition, the type of ignition, and the congestion level inside the cloud.
Two primary hazards are associated with a vapor cloud explosion: overpressure and hazardous fragments.

4.2 Damage Criteria:

Thermal Damage:

A ***Level of Concern*** *(LOC)* is a threshold level of thermal radiation, usually the level above which a hazard may exist.

ALOHA uses three threshold values (measured in kilowatts per square meter) to create the default threat zones:

- Red: 10 kW/(sq. m.) -- potentially lethal within 60 sec;
- Orange: 5 kW/(sq. m.) -- second-degree burns within 60 sec; and
- Yellow: 2 kW/(sq. m.) -- pain within 60 sec.

The thermal radiation effects that people experience depend upon the length of time they are exposed to a specific thermal radiation level. Longer exposure durations, even at a lower thermal radiation level, can produce serious physiological effects. The threat zones displayed by ALOHA represent thermal radiation levels; the accompanying text indicates the effects on people who are exposed to those thermal radiation levels but are able to seek shelter within one minute.

Below are some effects at specific thermal radiation levels and durations (on bare skin):

Radiation Intensity (kw/m^2)	Time for Severe Pain(s)	Time for 2nd Degree Burns (s)
1	115	663
2	45	187
3	27	92
4	18	57
5	13	40
6	11	30
8	7	20
10	5	14
12	4	11

Source: Federal Emergency Management Agency et al. 1988.

Overpressure:

Overpressure, also called a blast wave, refers to the sudden onset of a pressure wave after an explosion. This pressure wave is caused by the energy released in the initial explosion -- the bigger the initial explosion, the more damaging the pressure wave. Pressure waves are nearly instantaneous, traveling at the speed of sound.

An *Overpressure Level of Concern (LOC)* is a threshold level of pressure from a blast wave, usually the pressure above which a hazard may exist.

ALOHA uses three threshold values to create the default threat zones:

- Red: 8.0 psi (destruction of buildings);
- Orange: 3.5 psi (serious injury likely); and
- Yellow: 1.0 psi (shatters glass).

The following table relates overpressure values to the structural and physiological effects produced.

Overpressure* (psig)	Expected Damage
0.04	Loud noise (dB); sonic boom glass failure.
0.15	Typical pressure for glass failure.
0.4	Limited minor structural damage.
0.50 - 1.0	Windows usually shattered.
0.7	Minor damage to house structure.
1	Partial demolition of houses; made uninhabitable.
1.0 - 2.0	Corrugated metal panels fail and buckle. Housing wood panels blown in.
1.0 - 8.0	Range for slight to serious injuries from flying glass and other

Overpressure* (psig)	Expected Damage
	missiles.
2.0	Partial collapse of walls and roofs of houses.
2.0 - 3.0	Non reinforced concrete or cinder block walls shattered.
2.4 - 12.2	Range for 1-90% eardrum rupture among exposed populations.
2.5	50% destruction of home brickwork.
3.0	Steel frame building distorted and pulled away from foundation.
5.0	Wooden utility poles snapped.
5.0 - 7.0	Nearly complete destruction of houses.
7.0	Loaded train cars overturned.
9.0	Loaded train box cars demolished.
10.0	Probable total building destruction.
14.5 - 29.0	Range for 1-99% fatalities among exposed populations due to direct blast effects.

*Note: * These are peak pressures formed in excess of normal atmospheric pressure by blast and shock waves.*

Hazardous Fragments:

One of the major hazards associated with any explosion is flying debris (hazardous fragments) propelled by the explosion's pressure wave. Hazardous fragments come from two primary sources: container fragments and debris from the surrounding area.

If an explosion is likely to occur, first responders must be aware of the possibility of hazardous fragments and take necessary precautions to shield responders and others from the potentially fatal fragments. Some hazardous fragments may be projected into areas well beyond those affected by the thermal or overpressure explosion hazards.

Toxic Release:

For toxic release, there are several hazard classification systems in use. Some chemicals have not been classified in every system. ALOHA determines its default toxic Level of Concern (LOC) values based on the following:

a. AEGLs :

Acute Exposure Guideline Levels (AEGLs) are Toxic Levels of Concern (LOCs) that is used to predict the area where a toxic gas concentration might be high enough to harm people. The guidelines define three-tiered AEGLs as follows:

AEGL-1: The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

AEGL-2: The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

AEGL-3: The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

Each of the three levels of AEGL -- AEGL-1, AEGL-2, and AEGL-3 -- are developed for **Formaldehyde** (37% solution) for which this is applicable for this unit. AEGLS are available for each of five exposure periods: 10 minutes, 30 minutes, 1 hour, 4 hours, and 8 hours. ALOHA only includes AEGL values with an exposure period of 60 minutes.

b. ERPGs:

The **Emergency Response Planning Guidelines** (ERPGs) are Toxic Levels of Concern (LOCs) that is used to predict the area where a toxic gas concentration might be high enough to harm people. The ERPGs are three-tiered guidelines with one common denominator: a 1-hour contact duration. Each guideline identifies the substance, its chemical and structural properties, animal toxicology data, human experience, existing exposure guidelines, the rationale behind the selected value, and a list of references.

ERPG 1: The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined, objectionable odor.

ERPG 2: The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.

ERPG 3: The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

The most important point to remember about the ERPGs is that they do not contain safety factors usually incorporated into exposure guidelines. Rather, they estimate how the general public would react to chemical exposure. Just below the ERPG-1, for example, most people would detect the chemical and may experience temporary mild effects. Just below the ERPG-3, on the other hand, it is estimated that the effects would be severe, although not life-threatening. The ERPG should serve as a planning tool, not a standard to protect the public.

c. TEELs:

There are three TEEL levels that are important for responders to consider:

TEEL-1: Maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing other than mild transient health effects or perceiving a clearly defined objectionable odor.

TEEL-2: Maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

TEEL-3: Maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing life-threatening health effects.

d. IDLH:

Immediately Dangerous to Life or Health (IDLH) level is a limit originally established for selecting respirators for use in workplaces by the **National Institute for Occupational Safety and Health** (NIOSH). A chemical's IDLH is an estimate of the maximum concentration in the air to which a healthy worker could be exposed without suffering permanent or escape-impairing health effects. We recommend that appropriate respirator (as per NIOSH) be kept handy/easily available.

The IDLH was not designed to be an exposure limit for the general population. It does not take into account the greater sensitivity of some people, such as children and the elderly.

Note: For AEGLs, ERPGs and TEELs, the rank number increase with the hazard level, so that AEGL-3 is more hazardous than AEGL-1. Typically, the "3" values are used for the most hazardous (red) threat zones because they represent the threshold concentration above which health effects may be life threatening.

5. Results:

Hazardous chemicals have been identified using the **Manufacture, Storage and Import of Hazardous Chemicals** (MSIHC) Rules 2000. The chemicals having hazardous nature but not listed in the said notification are screened and confirmed using "Fire Diamond" [**National Fire Protection Association (NFPA) Diamond**] classification. Details of the same are depicted in **Table No. – 1 and Table No. – 2**.

Consequences analysis for failure scenarios with respect to considering hazardous chemicals has been tabulated as **Table No. – 3** and threat zone for each consequence analysis is drawn in **Annexure – 1.**

Hazards and response recommendations with respect to each hazard for each hazardous chemical have been described in **Annexure - 2.**

Typical failures with respect to storage tanks and storage vessels have been decided as per "***World Bank Technical Paper -55, Techniques for Assessing Industrial Hazards – A Manual***" for the presumption of consequence analysis scenarios.

All the scenarios and results depicted in this report are of worst case situations. In actual practice, these situations would not arise up to this extent because appropriate preventative precautionary measures and safety related installations would be a part of manufacturing process as well as plant. It may be noted that consequences analysis for each hazardous chemical has been carried out considering the stability class "C" and average wind speed measured in the project area.

Table No. – 1: Details of Hazardous Chemicals along with their Properties & Storage Details

Name of RAW MATERIAL	*Cas #*	*Physical State*	*B.P./M.P. (°C)*	*Vapour Density (Air=1)*	*Specific Gravity (Water=1)*	*F.P. (°C)*	*LEL-UEL (%)*	*IDLH (ppm)*	*Sr. No. as per MISHC Rules*	*Mode of Storage & its Capacity*	*MOC of Storage Vessel*	*Storage Parameters*
Acetic acid	64-19-7	Liquid	118.1/16.6	2.07	1.05	44.4	4/ 19.9	50	2	Container 50 L	MS	NTP
Acetic Anhydride	108-24-7	Liquid	139.9/-73.1	3.5	1.08	49	2.7/ 10.3	200	3	Containers 25 L	HDPE	24°C, Normal Pressure
Carbon disulphide	75-15-0	Liquid	46.3/-111.6	2.63	1.263	-30	1.3/50	500	110	Drums 150 L	HDPE	NTP
Ethanol	64-17-5	Liquid	78.5/-114.1	1.59	0.789	12.78	3.3/19	3300	248	Drums 50 L	HDPE	NTP
Ethylene Oxide	75-21-8	Liquid	10.5/NA	0.87	NA	-20	3/100	800	269	Drums 100 L	HDPE	24°C, ambient
Isopropanol (IPA)	67-63-0	Liquid	82.5/-88.5	2.07	0.785	11.667	2/12.7	2000	334	Drums 150 L	HDPE	NTP
Methanol	67-56-1	Liquid	64.5/-97.8	1.11	0.7915	12	6/36.5	6000	377	Carboys/ Drums 100L	HDPE	NTP
Nitric Acid	7697-37-2	Liquid	121/-41.6	2.5	1.408	NA	NA	25	422	Carboys/ Glass 50 L	HDPE	NTP
Phosphorous Pentoxide	1314-53-3	Solid	Decomposes/ 340	NA	2.39	NA	NA	NA	504	Bags 25 Kg	HDPE	NTP
Propylene oxide	75-56-9	Liquid	34.23/-112	2	0.83	NA	2.3/36	400	541	Containers 100 L	HDPE	24°C, ambient
Sodium Hydroxide	1310-73-2	Solid	1388/323	NA	2.13	NA	NA	10 mg	570	Bags 25 Kg	HDPE	NTP
Sulphuric Acid	7664-96-9	Liquid	270/-35	3.4	1.84	NA	NA	15 mg	590	Carboys 10 L	HDPE	NTP
Toluene	108-88-3	Liquid	110.6/-95	3.1	0.86	16	1.1/ 7.1	500	627	Containers/ Drum 50 L	MS	NTP

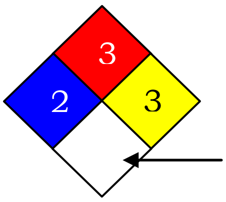
Note:

B.P.	:	Boiling Point	IDLH	:	Immediately Dangerous to Life & Health
M.P.	:	Melting Point	MSIHC	:	Manufacture Storage & Import of Hazardous Chemicals
F.P.	:	Flash Point	NTP	:	Normal Temperature Pressure
LEL	:	Lower Explosive Limit	N. Av.	:	Not Available
UEL	:	Upper Explosive Limit	N. App	:	Not Applicable
			N.Flam	:	Not Flammable

Table No. – 2: National Fire Protection Association (NFPA) Classification

Sr. No.	Full Name of Hazardous Chemicals	NFPA Classification			
		Flammability Hazard	Health Hazards	Reactivity Hazard	Special Hazard
1	Acetic acid	2	3	0	H
2	Acetic Anhydride	2	3	0	N. A.
3	Carbon disulphide	4	3	0	H
4	Ethanol	3	2	0	E
5	Ethylene Oxide	1	2	0	J
6	Isopropanol (IPA)	3	1	0	H
7	Methanol	3	1	0	N. A.
8	Nitric Acid	0	4	0	N. A.
9	Phosphorous Pentoxide	0	3	2	J
10	Propylene oxide	4	3	2	H
11	Sodium Hydroxide	0	3	1	J
12	Sulphuric Acid	0	3	2	N.A.
13	Toluene	3	2	0	H

Note: Interpreting NFPA 704 Codes



Red -- Flammability Hazard, **Blue** -- Health Hazard,

Yellow -- Reactivity Hazard

Special Hazard

N.A.: Not applicable

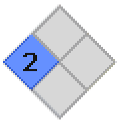
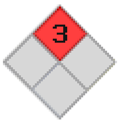
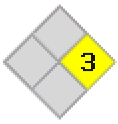
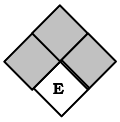
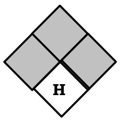
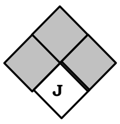
Quadrant	Code	Meaning
Health Hazard 	4	Too dangerous to enter - ***vapor*** or liquid.
	3	Extremely hazardous - use full protection.
	2	Hazardous - use breathing apparatus.
	1	Slightly hazardous.
	0	Like ordinary material.
Flammability Hazard 	4	Extremely ***flammable***.
	3	Ignites at normal temperatures.
	2	Ignites when moderately heated.
	1	Must be preheated to burn.
	0	Will not burn.
Reactivity Hazard 	4	May detonate - evacuate area if materials are exposed.
	3	Strong shock or heat may detonate - use monitors.
	2	Violent chemical change possible.
	1	Unstable if heated - use normal precautions.
	0	Normally stable.
Special Hazard 	E	Safety Glasses, Gloves, Dust Respirator
	H	Indicates need of Splash Goggles, Gloves, Protective Apron, Dust Respirator, Vapor Respirator while interacting with the chemical
	J	Indicates need of Splash Goggles, Gloves, Protective Apron, Vapor Respirator while interacting with the chemical

Table No. – 3: Consequences Analysis for Failure Scenarios

Sr. No.	Hazardous Chemicals	Scenario Considered & Consequences	Damage Distance			
			Red Threat Zone	Orange Threat Zone	Yellow Threat Zone	Remarks
1.	**Acetic Acid** *[Direct Source 0.025 KL in one 25 L HDPE Carboy]*	***Toxic Area of Vapour Cloud**	**34 meters (250 ppm = ERPG 3)** Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances	**91 meters** (35 ppm = ERPG-2)	**252 meters** (5 ppm = ERPG 1)	**Refer Figure: 1.1a**
		***Flammable Area of Vapour Cloud**	**10 meters** (40000 ppm = LEL)	**11 meters** (24000 ppm = 60 % LEL= Flame Pockets)	**11 meters** (4000 = 10% LEL)	Threat zone was not drawn because effects of near- field patchiness make dispersion predictions less reliable for short distances
		***Blast Area of Vapour Cloud Explosion**	**LOC never exceeded** (8.0 psi = destruction of building)	**Less than 10 meters** (3.5 psi = serious injury likely)	**17 meters** (1.0 psi = shatters glasses)	**Refer Figure: 1.2a**

Sr. No.	Hazardous Chemicals	Scenario Considered & Consequences	Damage Distance			Remarks
			Red Threat Zone	**Orange Threat Zone**	**Yellow Threat Zone**	
2.	**Acetic Anhydride** *Direct Source 400 L in 2 MS containers of 200 L capacity*	***Toxic Area of Vapour Cloud**	**Less than 10 meters** (100 ppm = ERPG 1)	**Less than 10 meters** (15 ppm = ERPG 2)	**Less than 10 meters** (0.5 ppm = ERPG 3)	Threat zone was not drawn because effects of near- field patchiness make dispersion predictions less reliable for short distances
		***Flammable Area of Vapour Cloud**	**Less than 10 meters** (162000 ppm 60 % LEL= Flame Pockets)	--	**11 meters** (2700 = 10% LEL)	
		***Overpressure from Vapour Cloud Explosion**	**No explosion: no part of the cloud is above the LEL at any time**			
3.	**Ethanol** *[Direct Source 0.3 KL in 3 HDPE Carboys/Drums of 100 L capacity]*	***Toxic Area of Vapour Cloud**	**No recommended LOC values** (N/A = ERPG 3)	**11 meters** (3300 ppm = ERPG-2)	**11 meters** (1800 ppm = ERPG-1)	Threat zone was not drawn because effects of near- field patchiness make dispersion predictions less reliable for short distances
		***Flammable Area of Vapour Cloud**	**Less than 10 meters** (19800 ppm 60 % LEL= Flame Pockets)	--	**11 meters** (3300 = 10% LEL)	
		***Overpressure from Vapour Cloud Explosion**	**LOC never exceeded** (8.0 psi = destruction of building)	**LOC never exceeded** (3.5 psi = serious injury likely)	**12 meters** (1.0 psi = shatters glasses)	**Refer Figure 2.1a**
4.	**Ethylene Oxide** *Direct Source 1 KL in 20 Cylinders of*	***Toxic Area of Vapour Cloud**	**Less than 10 meters** (200 ppm = AEGL-3)	**14 meters** (45 ppm = AEGL-2)	**No recommended LOC values** (N/A = AEGL-1)	Threat zone was not drawn because effects of near- field patchiness make dispersion predictions less
		***Flammable Area of Vapour Cloud**	**11 meters** (18000 ppm 60 % LEL=	--	**11 meters** (3000 = 10% LEL)	

Sr. No.	Hazardous Chemicals	Scenario Considered & Consequences	Damage Distance			
			Red Threat Zone	**Orange Threat Zone**	**Yellow Threat Zone**	**Remarks**
	50 L capacity		Flame Pockets)			reliable for short distances
		***Overpressure from Vapour Cloud Explosion**	**12 meters** (8.0 psi = destruction of building)	**17 meters** (3.5 psi = serious injury likely)	**34 meters** (1.0 psi = shatters glasses)	**Refer Figure 3.1a**
5.	**Isopropanol** *Direct Source 1.5 KL in 15 HDPE Cylinders of 100 L capacity*	***Toxic Area of Vapour Cloud**	**11 meters** (12000 ppm = PAC-3)	**17 meters** (400 ppm = PAC-2)	**17 meters** (400 ppm = PAC-1)	Threat zone was not drawn because effects of near- field patchiness make dispersion predictions less reliable for short distances
		***Flammable Area of Vapour Cloud**	**11 meters** (12000 ppm 60 % LEL= Flame Pockets)	--	**11 meters** (2000 = 10% LEL)	
		***Overpressure from Vapour Cloud Explosion**	**LOC never exceeded** (8.0 psi = destruction of building)	**10 meters** (3.5 psi = serious injury likely)	**19 meters** (1.0 psi = shatters glasses)	**Refer Figure 4.1a**
6.	**Methanol** *Direct Source 0.5 KL in 5 Tanks/Containers/Barrel of 100 L capacity*	***Toxic Area of Vapour Cloud**	**Less than 10 meters** (7200 ppm = AEGL-3)	**Less than 10 meters** (2100 ppm = AEGL-2)	**11 meters** (530 ppm = AEGL-1)	Threat zone was not drawn because effects of near- field patchiness make dispersion predictions less reliable for short distances
		***Flammable Area of Vapour Cloud**	**Less than 10 meters** (43080 ppm 60 % LEL= Flame Pockets)	--	**Less than 10 meters** (7180= 10% LEL)	
		***Overpressure from Vapour Cloud Explosion**	**No explosion: no part of the cloud is above the LEL at any time**			
7.	**Methyl**	***Toxic Area of**	**32 Meters**	**68 Meters**	**No Recommended**	**Refer Figure 5.1a**

Sr. No.	Hazardous Chemicals	Scenario Considered & Consequences	Damage Distance			
			Red Threat Zone	Orange Threat Zone	Yellow Threat Zone	Remarks
	Chloride *Direct Source 1.5 KL in 15 HDPE Cylinders of 100 L capacity*	**Vapour Cloud**	(3000 ppm = AEGL-3)	(910 ppm = AEGL-2)	**LOC Values** (N/A = AEGL-1)	
		***Flammable Area of Vapour Cloud**	**11 meters** (48600 ppm 60 % LEL= Flame Pockets)	--	**19 meters** (8100= 10% LEL)	Threat zone was not drawn because effects of near- field patchiness make dispersion predictions less reliable for short distances
		***Overpressure from Vapour Cloud Explosion-Spark/Flame as source of Ignition**	**LOC never exceeded**	**LOC never exceeded**	**15 meters** (1.0 psi = shatters glasses)	**Refer Figure 5.2a**
		Thermal Radiation from Fireball	**18 meters** (10.0 kW/(sq m) = potentially lethal within 60 sec)	**26 meters** (5.0 kW/(sq m) = 2nd degree burns within 60 sec)	**42 meters** (2.0 kW/(sq m) = pain within 60 sec)	**Refer Figure 5.3a**
		Thermal Radiation from Jet Fire	**10 meters** (10.0 kW/(sq m) = potentially lethal within 60 sec)	**10 meters** (5.0 kW/(sq m) = 2nd degree burns within 60 sec)	**14 meters** (2.0 kW/(sq m) = pain within 60 sec)	**Refer Figure 5.4a**

Sr. No.	Hazardous Chemicals	Scenario Considered & Consequences	Damage Distance			
			Red Threat Zone	Orange Threat Zone	Yellow Threat Zone	Remarks
8.	**Methylene Chloride** *Tank Source 1.2 KL in 4 HDPE Drums of 300 L capacity*	***Toxic Area of Vapour Cloud**	**11 meters (6900 ppm=AEGL-3)** Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances	**60 meters (560 ppm=AEGL-2)**	**105 meters (200 ppm=AEGL-1)**	**<u>Refer Figure 6.1a</u>**
		Thermal Radiation from Pool Fire	**<10 meters**			**LOC never exceeded**
		Thermal Radiation from Fireball	**22 meters** (10.0 kW/(sq m) = potentially lethal within 60 sec)	**36 meters** (5.0 kW/(sq m) = 2nd degree burns within 60 sec)	**60 meters** (2.0 kW/(sq m) = pain within 60 sec)	**<u>Refer Figure 6.2a</u>**
		***Flammable Area of Vapour Cloud**	**10 meters** (84000 ppm 60 % LEL= Flame Pockets)	--	**10 meters** (14000 ppm= 10% LEL)	Threat zone was not drawn because effects of near- field patchiness make dispersion predictions less reliable for short distances

Sr. No.	Hazardous Chemicals	Scenario Considered & Consequences	Damage Distance			
			Red Threat Zone	**Orange Threat Zone**	**Yellow Threat Zone**	**Remarks**
		***Overpressure from Vapour Cloud Explosion**	**No explosion: no part of the cloud is above the LEL at any time**			
9.	**Nitric Acid** *Evaporating puddle of 40L in 4 Glass bottles of 10 L capacity*	***Toxic Area of Vapour Cloud**	**Less than 10 meters (92 ppm=AEGL-3)** Threat zone was not drawn because effects of near- field patchiness make dispersion predictions less reliable for short distances	**Less than 10 meters (24 ppm=AEGL-2)**	**94 meters (0.16 ppm=AEGL-1)**	**Refer Figure 7.1a**
10.	**Propylene Oxide** *Tank Source of 1 Kl in 20 Cyl;inders of 50L capacity*	***Toxic Area of Vapour Cloud**	**11 meters (870 ppm=AEGL-3)**	**19 meters (290 ppm=AEGL-2)**	**35 meters (73 ppm=AEGL-1)**	Threat zone was not drawn because effects of near- field patchiness make dispersion predictions less reliable for short distances
		***Flammable Area of Vapour Cloud**	**11 meters** (13200 ppm 60 % LEL= Flame Pockets)	--	**10 meters** (2200 ppm= 10% LEL)	Threat zone was not drawn because effects of near- field patchiness make dispersion predictions less reliable for short

Sr. No.	Hazardous Chemicals	Scenario Considered & Consequences	Damage Distance			
			Red Threat Zone	Orange Threat Zone	Yellow Threat Zone	Remarks
						distances
		***Overpressure from Vapour Cloud Explosion (Ignited by spark or flame)**	**13 meters** (8.0 psi = destruction of building)	**19 meters** (3.5 psi = serious injury likely)	**39 meters** (1.0 psi = shatters glasses)	**Refer Figure 8.1a**
		Thermal Radiation from Fireball	**25 meters** (10.0 kW/(sq m) = potentially lethal within 60 sec)	**36 meters** (5.0 kW/(sq m) = 2nd degree burns within 60 sec)	**57 meters** (2.0 kW/(sq m) = pain within 60 sec)	**Refer Figure 8.2a**
11.	**Toluene** *Tank Source of 5 L in 6 MS Tank/Drums of 200L capacity*	***Toxic Area of Vapour Cloud**	**< 10 meters (4500 ppm=AEGL-3)**	**< 10 meters (1200 ppm=AEGL-2)**	**16 meters (200 ppm=AEGL-1)**	Threat zone was not drawn because effects of near- field patchiness make dispersion predictions less reliable for short distances
		Thermal Radiation from Pool Fire	**16 meters** (10.0 kW/(sq m) = potentially lethal within 60 sec)	**21 meters** (5.0 kW/(sq m) = 2nd degree burns within 60 sec)	**29 meters** (2.0 kW/(sq m) = pain within 60 sec)	**Refer Figure 9.1a**
		Thermal Radiation from Fireball	**67 meters** (10.0 kW/(sq m) = potentially lethal within 60 sec)	**94 meters** (5.0 kW/(sq m) = 2nd degree burns within 60 sec)	**147 meters** (2.0 kW/(sq m) = pain within 60 sec)	**Refer Figure 9.2a**

Sr. No.	Hazardous Chemicals	Scenario Considered & Consequences	Damage Distance			
			Red Threat Zone	Orange Threat Zone	Yellow Threat Zone	Remarks
		***Flammable Area of Vapour Cloud**	**< 10 meters** (6600 ppm 60 % LEL= Flame Pockets)	--	**< 10 meters** (1100 ppm= 10% LEL)	Threat zone was not drawn because effects of near- field patchiness make dispersion predictions less reliable for short distances
		***Overpressure from Vapour Cloud Explosion**	**No explosion: no part of the cloud is above the LEL at any time**			

6. Preventive & Mitigative Measures:

- Hazardous chemicals such as Toluene, Methanol etc. will be stored in tanks which will have individual dyke.
- Flame proof fittings will be provided to all areas where flammable chemicals are to be used.
- All spillages contained in dykes will be transferred back to the mother tank/ additional safety tank in a safe manner.
- Earthing systems will be provided at all places whenever there is a likelihood of a static charge being generated.
- Appropriate fire extinguishers will be installed and tested periodically.
- Appropriate personal protective equipments and fire extinguisher will be used in case of an emergency.
- In case of an emergency, affected area will be cordoned.
- All hot works will not be permitted or will be stopped in case of an emergency.
- All workers will be trained on respective **Standard Operating Procedure** (SOP) so as to enable them to prevent any possible mishaps.
- All loading/unloading will be carried out under technical guidance as per the **Standard Operating Procedure** (SOP) generated for the particular raw material/product.
- On-site Emergency Plan will be prepared, rehearsed and upgraded on a regular basis.

7. Disaster Management Plan

1. Introduction

An emergency is said to have arisen when operations in the plant are not able to cope up with a potential hazardous situation i.e. loss of control of an incident cause the plant cause the plant to go beyond its normal operating conditions, thus creating danger. When such an emergency evolves chain of events affect the normal working within the factory area and/or which may cause injuries, loss of life, substantial damage to property and environment both inside & outside the factory and a disaster is said to have occurred.

The steps involves in the process of Disaster Management can be summarized as:

- Minimize Risk Occurrence (Prevention)
- Rapid Control (Emergency Response)
- Effectively Rehabilitate Damaged Areas (Restoration)

Disaster Management Plan is involved by careful scrutiny and interlinking of:

- Types & causes of disaster
- Technical know-how
- Resource availability

2. Objective of Plan

The disaster management plan is developed to make best possible of M/s. FR Chem to:

- Rescue the victims and treat them suitable.
- Safe guard others (evacuating them to safer places)
- Contain the incident and control it with minimum damage
- Identify the persons affected
- Preserve relevant records and equipment needed as evidence in case of on inquiry
- Rehabilitate the affected areas

3. General Disaster Management Plan

Based on the risk assessment study carried out, M/s. FR Chem Pvt. Ltd. will prepare Disaster Management Plan. Nevertheless, General Disaster Management Plan is explained as below:

The various aspects that will be taken care during preparation of Disaster Management Plan are:

- Informative brochure, on emergency, will be distributed to each staff member of the plant and telephone number of key personnel to be contacted during an emergency will be placed at all the operator placement points in the plant.
- All Plant Control Rooms, Electrical Sub-station, Maintenance Department, Instrument, Civil, and all emergency services will be connected with internal telephones network which will act as easy and immediate means of communication.
- The industry will install a fire alarm and fire extinguishers.
- For blocking flame propagation back in the gas flame traps will be provided.
- Workers will be trained regularly on fire hazard drill, which will be organized every month by the safety officer.
- 24 hours vehicle service and in-plant First Aid Emergency Kit will be provided.
- Once the plant is commissioned, the Collector, the Police Control Room, Civil Defense authorities and Local authorities will be informed and kept in co-ordination.
- Coded colors for pipe line, vessels etc. will be used as per ISI.

4. Availability, Organization & Utilization of Resources & Facilities for Emergencies

In order to maintain an emergency response capability, certain facilities must be kept in a state of readiness, and sufficient supplies and equipment must be available. In some cases, it may be impossible to maintain all of the equipment necessary for all possible emergencies. In these cases, agreements have to be made with neighboring facilities to provide additional support as and when necessary.

Where the local police or private agencies may be called upon, such as volunteer fire companies and ambulance associations, agreements have to be developed ahead of time. Emergency hardware can be classified according to its use during the response operations.

Typical examples are:

- Emergency operation centers
- Communication equipment
- Alarm system
- Personal protection equipment
- Fire fighting facilities, equipment and supplies
- Spill and vapor release control equipment and supplies
- Medical facilities, equipment and supplies
- Monitoring systems
- Meteorological equipment
- A media center
- Transportation systems
- Security and access control equipment

Some of these resources will also be available in the local municipalities, local fire departments, and at neighboring facilities. It is the responsibility of the plant management to ensure that the appropriate equipments and materials are available to respond to their very hazard-specific emergencies at the facility, independently from external resources. These resources can be extremely valuable, but should be used mainly in support of the main response actions that the facility personnel will have to implement in case of a serious emergency.

A mutual aid from neighboring industries is also a resource that could be tapped in case of an emergency. However, even in this case, facility officials will first have to assess the emergency and provide information for their own records ahead of time. Emergency hardware can be classified according to its use during the response operations.

In any case, the availability of resources within the community must be determined beforehand, so that these resources can be mobilized, if the time comes to do so.

5. Commands, Co-ordination & Response Organization Structure

One of the most important objectives of emergency plan is to create a response organization structure capable of being developed in the shortest time possible during an emergency.

Command and control of emergency condition encompasses the key management functions necessary to ensure the health and safety of employees, as well as the public, living in the vicinity. These primary functions are summarized as follows:

- Detection of the emergency condition
- Assessment of the condition
- Classification of the emergency
- Mitigation of the emergency conditions
- Notification to management personnel
- Notification to local, state, and government agencies
- Activation and response of the necessary on-site and off-site support personnel

- Continuous assessment and reclassifications, as necessary
- Initiation of protective actions
- Recovery and re-entry

Effective command and control to accomplish these functions necessitates personnel trained in this Emergency Response Plan with adequate facilities and equipments to carry out their duties and functions. These organizations and the facilities required to support their response are summarized in the following subsections.

Main Controller - Works Manager / Chief Manager

He will assume the role of Main Controller and be overall in-charge of the situation. His task will be to co-ordinate all internal and external activities from the emergency operation centre, from where all operations will be directed.

He will:

- Relieve the Incident Controller from responsibility of the Main Controller.
- Co-ordinate to avail services from external agencies like police, fire brigade, hospitals, etc., if called for, following the declaration of a major emergency. If necessary, major installations in the vicinity like factories and nearby facilities control rooms etc. may also be informed of the situation.
- Exercise direct operational control of the unaffected section of the facility.
- In consultation with the Incident Controller, expedite the shutting down of operations at the affected installation, and if necessary instruct to remove the road tankers (if any) or to take any other appropriate action advised by the facility supervisor.
- Ensure that all the employees are evacuated from the affected area and the casualties, if any, are given necessary medical attention. Instruct security and transport department for rushing casualties to hospitals, if required.
- Liaise with fire and police officials, Pollution Control Boards and others statutory bodies and advise them of all possible consequent effects outside the facility premises.
- Arrange for obtaining the count of all the personnel within the factory.
- Liaise with factory supervisor to regulate vehicular movement within the factory premises.
- Instruct the security staff to remove the unaffected tanks-lorries, cars and park them in a safe area.
- Arrange for relief of personnel when emergency is prolonged.
- Issue authorized statement or press release to the news media.
- Ensure preservation of evidence for enquiries to be conducted by statutory authorities.
- Authorize the sounding of the “all clear” siren, which will be one continuous long siren for one minute.

Incident Controller – Manager / Shift – In - Charge

He will assume the role of Incident Controller and take charge of the situation. Keep the main Controller informed of the situation from time to time.

He will:

- Proceed to the scene of emergency and assess the situation.
- Direct all operations within the affected areas with the following priorities:
  - Safety of personnel.
  - Minimize damage to property and loss of material.
  - Co-ordinate with the Security In-charge of the factory, Fire Controller and local fire fighting service in case of fire emergency.
- Arrange for rescue of trapped workers and those in a state of shock.
- Advise Medical Officer to send medical staff to provide first aid and instruct the transport department to rush causalities to hospital.
- Get all non-essential persons safely evacuated after stopping all the engineering/hot jobs.
- Set up a communication system with the emergency operation center / main control center through walkie-talkie, telephone and/or messenger system.
- Pending arrival of the Main Controller, direct the shutting down and evacuation of the factory. In extreme emergency instruct the factory supervisor for moving of the road tanker from the factory. Call outside emergency service, if necessary. Allot jobs to the emergency squad.
- Report all developments to the Main Controller.
- Nominate a person / operator to maintain the chronological log of event during the entire period of emergency.
- Preserve all evidence for use in the subsequent inquiry.

Head of Administration Department/ Administrative Officer

He will:

- Proceed immediately to the emergency operation center.
- Also work as a liaison officer during emergency.
- Under the direction of the Main Controller, handle police, press and other inquiries, receive reports of roll call from emergency assembly areas and pass on the absenteeism information to the Incident Controller. Ensure the system for logging in the roll all for persons in the premises.
- Ensure that causalities receive adequate and immediate attention. Inform the relatives of causalities, if necessary.
- Control Traffic into the factory and ensure that alternate transport is available when need arises and ensure free access is available for temporary causalities.
- Check the availability of emergency equipments in the emergency operation center and make up for shortages.
- Arrange the cash required for handling critical situations during the emergency.

Safety Officer

He will:

- Co-ordinate with the Incident Controller and assume overall responsibility of the fire fighting operation.
- Advise the Main Controller if additional fire tanker/fire fighting equipments /materials / aid from other agencies is required.
- Rush to the emergency operation center. Report to the Incident Controller and advice suitably on mitigation measures, keeping in mind the type of emergency and the chemical involved.
- Assist First-aiders.
- Liaise with the utilities and arrange for external Water supply.
- Liaise with all external agencies, which could render assistance for fire fighting.
- Keep all vehicles and drivers in readiness and maintain continuous contact with the Main Controller / Medical Officer / Security In- charge and dispatch the vehicles as per their needs.
- Keep a minimum of two cars, as standby, at the factory for the emergency use. Do not use the cars for any purpose other than trips in the factory and for transporting critically injured to hospital.

Office Personnel

They will:

- Remain at work place until instructed otherwise by Incident controller and take steps to safeguard important documents, if the area is likely to be affected. Evacuate the work place as instructed by the Incident Controller along the pre-identified emergency exit and escape route.

Engineering / Technical Personnel

The main responsibility of this team is to provide technical support during the emergency.
They will:

- Prepare elaborated plans for providing a continuity of emergency supplies and services such as fire, water, electric power, emergency lighting, and other required utilities.
- Suggest optional strategies for conducting emergency isolation operations of damaged process equipments, the emergency transfer of materials to safe vessels, and all other process-related emergency operations.
- Assess damages and provide technical assistance to determine the operability of damaged units.
- Carry out or assist the accident investigation.
- Act as the main technical advisory team during the emergency.

Emergency Squad

Member of the emergency squad drawn up from security department and various departments of the factory will respond to the alarm and report to the Incident Controller.

They will:

- Carry out fire fighting and assist firemen in fire fighting and salvaging operations after the arrival of fire brigade.
- Rescue the persons from the affected area and provide first aid to the injured due to fire or inhalation of toxic gas.
- Assist for rushing casualties to hospitals and report details of causalities to Main Controller.
- Act as runners and messengers.
- Evacuate non-essential personnel and visitors.
- Maintain records of evacuated personnel.
- Any other job assigned by the Incident Controller.

Personnel of the Affected Area

They will:

- Do as directed by the Main/Incident Controller.
- Continue to handle the emergency as per the laid down practice and codes and as guided by the Incident Controller.
- Stop all hot work.
- Remove unwanted persons from the affected area to the "Safe Assembly Area"
- Stop all non-essential operations.

Personnel of Non-Affected Areas

They will:

- Promptly relieve the Emergency Squad personnel and direct them to rush to the scene of incident.
- Those employees who may be in the canteen or toilet or any other place, on hearing the alarm will:
- Immediately rush back to their work area.
- Act as per the instructions of the Incident Controller.
- All the employees shall confine themselves at the place of work and wait for further instructions.
- Take adequate steps to safeguard important documents in case their areas likely to be affected.
- Contractor employees shall stop their work and report at the assembly areas.

Environment Officer

He will:

- Be responsible for minimizing the impact of an accident on the environment. In this regard, he could develop methodologies to control hazardous spills and co-operate with emergency response squads to conduct the actual clean-up work during and after the emergency. In case of fire, his function will be responsible for containing the runoff of firewater from the damaged unit.

- Be responsible for determining the level of contamination of the site as a result of an accident. Therefore, he will be in-charge of developing the analytical techniques as well as obtaining the appropriate instruments, supplies and equipments for this purpose.
- Advise the Main Controller and his staff on whether the law requires reporting the spill to the appropriate local or governmental agencies, and also suggest possible counter measure to reduce the impact of the accident on the environment.

6. Post Disaster Analyses and Evaluation

When an emergency is over, it is desirable to carry out a detailed analysis of the causes of accidents to evaluate the influence of various factors involved and to propose methods to eliminate or minimize them in future. Simultaneously, the adequacy of the disaster preparedness plan can be evaluated and any shortcomings can be rectified.

References:

- ALOHA (Areal Locations of Hazardous Atmosphere) developed by *U.S. Environmental Protection Agency and National Oceanic and Atmospheric Administration*.
- World Bank Technical Paper – 55, "*Techniques for Assessing Industrial Hazards" – A Manual*.
- "*Manual of EHS Management*" by Dr. Ram S. Hamsagar.
- *Manufacture, Storage and Import of Hazardous Chemicals (MSIHC) Amendment Rules- 2000.*

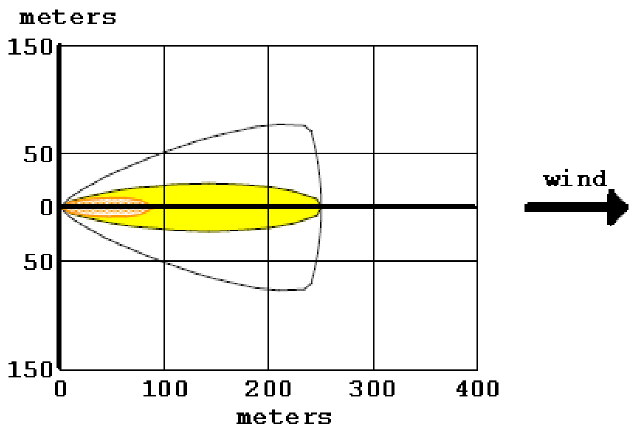
List of Antidotes

Sr. N	Name of Toxic Chemical	Possible Antidotes
1.	**Acetic Acid**	Milk of magnesia, Activated Charcoal or Water
2.	**Benzene, Xylene, Toluene**	Wash the skin area plenty of water if affected. Fresh air or oxygen, 0.1 mg/kg slowly through injection rest in bed. Don't apply Epinefrin, Ifridin etc. Don't apply milk, vegetable oil or alcohol.
3.	**Ethanol**	2 gm sodium bi carbonate in 250 ml water. Diazepam 10 mg through injection. If injury in eye or skin wash plenty of water.
4.	**Ethylene or Di-ethylene glycol**	Ethanol, Calcium gluconate.
5.	**Isopropyl Alcohol (IPA)**	Novasine Eye Drops
6.	**Phenol**	Take the patient in clean air, activated charcoal and 240 ml milk, if the eye or skin affected than wash with plenty of water, clean the skin with Poly Ethylene Glycol.
7.	**Methanol**	Ethanol (30% solution through oral, 5% solution through injection), ipicac syrup, if Acidosis than Sodium Bicarbonate, if effect of delirium than give 10 mg Diazepam through injection.

ANNEXURE 7.1b
THREAT ZONE FOR CONSEQUENCE ANALYSIS

1. Acetic Acid

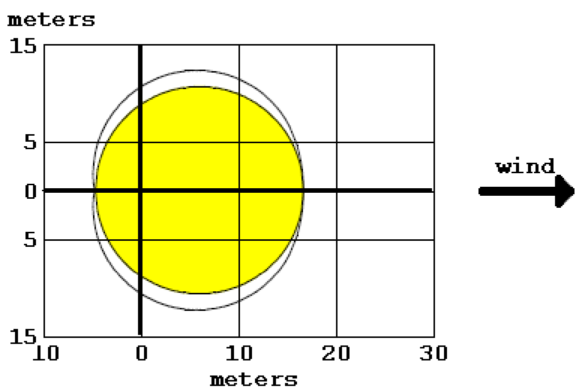
Scenario -1: Direct Source 0.025 KL in one 25 L HDPE Carboy – Toxic Area of Vapour Cloud



greater than 250 ppm (ERPG-3) (not drawn)
greater than 35 ppm (ERPG-2)
greater than 5 ppm (ERPG-1)
wind direction confidence lines

Figure 1.1a

Scenario -2: Direct Source 0.025 KL in one 25 L HDPE Carboy –Blast Area of Vapour Cloud Explosion



greater than 8.0 psi (destruction of buildings)
greater than 3.5 psi (serious injury likely)
greater than 1.0 psi (shatters glass)
wind direction confidence lines

Figure 1.2a

2. Ethanol

Scenario -1: Direct Source 0.3 KL in 3 HDPE Carboys/Drums of 100 L capacity – Blast Area of Vapour Cloud Explosion

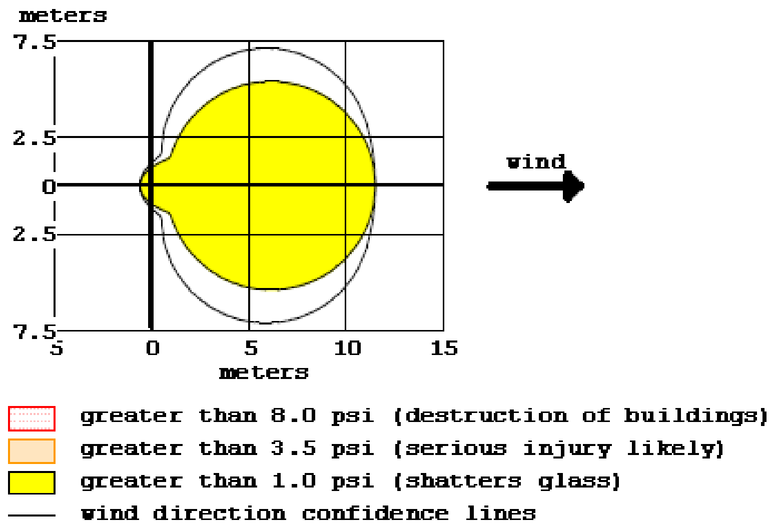


Figure 2.1a

3. Ethylene Oxide

Scenario -1: Direct Source 1 KL in 20 Cylinders of 50 L capacity – Blast Area of Vapour Cloud Explosion

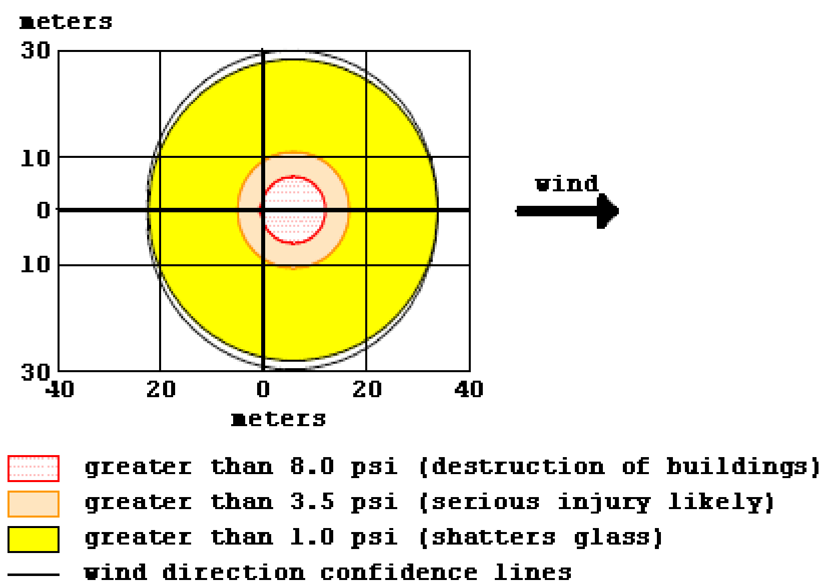


Figure 3.1a

4. Isopropanol

Scenario -1: Direct Source 1.5 KL in 15 HDPE Cylinders of 100 L capacity– Blast Area of Vapour Cloud Explosion

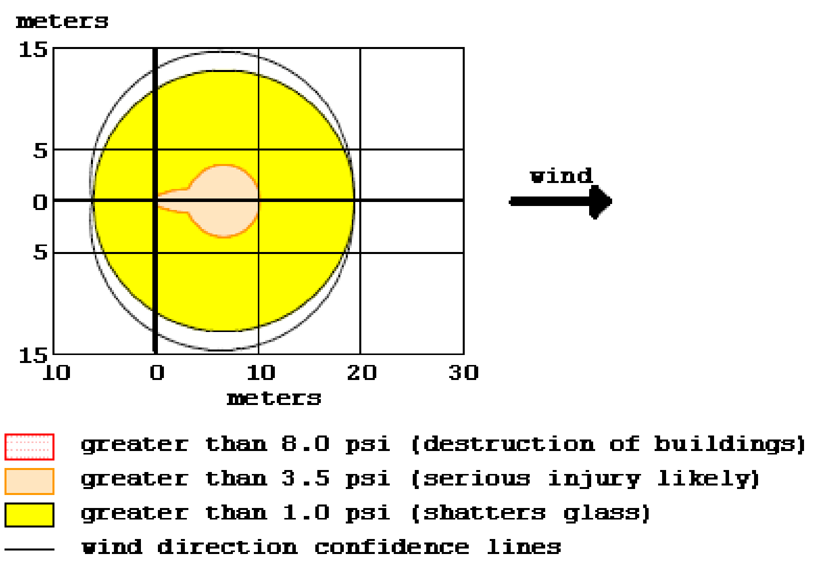


Figure 4.1a

5. Methyl Chloride

Scenario -1: Direct Source 1.5 KL in 15 HDPE Cylinders of 100 L capacity – Toxic Area of Vapour Cloud

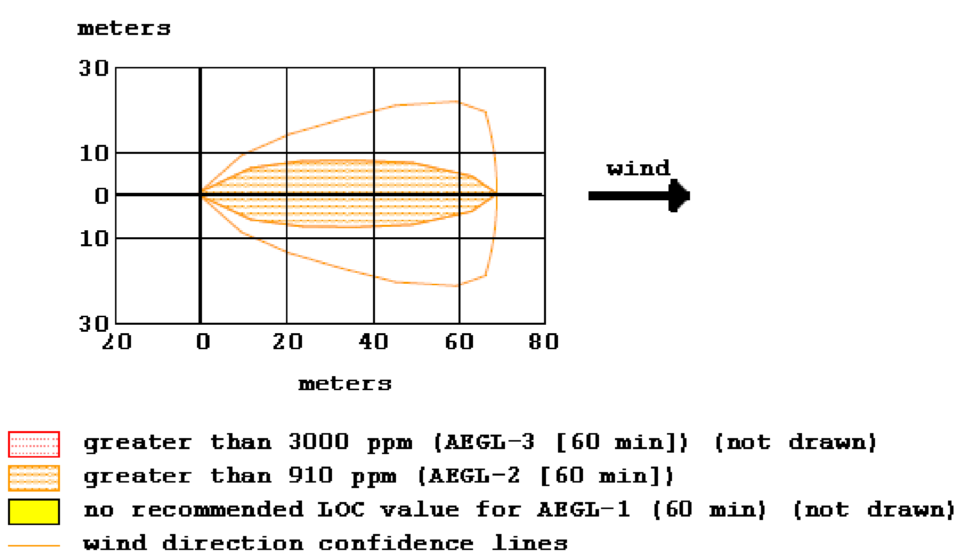


Figure 5.1a

Scenario -2: Direct Source 1.5 KL in 15 HDPE Cylinders of 100 L capacity – Blast Area of Vapour Cloud Explosion with spark or flame as ignition source.

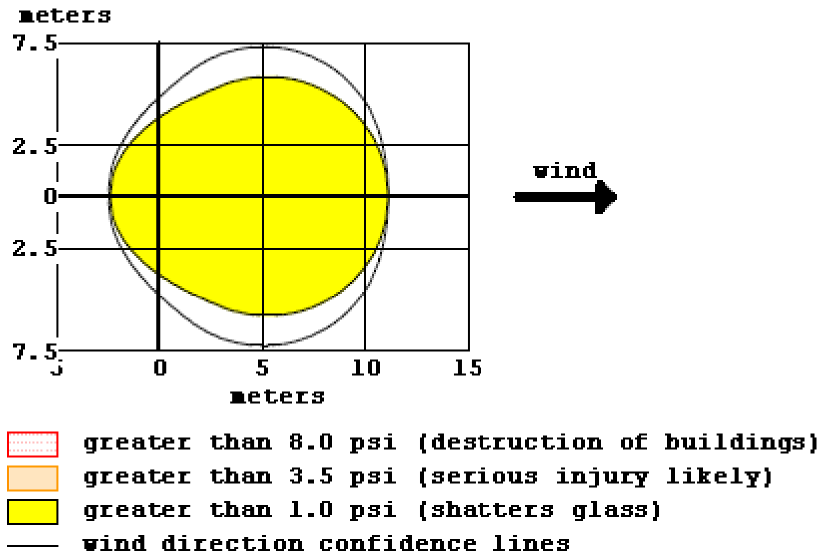


Figure 5.2a

Scenario -3: Direct Source 1.5 KL in 15 HDPE Cylinders of 100 L capacity –Thermal Radiation from fireball.

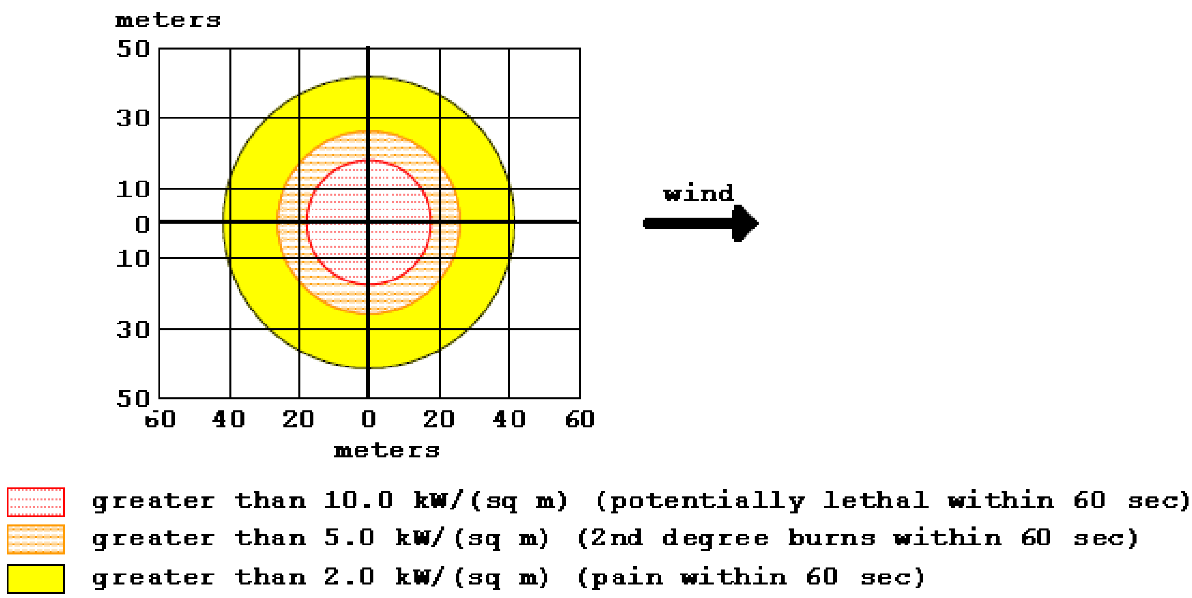


Figure 5.3a

Scenario -4: Direct Source 1.5 KL in 15 HDPE Cylinders of 100 L capacity –Thermal Radiation from jet fire.

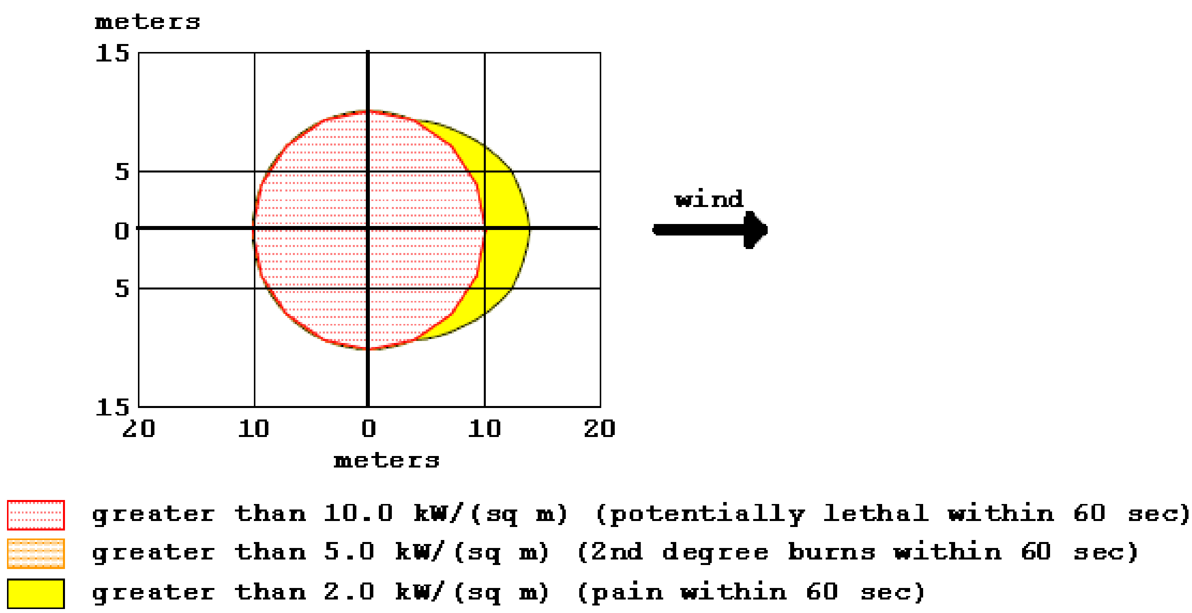


Figure 5.4a

6. Methylene Chloride

Scenario -1: Tank Source 1.2 KL in 4 Drums of 300 L capacity – Toxic Area of Vapour Cloud

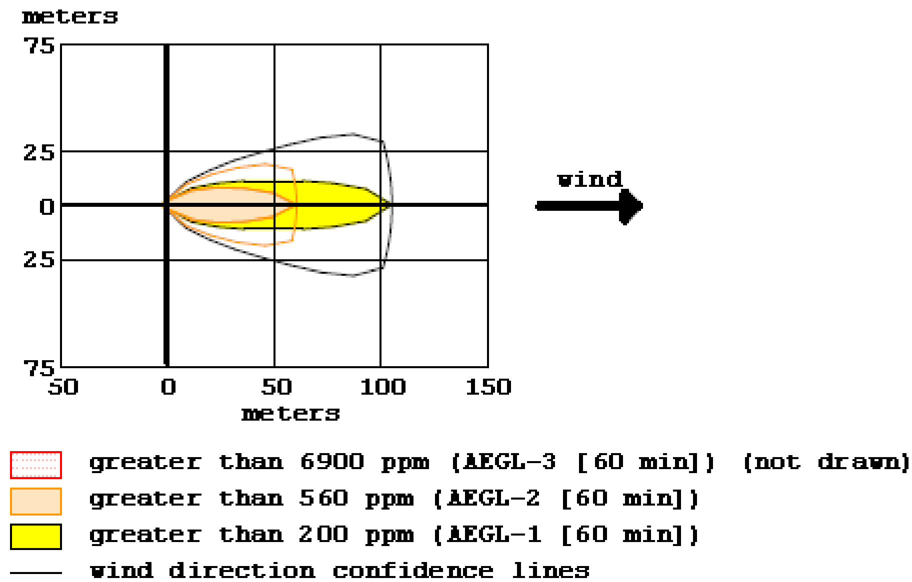


Figure 6.1a

Scenario -2: Tank Source 1.2 KL in 4 Drums of 300 L capacity – Thermal Radiation from fireball

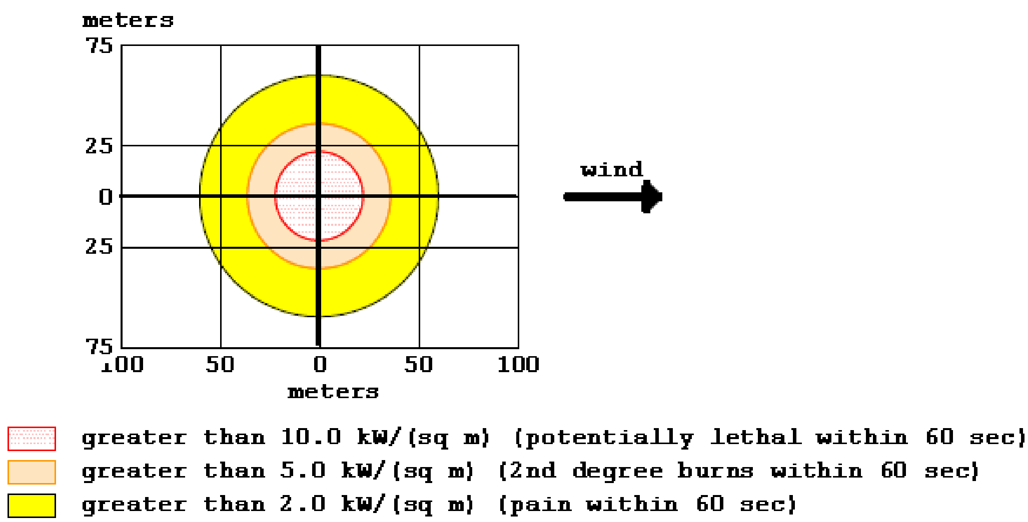
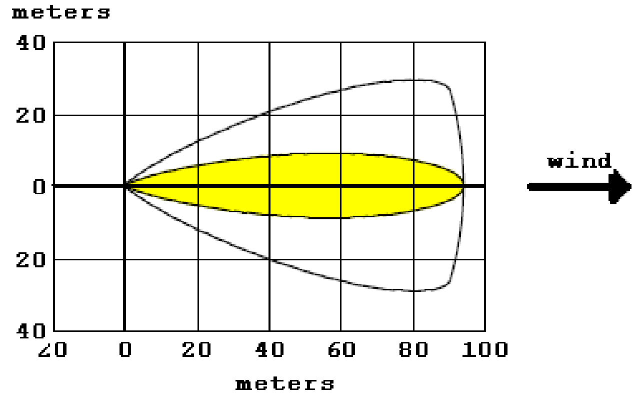


Figure 6.2a

7. Nitric Acid

Scenario -1: Evaporating Puddle, 40 L in 4 Glass Bottles of 10 L capacity – Toxic Area of Vapour Cloud

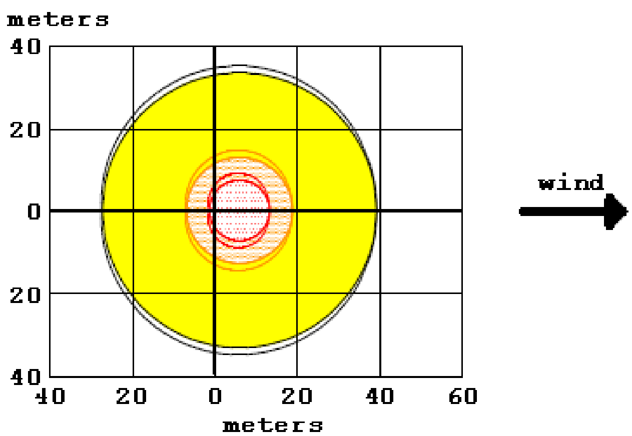


greater than 92 ppm (AEGL-3 [60 min]) (not drawn)
greater than 24 ppm (AEGL-2 [60 min]) (not drawn)
greater than 0.16 ppm (AEGL-1 [60 min])
wind direction confidence lines

Figure 7.1a

8. Propylene Oxide

Scenario -1: Tank Source, 1 KL in 20 Cylinders of 50 L capacity – Blast Area of Vapour Cloud Explosion with spark or flame as ignition source.



greater than 8.0 psi (destruction of buildings)
greater than 3.5 psi (serious injury likely)
greater than 1.0 psi (shatters glass)
wind direction confidence lines

Figure 8.1a

Scenario -2: Tank Source, 1 KL in 20 Cylinders of 50 L capacity – Thermal Radiation of Vapour Cloud Explosion with detonation as ignition source.

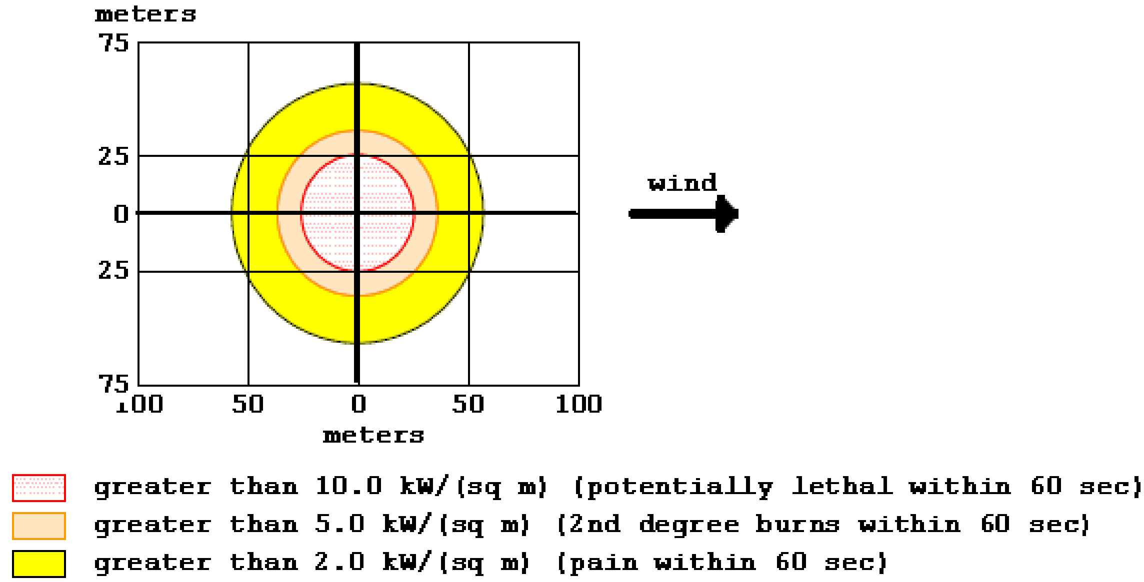


Figure 8.2a

9. Toluene

Scenario -1: Tank Source, 5 L in 6 MS Tank/Drums of 200 L capacity – Thermal radiation from pool fire.

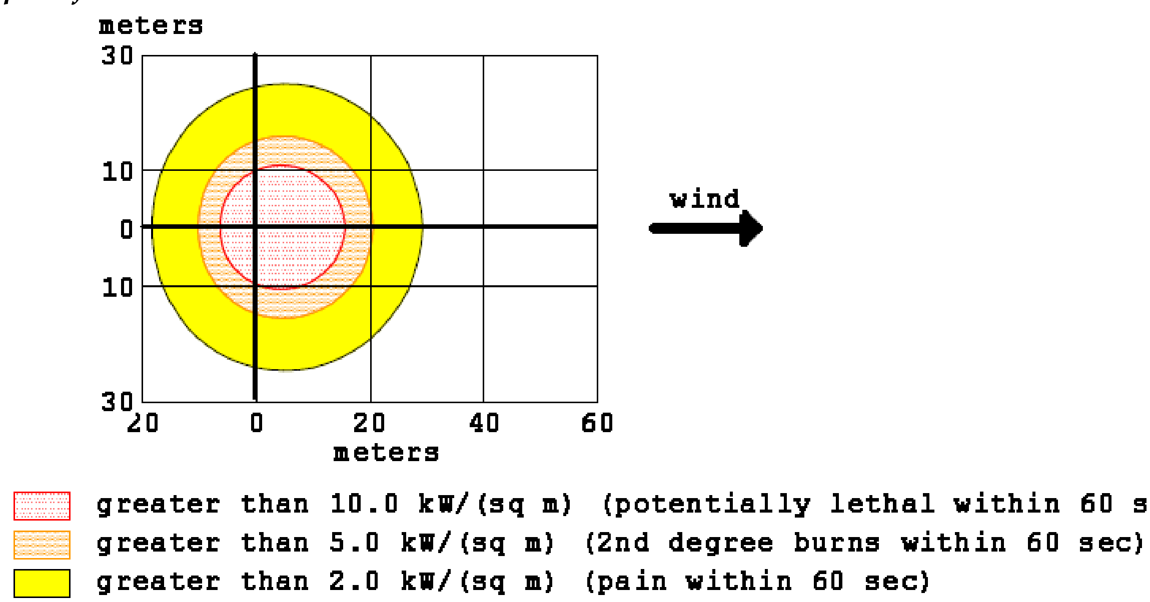


Figure 9.1a

Scenario -2: Tank Source, 5 L in 6 MS Tank/Drums of 200 L capacity – Thermal radiation from fireball.

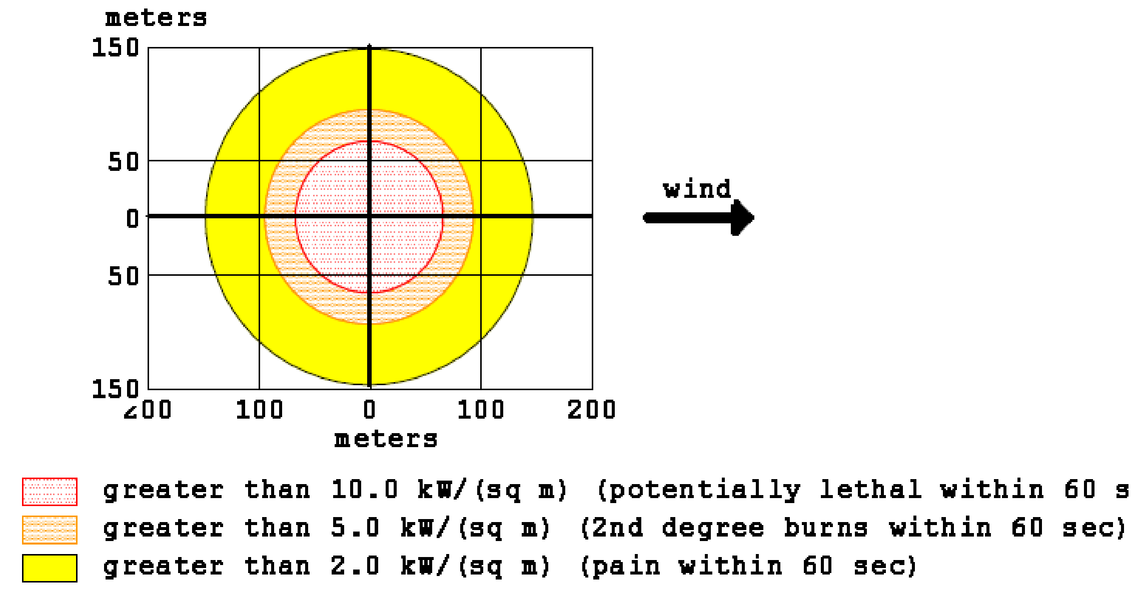

meters
150
50
0
50
150
200
100
0
100
200
meters
wind
greater than 10.0 kW/(sq m) (potentially lethal within 60 s
greater than 5.0 kW/(sq m) (2nd degree burns within 60 sec)
greater than 2.0 kW/(sq m) (pain within 60 sec)

Figure 9.2a