Quantitative Risk Assessment for Accidental Release of Ammonia from Fertilizer Process Plant

by

Izwan Shahmin Bin Mohd Husin

Dissertation submitted in partial fulfillment
of the requirements for the
BACHELOR OF ENGINEERING (Hons)
(CHEMICAL ENGINEERING)

JUNE 2004

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2004

1. Ammonia -- physiological effect
2. Ammonia -- toxicology
3. ChE -- thesis

CERTIFICATION OF APPROVAL

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A Project Dissertation submitted to the
Chemical Engineering Programme
Universiti Teknologi PETRONAS
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JUNE, 2004

Approved by,

....
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UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
June, 2004

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that original work contained herein have not been undertaken or done by unspecified sources of person.

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IZWAN SHAHMIN BIN MOHD HUSIN

ABSTRACT

Quantitative risk assessment is currently popular in the industrial sector over the past fifteen years. The application of Quantitative Risk Analysis for this study is to achieve several objectives that are, to determine the risk of an existing of an ammonia process plant, to ascertain the effects of accidental release of ammonia at different concentration and to propose risk reduction measure during design or operation stage. The subject of this study is PETRONAS Fertilizer Kedah (PFK) that has experienced on accidental release of ammonia. This study is focused on the toxicology and explosion aspects. The methodology for this study was literature survey and using SAFETI (Software for Assessment of Flammable, Explosive and Toxic Impacts) with real plant data. SAFETI is the main tool and has wide function for risk/consequence/risk and consequence studies. As for this study, the risk analysis was run through a combination of several data (plant layout and location, ammonia and methane properties, and atmospheric parameter) and manipulated with assists of SAFETI in achieving the objectives. After defining the boundaries of the system to be analyzed, this study identifies the hazards, risk level and suggest with mitigation action. Based on the frequency of accidental events, the model of consequence will be analyzed. From Societal Risk FN Curve, the case is lies in the alert region. Therefore, there is requirement of Quantitative Risk Analysis. The highest risk level is 1E-5 per year for 0.7 km distance from the hazard source and the lowest risk level is 1E-9 per year for 2.5 km distance from the hazard source. Generally, in dispersion graphs of ammonia, as the downwind distance increases the centerline concentration are decreases. For 2 inches and 3 inches leak diameter, there is unique trend where the centerline concentration increases back after a several period due to vaporization of spill. In probability of fatality graph of ammonia for four weather conditions, the probability of fatality decreases with the increasing downwind distance. Weather I is the worst case since the probability of fatality is the highest and reach the furthest distance than other weather condition. For explosion, the dispersion graph of methane show similar trends as ammonia dispersion graph. However the cloud radius only 16.3 m and the BLEVE radius is 29.81 m. Mitigation actions are proposed to lessen the risk. By inherent safety, the

mitigation actions are to use small amount of ammonia and methane, to produce and consume the substance in-situ, and to reduce the process pressure and temperature to less hazardous condition. By engineering design, the mitigation action is to locate a dike at 0.52 m from the hazard sources. By emergency response, the mitigation action is to develop an emergency plan on how fast people should react. A few recommendations can be made for this study which is, to study the alternative to use lower energy material, to analyze the possibility of unusual wind condition, and to study the toxicology of long term effects to the agriculture activities and products.

ACKNOWLEDGEMENT

Alhamdulillah praise to Allah the Al Mighty, this study is able to be completed. Nevertheless, no study could be written without information, help, and support from others.

The debt due to Associate Professor Ir. Abdul Aziz Omar for giving space in developing self study style. The simple way of his supervision put no stress on the work.

Thanks also to Pn. Risza Rusli for her guidance in comprehending SAFETI software that is very first time I am using it.

And thanks to PETRONAS Fertilizer (Kedah) Sdn Bhd staffs for entertaining me during my site visit to their plant.

Any errors or omissions are entirely my responsibility

Izwan Shahmin Mohd Husin

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

1.1 Background of Study

Ammonia is widely used in large quantity as raw material in fertilizer manufacturing. Ammonia is present in production, storage, transport and end use. The facilities for the fertilizer manufacturing plant are designed and constructed following the standards and practices. However, awareness must not be overlook on the probabilities of fatalities.

Ammonia is intensely hygroscopic and has a special affinity for damp tissue surfaces. Brief exposure of ammonia concentration particularly affects the upper part of the lung. At lower levels of concentration there is little doubt that people can acquire a tolerance towards ammonia so that a level which is intolerable, to some people may pass unnoticed by others who work habitually in such levels. On the other hand chronic residual disability and disease have been recorded after single high level exposure to ammonia (Crowl and Lovar et al, 2002).

In addition, there is interest to perform explosion analysis. In this case, flammable material that is methane, which passes through an ammonia reactor, may have the potential for a vapor cloud explosion. Study will focus on the accidental release of methane.

Explosion overpressure may be developed from explosions involving a boiling liquid expanding vapor explosion (BLEVE), vapor cloud explosion, chemical decomposition, or mechanical failure of the ammonia reactor (API et al, 1995).

Flixborough, Bhopal and Seveso are infamous for the most tragic accidents that have caused multiple death as well as damage to the environment and the property (V.C Marshall et al, 1987). In Malaysia, few similar cases occur such as Shell Bintulu synthesis plant explosion. These accidents represent a catastrophe in engineering that attract attention from new media and as unforgettable memories to the public. Therefore few issues constantly rose; safety of the project, safety design and operation, and mitigation action.

For above cases, a methodology of quantitative risk assessment will do in this study. According to Det Norske Veritas (DNV), "Quantitative Risk Assessment is the systematic use of available information to identify hazards and estimate the risk to individuals or population, property and the environment and the evaluation of risk" (DNV et al, 1998).

Quantitative risk assessment process is aim at analyzing numerically the probability of each risk and its consequence on project objectives, as well as the extent of overall project risk. This process is capable of determining the probability of achieving specific project objectives; to identify risks requiring the most attention by qualifying their relative contribution to project risk; to identify realistic and achievable cost, schedule or scope targets. For this quantitative risk assessment, this study undertaken to determine the risk of ammonia storage tank and the risk of ammonia reactor located in PETRONAS Fertilizer (Kedah) Sdn Bhd plant in Gurun.

1.2 Problem Statement

PETRONAS Fertlizer (Kedah) Sdn Bhd plant is an integrated petrochemical complex, which consists of ammonia, methanol, urea, and urea formaldehyde plant. The plant was constructed in 1995 by Mitsubishi Heavy Industries and Shapadu Corporation. The plant started commercial operations in October 1999.

On 20^{th} May 2003, nearly a year before this Quantitative Risk Assessment is done, an unusual wind conditions caused a small volume of ammonia to drift from the PETRONAS Fertilizer (Kedah) Sdn Bhd plant in Gurun, briefly exposing a number of students, teachers and members of public to the gas.

This 'brief exposure' caused about 80 people, including 55 students and 10 teachers from Sekolah Kebangsaan Guar Chempedak Satu, Sekolah Kebangsaan Husin Dol and Sekolah Menengah Langkasuka, 10 villagers, and 4 canteen workers to suffer difficulties in breathing, nausea and vomiting. According to a spokesman from the Guar Chempedak Health Clinic, the local clinic at the district, 55 people comprising 33 students and 22 adults had sought medical help after they were affected by the ammonia gas exposure.

A PETRONAS Fertilizer (Kedah) Sdn Bhd, spokesman said its operations were based on industry best practices and were fully in compliance with all legal requirements. The ammonia, which was released by the plant, would have dispersed in the atmosphere under normal conditions.

The national petroleum company said the controlled release of the gas was within the plant's design safety limit, and it was done to ease the pressure within the plant, associated with a start-up process following its planned shutdown. (Utusan Malaysia et al, 2003).

From the issue raised, a Quantitative Risk Assessment is being favored as final year research project in Universti Teknologi PETRONAS. This study will not be used as local political opposition to the plant; main purpose is for academic benefit in appreciating Quantitative Risk Assessment.

The significance of this study is it helps to minimize the capital expenditure and operating expenditure of the plant by reducing the release of the raw material and the fatalities through a risk reduction measure.

This study will determine the time for evacuation for nearby population in case of any accidental release of ammonia from the storage tank. This study will also assist in comprehending environment engineering aspects and the subset of project risk management that is quantitative risk assessment.

1.3 Objectives and Scope of Study

The primary objectives of this Quantitative Risk Assessment study are as follows:

i. To determine the risk of toxicity and explosion from a fertilizer process plant.

ii. To ascertain the effects of the accidental release of ammonia at different concentration during emergency shutdown of the plant.

iii. To propose the risk reduction measures during the design or/and operation stage to minimise the exposure of toxic gas.

The scope of the studies will be the toxicology of ammonia release in a process involved in the fertilizer process plant and the risk of explosion from highly hazardous process equipment. With the optimal objectives to be fulfil within the define scope this study is feasible to be completed within fourteen weeks.

CHAPTER 2

LITERATURE REVIEW

2.1 Hazard Identification

The hazard identification process is the most important component of the Quantitative Risk Assessment, as the hazard identification and failure cases definition has a major impact on the type and the accuracy of risk result produce.

The objective of the hazard identification process is to focus on the type and nature of hazards which may be present and require further evaluation. Hazard identification provides a list failures and failure combination.

In this study the focus are variation of small leak diameter and rupture. The selected cases have been developed based similar scenario identified by J.R Taylor which mainly related to major hazard that occur for process plant, pipelines and transport.

Ammonia is a chemical that is difficult to ignite in open air as its flame is unstable and cannot propagate itself. Though explosions can occur in flammable mixtures in vessels or enclosed spaces, ignition is so difficult and the possibility of an explosion in the open air is generally discounted. However with interest of methane at ammonia reactor explosion hazard will also be in consideration.

2.2 Major Accidents in a Process Plant

Three major hazards with large consequences in a process plant are fire, explosions, and major toxic release (J.R Taylor et al, 1994). Nowadays, Health, Safety and Environment issue is important in both developed countries and developing countries. Execution of strict action on continuing pollution and deliberate dumping is common practice in the world. However, most of accidents occur accidentally not with intention and it increases year by year.

Developments over the last 20 to 30 years have led to a steady fall in the number of fatalities on average. However, at the same time there has been a continuing increase in the size of individual toxic release accident, and in the average losses from chemical plant and petrochemical plants (W.G Garrison et al, 1989).

2.2.1 Gas Release

The behaviour of flammable gas and vapours release is different from release of liquids below their boiling point. The gas spreads as a jet, with air moved into the jet by the turbulence of the gas flow. Once the jet is expended, the gas will disperse with the wind. For natural gas, ammonia and similar light gases, the gas tend to rise and spread with the wind turbulence. While for heavier hydrocarbons the mixture of air and gas will be heavier than air, therefore the clouds will spread as flat pancake on the ground (J.R. Taylor et al, 1994).

As an example, there was a release of ammonia due to collapse of large cryogenic storage tank, at Jonava, Lithuania in 1990. Over pressuring, possibly caused by the rollover, that is rapid mixing of hot and cold layer of liquefied gas caused the tank to collapse. The vapor cloud destroyed a considerable part of ammonia plant and as well as causing seven death.

2.2.2 Toxic Gas Release

There are two types of category of toxic gases that is light gases and heavy gases. Light gas such as ammonia spread initially upward, later diffusing neutrally to the atmosphere. These rarely present serious threat to life unless they occur in a narrow valley, between buildings, or indoors.

Heavy gases and mixture tends to spread horizontally, forming a dense low lying cloud of gas. This may travel with the wind across a populated area or collect in narrow valleys, so that the hazard us much greater. The cloud will often disperse, but in some few cases will exist as a cloud in a valley for a longer period, if the weather is very still.

2.2.3 Toxic Liquid Release

Toxic liquid release can arise at pipeline in plant or during transport. Almost always they present an environmental threat, for example to water courses, agricultural ground, dwelling areas and to ground water resources. Often too such release represents a threat from evaporators which can penetrate houses, requiring decontamination of the affected soil.

2.2.4 Internal Equipment Explosions

Chemical plant equipment can explode as a result of runaway reactions, or as result of ingress of air to the equipment, followed by burning. Such explosions can be very violent, and affect persons outside the plant. As an example, explosion of in a dinitrotoluene transfer line occurred at Institute West Virginia in 1972 as a result of overheating of a steam jacket and subsequent decomposition. 300 feet of 2 inch pipeline were affected and caused severe damage to surrounding equipment (Baetman, Small, and Syder et al, 1973).

2.2.5 Gas explosion

Flammable gas clouds, and gas in buildings, can explode violently at certain condition. Inside the building the explosion will occur when there is gas be mixed with air in flammable mixture. Outdoor is much more complex requirement, the important is for petroleum gases, is that the amount of gas in the cloud must be large.

Example of gas explosion is at Flixborough, England in 1974, in which some 60 tonnes of hexane exploded, demolishing the plant and killed 26 people.

2.3 Toxicology

2.3.1 How Toxicant Enter the Biological Organism

For higher order organism (human/animal) the path of the chemical agent through the body is well defined. When the toxicants enter the bloodstream it will be eliminated or transport to the target organ. The damage is exerted on the target organ. A common misunderstanding is the most concentrated part with the toxicant will be damaged. For instance Lead is most concentrated in the bone structure, but the damage occurs in other body part.

Table 2-1 summarizes the entry routes for the toxicant and method to control.

ENTRY ROUTE	ENTRY ORGAN	METHOD TO CONTROL
Ingestion	Mouth or stomach	Enforcement of rule on eating, drinking and smoking
Inhalation	Mouth or nose	Ventilation, respirators, hoods and other PPE
Injection	Cuts in skins	Proper protective clothing (PPE)
Dermal absorption	Skin	Proper protective clothing (PPE)

Table 2-1: Entry route and organ, and method to control

2.3.2 How Toxicant are Eliminated from Biological Organism

Toxicants are eliminated or rendered inactive by following routes.

- Excretion: through the kidneys, liver, lungs, or other organs
- Detoxification: by changing the chemical into something less harmful by biotransformation
- Storage: in the fatty tissue

Kidney is the dominant mean of excretion in human body. It extracts the toxicants and excreted it in the urine. The kidney usually counters the toxicants that enter through ingestion, inhalation, injection and dermal absorption.

Toxicants that enter the body through digestive tract are excreted by the liver. Chemical compounds with molecular weight greater than about 300 are excreted by liver into the bile. The liver is the dominant organ in detoxification process. The detoxification occurs by biotransformation where the chemical agents are transforming to harmless or less harmless substances.

The lung are also means for elimination of the substance particularly those that are volatile. As an example, the substances that are excreted by this route are alcohol and chloroform.

The final mechanism is by storage. This process involves depositing the chemical agent mostly in the fatty area of the organism and also in the bones, blood, liver and kidney. However this may cause future problem if the food supply reduced and the metabolism increase where the fatty deposits are metabolized.

2.3.3 Effect of Toxicants on Biological Organism

Here are several responses to toxicants as below.

Effects that are irreversible

- Carcinogen causes cancer
- Mutagen causes chromosome damage
- Reproductive hazard cause the damage to reproductive system
- Teratogen causes birth defects

Effect that may or may not be reversible

- Dermatotoxic affects skin
- Hemotoxic affects the blood
- Hepatoxic affects the liver
- Nephrotoxic affects the kidneys
- Neurotoxic affects nervous system
- Pulmonotoxic affects lungs

2.3.4 Toxicological Studies

The main objective of this study is to quantify the effects of the suspect toxicants on a target mechanism. Once the effects of a suspect agent has been quantified, appropriate procedure are establish to ensure the agent is handled properly.

The followings items must be identified before undertaking any toxicology studies.

- The toxicant
- The target or test organism
- The effect or response to be monitored
- The dose range
- The period of test

The toxicant must be identified with respect to its chemical composition and its physical state. This is because different physical state may enter the body at preferential routes and it will require different toxicology studies.

2.4 Explosions

Explosions depend on large number of parameter as stated below.

- Ambient temperature
- Ambient pressure
- Composition of explosive material

- Physical properties of explosive material
- Nature of ignition source; type, energy, and duration
- Geometry of surroundings: confined or unconfined
- Amount of combustible material
- Turbulence of combustible material
- Time before ignition
- Rate at which combustible material is released

There are lots of approaches have been taken to characterize the explosion behavior such as theoretical, empirical and semi empirical studies but still not completely understood. An explosion occurs when there a rapid release of energy. The energy then dissipated by various way, including formation of pressure wave, projectiles, thermal radiation, and acoustic energy. The damage from an explosion is caused by the dissipating energy.

For explosion that occurs in the gas. The energy will cause the gas to expand rapidly outward from the blast source. The pressure wave contains energy, which result in damage to surroundings. For chemical plant much of the damage explosions are due to the pressure wave. Therefore dynamic of the pressure wave is the important part in understanding of explosion.

A pressure wave propagating in the air is called a blast wave because the pressure wave is followed by a strong wind. A shock wave is expected from highly explosive materials, such as TNT, but it can also occur from the sudden rupture of a pressure vessel. The maximum pressure over ambient pressure is called the peak overpressure.

2.5 Quantitative Risk Assessment

Quantitative Risk Assessment is a method that identifies where operations, engineering, or management systems can be modified to reduce risk. The complexity of Quantitative Risk Assessment depends on the objectives of the study and the available information. Maximum benefits results when Quantitative Risk Assessment is used at the beginning of a project and is maintained throughout the facility life cycle.

The Quantitative Risk Assessment method is designed to provide management with tool to help in evaluating the overall risk of a process. Quantitative Risk Assessment is used to evaluate potential risks when qualitative methods cannot provide an adequate understanding of the risks. Quantitative Risk Assessment is especially effective for evaluating alternative risk reduction strategies.

Major steps of a Quantitative Risk Assessment include

1. defining the potential event sequences and potential incidents
2. evaluating the incident consequences
3. estimating the potential incident frequencies
4. estimating the incident impacts on people, environment, and property, and
5. estimating the risk by combining the impacts and frequencies, recording the risk

In general, Quantitative Risk Assessment is a relatively complex procedure that requires expertise and a substantial commitment of resources and time.

During 1980s there was more or less continuing discussion concerning the use of quantitative risk assessment, in which professional variously supported its use as a tool for plant assessment, denied that could be useful, or recommended restricted use within design groups (Lans and Bjodarl et al, 1983).

The summary of the argument against Quantitative Risk Assessment as follows.

- It is costly; however this argument is not strong since improvement in techniques has reduced quantification cost to a small fraction of safety assessment cost.
- The method used involved great deals of uncertainty
- The methods encourage a rather mechanical approach to plant assessment
- The results can be understood by a layman in principle, but extremely easy to misinterpret.

There is a doubt too, many professional have been afraid that risk analysis would be used in local political opposition to the plants. Risk analyses which are published can undoubtedly be used for such purposes, since they generally require quite detailed descriptions of the accident which could happen. Quantitative Risk Assessment moreover require that full scope of potential accident, be described, including the largest.

The argument of use of Quantitative Risk Assessment has been:

- The quality of analysis and of resulting design is improved by use of quantitative analysis.
- The process of assessment is made much easier when quantitative analysis is used.
- Assessment of different plants can be made on a uniform basis. Authority approvals can be checked to avoid setting precedent which will be unworkable elsewhere.

The approach by Quantitative Risk Assessment has been found to be useful in many practical projects. Conclusion can be deduced are as follows.

- For design purposes the main effort should always be placed on qualitative risk analysis. If engineering effort or time is limited, it should be used primarily in hazard identification and risk reduction.
- For design purposes quantitative assessment is very useful for comparing design alternatives, but for this purpose it can generally take a quite

limited form. For difficult and expensive design decision, quantitative risk assessment an extremely useful tool.

- For authority approval purposes qualitative risk assessment is necessary and should ideally be performed by plant employees.
- Probability calculation for emergency planning is useful, but not essential. Consequence calculation is generally essential.
- Process plant risk analysis for insurance purpose is generally meaningless, unless it is performed quantitatively.
- In all cases, the primary effort should be on good hazard identification and risk reduction.

2.6 Failure Data for a Storage Tanks

Using a generic data for risk analysis is always dangerous. There exist of present problem in the actual is more poorly than a general industrial average. It is in practice rare to obtain a significantly pessimistic calculation.

For small storage tanks, almost the only failures are leaks and blockage. Bursting, as a failure mode, is generally caused by outside event such as over pressuring, crashes, or fires. Cover filing with wrong substance and foundation or support collapse are also possibilities.

The probability of leaks is a function of tank age, substance stored and how big a corrosion margin was applied. A minimum value if 1 per 10^6 hours is reasonable (J.R. Taylor et al, 1994), it being hard to come under this with ordinary mild tanks, unless there is frequent inspection.

The leak size will normally be at most few square millimeters initially.

There are several things which can occur to tanks as a result of failures and errors in pumping procedure. Tanks can be over pressurized because of fully filled with liquid with no overflow or expansion possibility. Similarly, they can be sucked in, if that is drained while vent lines are closed or blocked. Vent line are sometimes closed to keep out rain, or to prevent ingress of dirt, during repairs or installation, and this has led to the destruction of many tanks by over or under pressuring. Blockage with ice or birds nest has also been a problem. Even the pressure drop due to flow down through a drain pipe can cause a thin walled tank to be sucked in. Vent valves are often fitted or vacuum safety valves.

Large storage tanks have many and vary design of which the principal ones are cone roofed tanks and floating roofed tanks. Corrosion is a possibility, lead to a need for periodic inspection. Failure rates depend very much on the material stored.

Apart from various valves, the most likely causes of leaks is either overfilling and corrosion attacks around welds. A leak probability of 1 per 10^6 hours (J. R. Taylor et al, 1994) for a few square millimeters leak, and 0.1 per 10^6 hour for a large leak.

Catastrophic failures generally arise from overfilling, as a result of operator error, administrative error, or instrument failure and internal fires or explosions in oil tanks. The reliability of inerting systems used in hydrocarbon storage tanks to prevent explosive atmosphere arising requires a special study in itself. A typical pattern involves overfilling or over pressuring, which then result in a release from a weak, improperly welded, or corroded tank steam.

Floating roofs tanks have some special failures modes, in some designs it was possible for the floating roof to jam and then to be damaged as its full weight was unevenly supported. Seals against air ingress can also fail. A special failure mode is the possibility of the roof sinking, if sufficient blockage of drain pipe.

An unusual but relevant failure mode for large tanks in that it can float and break free from pipe works in floods or if the area within bund walls or berms becomes flooded.

CHAPTER 3
METHODOLOGY/PROJECT WORK

Figure 3.1 below represent the quantitative risk assessment methodology in the study. This methodology is based on commonly used methodologies for the application on many different hazardous activities but has been modified and simplified for the use of the study.

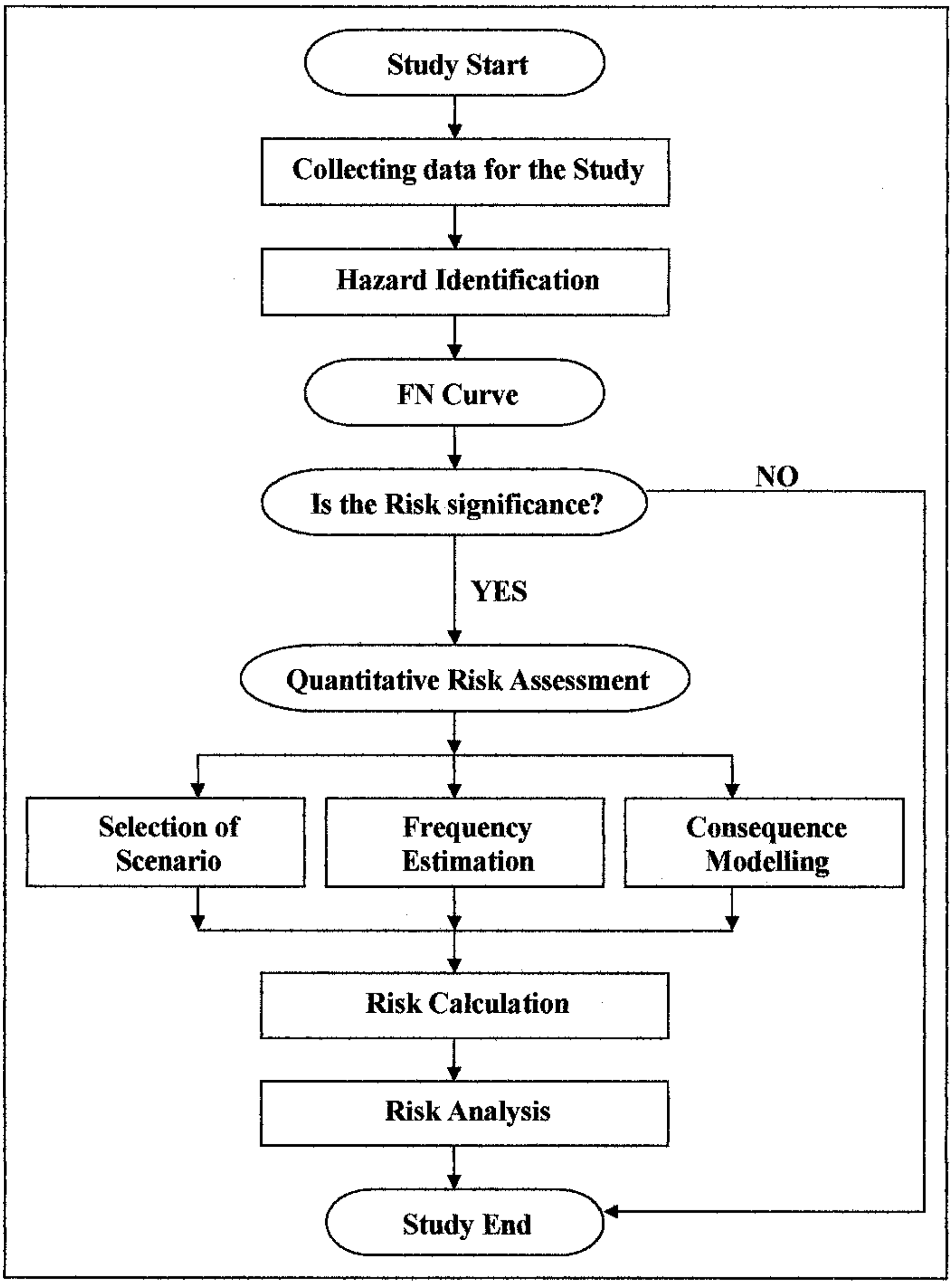

Figure 3-1: Quantitative Risk Assessment Flowchart

3.1 Collecting Data for the Study

In order to able to undertake a through analysis, it is important that necessary data be available, preferably right after the start of the project. In this study the data available on week 12.

The necessary basic data for this study as follows

- A plot plan or layout of the plant, together with a map of the population areas which could be threatened in an accident.
- A description of process condition, such as the temperature and pressure of the inventory
- Physical and toxicity data for the substance involve that is ammonia and methane
- The atmospheric parameter location of the plant

In the first stage of the Quantitative Risk Assessment, the study is to define the system of the study to be analyzed. System definition is an essential part in the Quantitative Risk Assessment that it would enable and distinguish of what should be and should not be included in the study.

This study based on existing storage tank of ammonia and ammonia reactor located at PETRONAS Fertilizer (Kedah) Sdn Bhd plant in Gurun. The ammonia storage tank is 50 m^3. The temperature and pressure of the inventory are 20 ^oC and 15 barg, which the ammonia exist as pressurized liquid. While ammonia reactor size is 37.2 m height and 2.42 m diameter, with operating pressure and temperature at 152 barg and 80 ^oC. The composition of methane is 0.05 mole%, with feed at 65 mT/hr.

3.1.1 Plant Layout and Location

PETRONAS Fertilizer (Kedah) Sdn Bhd plant is an integrated petrochemical complex, which consists of ammonia, methanol, urea, urea formaldehyde and bagging plant in Gurun and the Urea Export Terminal in Butterworth, Penang. The plant was constructed in 1995. Mitsubishi Heavy Industries and Shapadu were the main contractors. The plant started commercial operations in October 1999 with daily production capacity of 1,125 MT of ammonia, 200 MT of methanol, 2000 MT of granular urea and 17 MT of urea formaldehyde. About 50 million standard cubic feet of Natural Gas (NG) is used as the raw material for production.

The plant is supported by steam generation and distribution system, demineralization water system, cooling water system, instrument air system, nitrogen production unit and waste water treatment. The process technologies for the ammonia, methanol and urea formaldehyde are licensed by Haldor Topsoe of Denmark while those for urea synthesis and granulation are licensed by Snamprogetti, Italy and Hydro Agri, Belgium respectively.

Figure 3-2 shows the layout of the plant with the respective building. Figure 3-3 shows the location of the plant with the nearby residence area. The interest population distribution of nearby residence area is as Table 3-1.

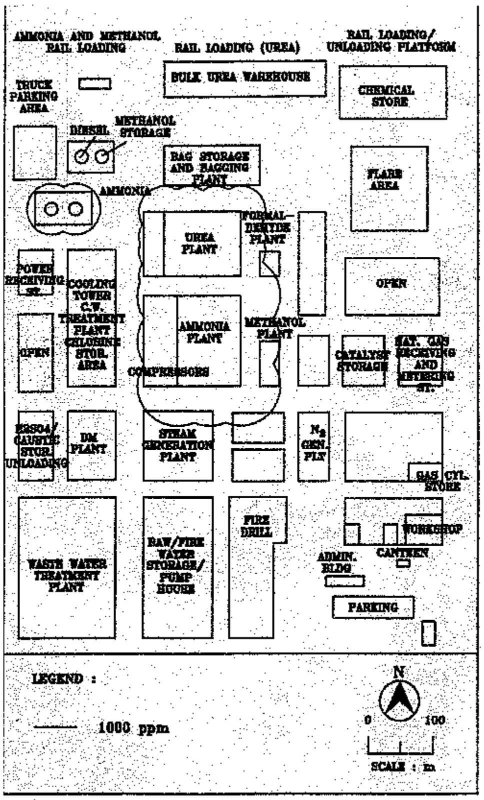

Figure 3-2: PF(K)SB Plant Layout

LOCATION	DIRECTION & DISTANCE (km)	LOCATION	POPULATION
Kg Siam	NNE, 6.5	Offsite	160
At North East	NE, 9.1	Offsite	384
At East	E, 9.1	Offsite	3467
Kg Batu Lima	ESE, 10.4	Offsite	324
Kg Batu Tiga	SE, 9.1	Offsite	625
Kg Batu Dua	S, 6.5	Offsite	271
Kg Chengal and Gurun	SW, 11.7	Offsite	2349
Kg Guar Jumaat	WSW, 7.8	Offsite	248
At West-South West	WSW, 9.1	Offsite	413
Kg Guar Nenas	W, 9.1	Offsite	100
Nearby Industry I	N, NNE, NE, ENE, 1.3	Offsite	152
Nearby Industry II	W, WNW, 1.3	Offsite	38
Ammonia plant	-	Onsite	5
Urea plant	-	Onsite	5
Utility	-	Onsite	4
Central Control Building	-	Onsite	20
Administration Building	-	Onsite	150

Table 3-1: Interest Population Distribution nearby PF(K)SB Plant at Gurun

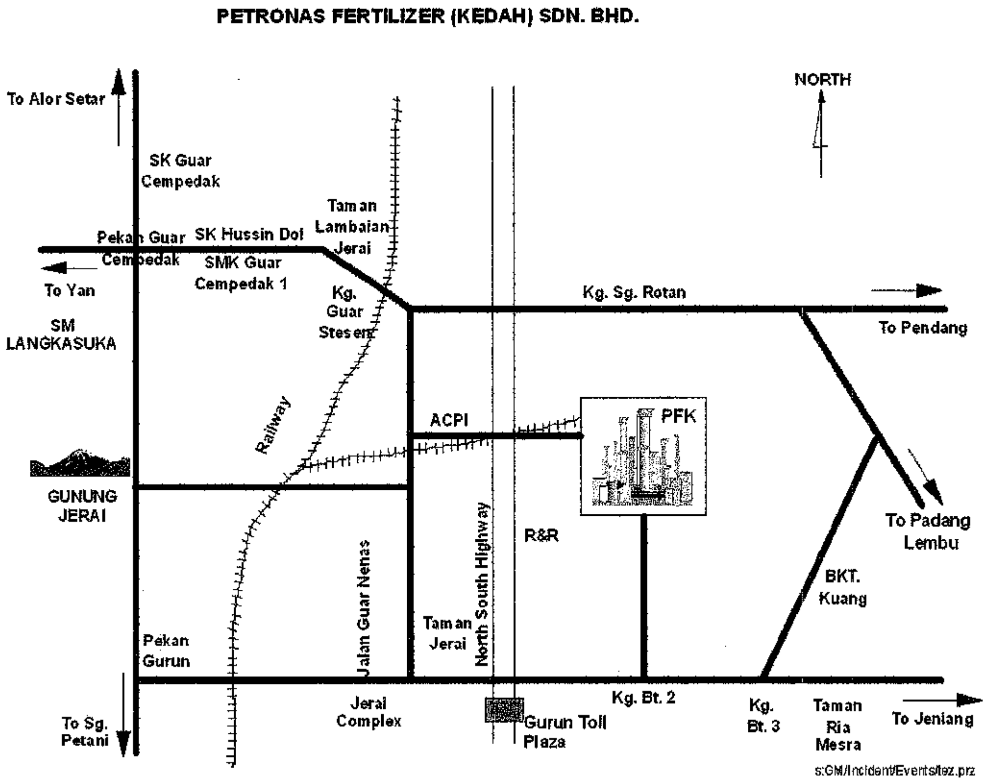

Figure 3-3: Location of PF(K)SB plant with nearby residence

3.1.2 Toxicology Assessment for Ammonia

Ammonia is a colorless gas with a sharp, penetrating, intensely irritating odor and a colorless liquid under pressure. It is not considered a flammable gas but a large and intense energy source may cause ignition and/or explosion. Ammonia gas can decompose at high temperatures forming very flammable hydrogen and toxic nitrogen dioxide. It is a compressed gas and a confined space explosion and toxicity hazard. Ammonia gas is a corrosive gas and may be fatal if inhaled. Ammonia gas causes lung injury-effects may be delayed. The liquefied gas can cause frostbite and corrosive injury to eyes and skin.

The primary use of ammonia gas is in the fertilizer industry, as a direct application fertilizer and as a building block for the manufacture of nitrogen fertilizers, such as urea, ammonium nitrate, ammonium sulfate, ammonium phosphate and nitrogen fertilizer solutions. It is also used in production of nitric acid and in the fibres and plastics industry for the production of caprolactam, acrylonitrile, hexamethylenediamine, toluene 2, 4-isocyanate and melamine.

Table 3-2 summarizes the general properties of ammonia.

PROPERTIES	AMMONIA	METHANE
Critical temperature	132.5°C	-82.6°C
Critical pressure	112.8bar	45.99bar
Normal boiling point	-33.43°C	-161.5°C
Melting point	-77.74°C	-182.5°C
Molecular weight	17.3	16.04

Table 3-2: Ammonia and Methane properties

3.1.3 Explosion Assessment for Methane

Methane is a simple hydrocarbon and very light fuel gas, a substance consisting of carbon and hydrogen. Natural gas is gaseous at any temperature over -161 °C, therefore methane is at gas phase at atmospheric condition. Natural gas boils at atmospheric pressure and a temperature of -161 C. Because of this property, natural gas is usually transmitted and stored as a gas,

In its pure state, natural gas is odorless, colorless, and tasteless. For safety reasons, an odorant called Mercaptan is added, so that any leak can be easily detected because of the typical smell.

Natural gas does not contain any toxic component; therefore there is no health hazard in handling of the fuel. Heavy concentrations, however, can cause drowsiness and eventual suffocation. The properties of methane are as in Table 3-2.

3.1.4 Atmospheric Parameter

The characteristic features of the climate of Kedah are uniform temperature, high humidity and copious rainfall and they arise mainly from the maritime exposure of the country. Winds are generally light. Situated at the equatorial doldrums area, it is extremely rare to have a full day with completely clear sky even in periods of severe drought. The climate in Kedah is tropical (sunny and humid all year round) with temperatures ranging from 21°C to 31°C. The are four variation of the wind speed in Alor Setar, Kedah that are 1.0m/s, 2.45m/s, 4.4m/s and 6.7m/s.The condition is stable where there are only moderate clouds and light or moderate wind. Table 3-3 and 3-4 are the atmospheric parameters and annual percentage frequency of wind directions for Alor Setar, Kedah. This atmospheric parameter is used for both ammonia and methane assessment.

ATMOSPHERIC PARAMETERS	
Atmospheric Temperature	30°C
Relative Humidity	0.7524
Surface Temperature for Dispersion Calculation	30°C
Surface Temperature for Pool Calculation	30°C

Table 3-3: Atmospheric Parameters used for Calculation

Weather	Speed m/s	N	NE	E	SE	S	SW	E	NW	CALM	TOTAL
-	<1.0	-	-	-	-	-	-	-	-	26.9	26.9
I	1.0	10.2	11.4	7.1	3.2	2.2	2.2	4.1	3.2	-	43.6
II	2.45	3.1	5.0	3.2	1.0	1.3	1.9	3.9	1.5	-	20.9
III	4.4	0.5	2.7	0.7	0.2	0.3	1.1	1	0.3	-	7.4
IV	6.7	0	0.2	0	0	0	0.1	0.1	0	-	0.4
-	9.35	0	0	0	0	0	0	0	0	-	0.2
-	>9.35	0	0	0	0	0	0	0	0	-	0

Table 3-4: Annual Percentage frequency of Wind Direction and Speed for Alor Setar, Kedah

3.2 Societal Risk FN Curve

Societal Risk provides a way to quantify actual risk to a given population near to the source of the hazard. A common measure of societal risk is the FN curve. The FN curve produce by assistance of SAFETI. The result will give the likelihood or frequency (F) of fatal events occurring, causing a certain number of fatalities (N), within a given period of time in one year.

The societal risk F-N curve is a plot of cumulative frequency versus consequences. The scale of the FN curve is in log-log plot because the frequency and number of fatalities range over several orders of magnitude.

Figure 3-4 displays the FN curve for this study.

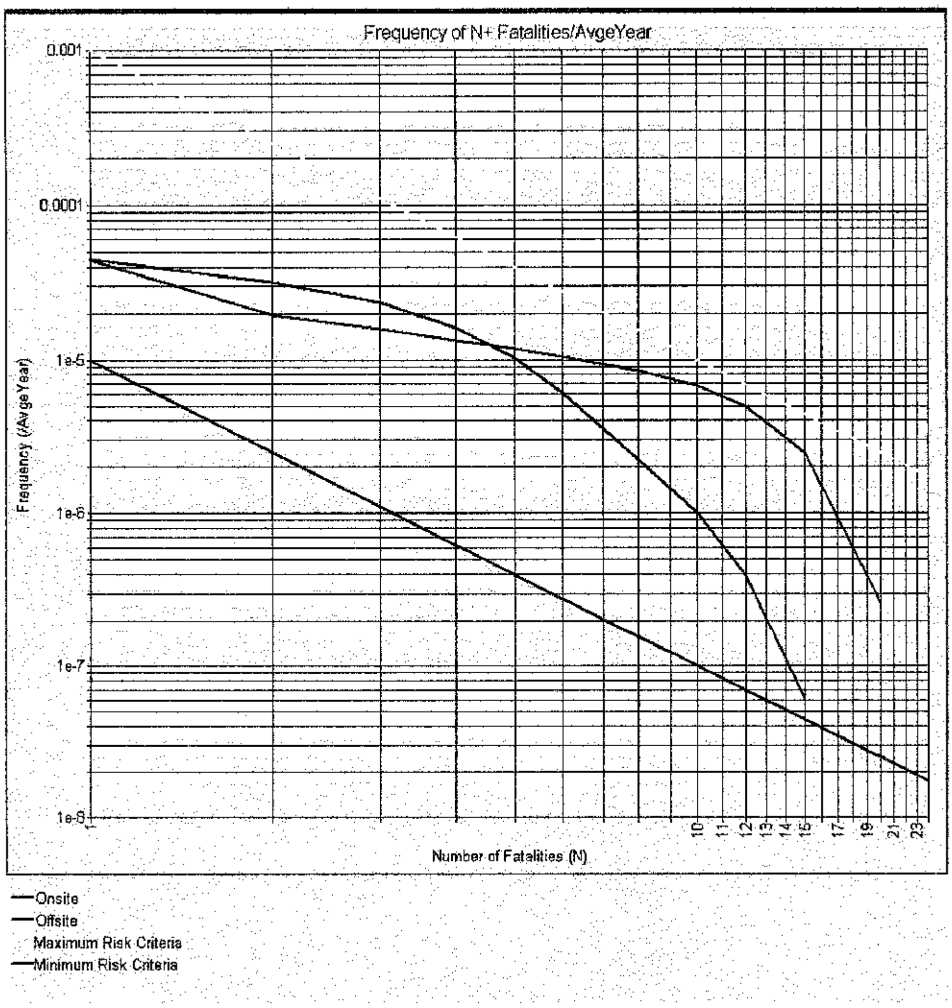

Figure 3-4: Societal Risk FN Curve

From Figure 3-4 it is clearly shows that execution of Quantitative Risk Assessment is necessary since for both cases, onsite and offsite, the lines lie between minimum unacceptable lines (yellow) and maximum acceptable lines (red), the blue and green line indicate onsite and offsite respectively. The onsite and offsite lines generally show the frequency decreasing for an increasing number of fatalities, which mean that, one person will die with frequency as high as 4.56E-5 years and as low as 2.62E-7 for 20 persons onsite and 6.18E-8 for 15 person offsite.

The minimum unacceptable line lies on the (1, 1E-2) and (10, 1E-5). The maximum acceptable line lies on the (1, 1E-5) and (10, 1E-7). The default data is base on default value of SAFETI software. For validation of the SAFETI default value, there is comparison exercise for those values with literature value.

In 1998 a team of analyst was asked to propose suitable acceptance criteria for risk acceptance (J.R. Taylor et al, 1989). As a result their value for minimum unacceptable line lies on (1, 1E-2) and (100, 1E-8) where it is quite similar with different of the slope value with SAFETI is 0.09E-4, that is 0.89% different. For maximum acceptable line it lies on (1, 1E-4) and (1000, 1E-8). For the maximum acceptable line case, SAFETI value is lower than the literature value, where the area for alert region will be larger for SAFETI value with slope value different of 1E-7 that is 11 times of the literature value. Therefore, SAFETI emphasize the risk, where the need of Quantitative Risk Assessment lies in larger domain.

3.3 Scenarios Selection

It is necessary to define the size of each release. There are some standardized sizes defined in terms of small sizes which are convenient to use. For this study the small leak and rupture are defines as below. The size for small, medium and large are 1 inch, 2 inches and 3 inches respectively, and the rupture size are full diameter that is larger than 3 inches (J.R. Taylor et al, 1994). Then the scenarios were run at different wind directions and for both offsite and onsite population as in Figure 3-5.

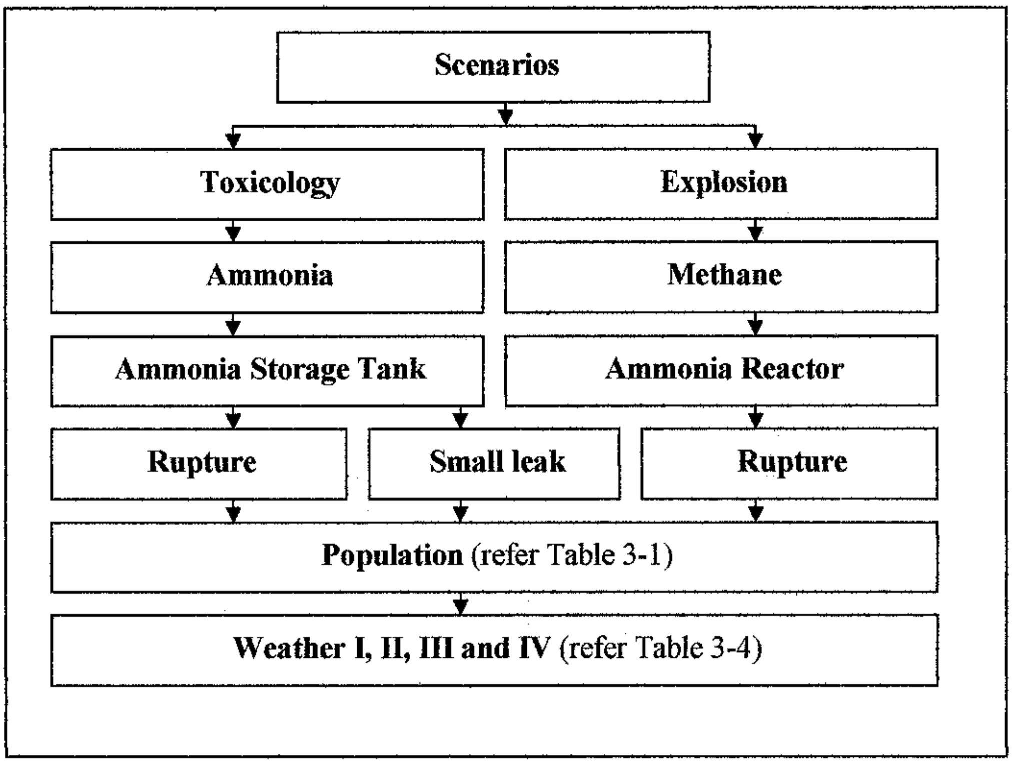

Figure 3-5: Overall scenario

3.4 Frequency Estimation

Subsequent to the hazard identification, the probability of each accidental event is then estimated. Information from historical data compiled over a number of years is commonly used. In this Quantitative Risk Assessment study historical data have been taken from J.R Taylor to estimate the frequency of the scenario.

The limitation in this data is it only relates to failure frequencies of equipment and does not include probabilities of human error causing accident. In reality, the human contribution on accidental events have become more important in recent times since equipment failure rates have been decreased parallel to improvement of equipment design. The failure rate used for this rupture and small leak are 3 x 10^{-6} per annum and 2.5 x 10^{-3} per annum respectively (J.R. Taylor et al, 1994).

3.5 Consequences Modelling

Consequence modelling determines the physical effects of hazards and the extent of the damage, which may ensure. There are many software models available for calculation of the consequences from an incident.

For this Quantitative Risk Assessment study a software package SAFETI (Software for the Assessment of Flammable Explosion and Toxic Impacts) developed by Det Norske Veritas has been used to model the resulting behavior of the released ammonia and the extent of damage expressed in terms of distance to certain effects level.

SAFETI is also used to determine the risk result in individual risk contours with description of the geographical distribution of annual risk of death to an individual in the nearby residence.

3.6 Risk Calculation

In this study, the calculated risk is reported in the form individual risk per year and the result are presented to levels corresponding to the guidelines for individual public in Malaysia. The guidelines stipulated that for residential area, a risk level of 1 x 10^{-6} per year is considered acceptable (Balasubramaniam et al, 2001).

CHAPTER 4

RESULTS AND DISCUSSION

In this section, the overall risk results of the accidental release of ammonia from storage and explosion possibility of methane of ammonia reactor in PETRONAS Fertilizer (Kedah) Sdn Bhd plant as discussed.

To present a systematic and resourceful report for this study, the results and discussion have been structured into several sections as follows:

Section 1: Risk Assessment for Ammonia Toxicology

Section 2: Toxicology Assessment for Ammonia

Section 3: Explosion Assessment for Methane

Section 4: Mitigation action

4.1 Risk Assessment for Ammonia Toxicology

Individual risk can be thought as the risk to person at a specific location. The risk is measured as a probability of fatality in a year. Figure 4-1 displays the risk level with the risk contour in the plant layout.

Risk contours connect point of equal risk around the source of hazard and presented in order of magnitude. In the Figure 4-1, the nearest contour (pink) to the hazard point is 1E-5 per year. On this contour, a person will have 1 in 10000 chance of fatality due to hazard. A person outside the contour will be exposed to the frequency of 1E-6, 1E-7, 1E-8, and 1E-9 with the respective area. The risk level is decreasing from reference point (hazard source) to the further distance.

From the Risk contour, the population affected are at PF(K)SB plant, nearby industry, Kg. Siam, Kg. Batu Dua, Kg Guar Jumaat, Kg Guar Nenas and Kg. Sungai Rotan that is within the further most distance the ammonia hazard able to reach. The detail of risk transect from the source of hazard with the respective location are in the Appendices.

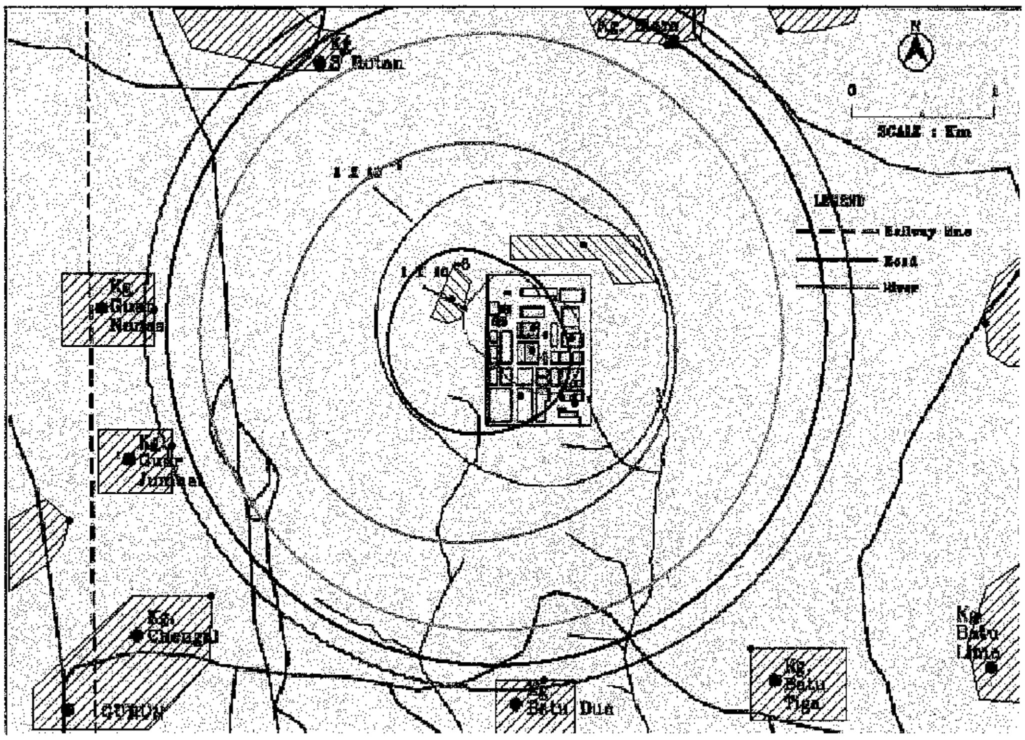

Figure 4-1: Risk Contour Plot of the plant layout

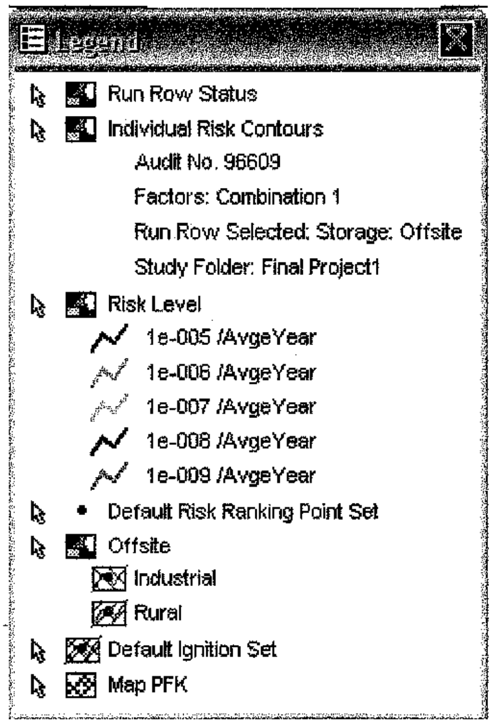

Figure 4-2: Legend for Figure 4-2

4.2 Toxicology Assessment for Ammonia

4.2.1 Dispersion Graph

During an accident, process equipment can release toxic material quickly and in significant enough quantities to spread in dangerous clouds throughout the plant site and nearby residence. Serious accidents emphasize the importance of planning for emergencies and of designing plant to minimize the occurrences and consequences of a toxic release on the plant and nearby residence. In this study two areas as focus are, developing a source model to describe how material are released and the rate of release, and estimating the downwind concentration of the toxic material using a dispersion model.

A wind variation of parameters affect atmospheric dispersion of toxic material. In this study the variation parameters are the wind speed and the atmospheric stability.

The dispersion is run using SAFETI at various wind speeds. Weather I is the lowest wind speed. However, weather I demonstrated the worst case with 1.0 m/s, because as the wind speed increases, the plume will become longer, narrower and the substance carried downwind faster, and diluted faster by larger quantities of air (Daniel A. Crowl et al, 2001).

Figures 4-3, 4, 5 and 6 show the dispersion of ammonia at weather I for 1 inch, 2 inches, 3 inches and rupture. The first Y-axis is centerline concentration in ppm and the second Y-axis is the time in second. The X-axis is the downwind distance in meter.

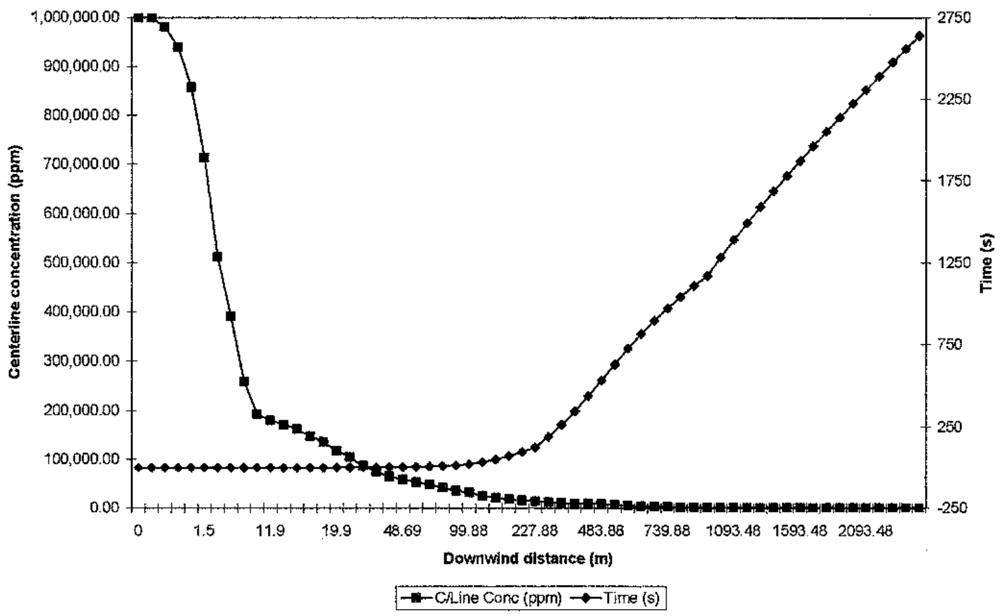

Figure 4-3: Dispersion of Ammonia, 1 inch leak diameter, Weather I

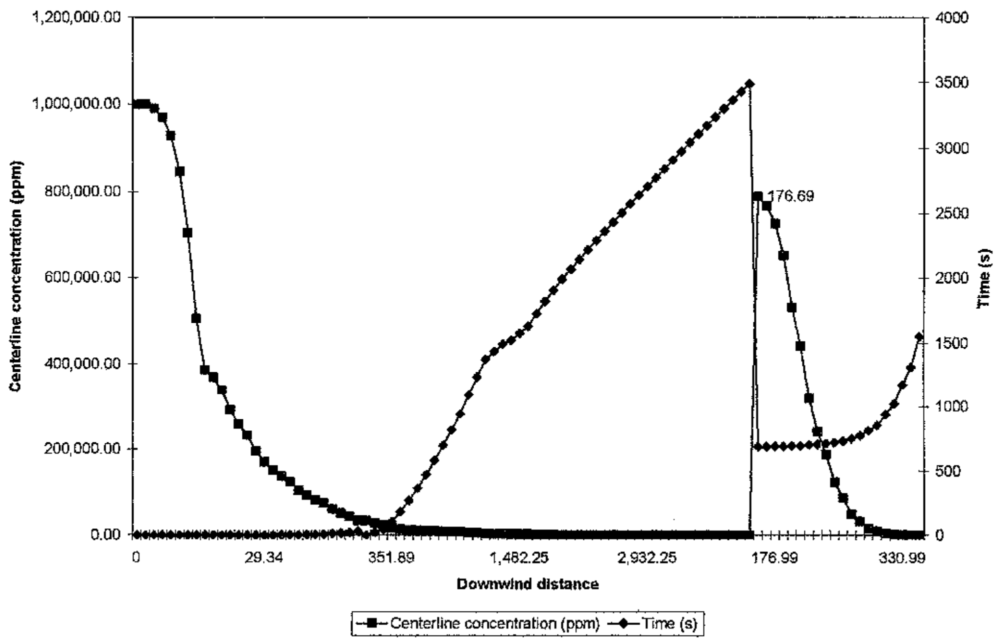

Figure 4-4: Dispersion of Ammonia, 2 inches leak diameter, Weather I

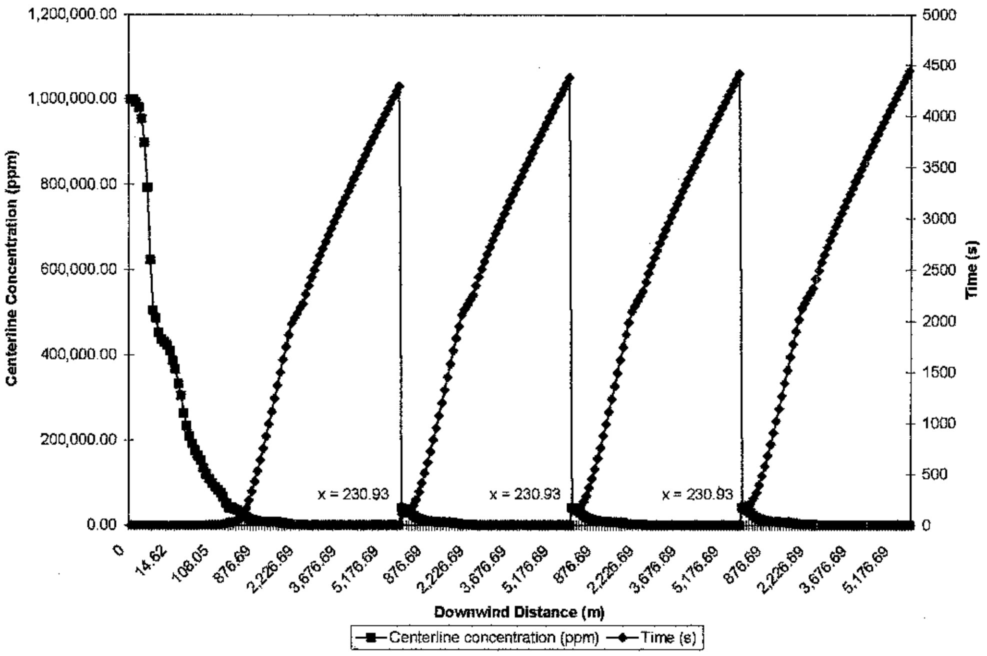

Figure 4-5: Dispersion of Ammonia, 3 inches leak diameter, Weather I

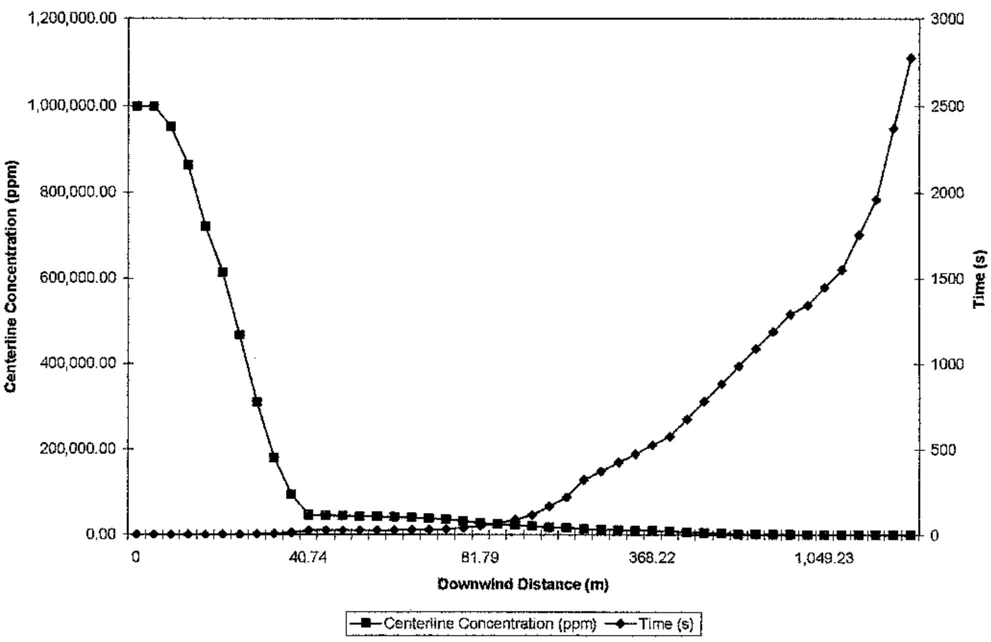

Figure 4-6: Dispersion of Ammonia, rupture, Weather I

In general, for Figures 4-3, 4, 5, and 6, with the increasing of the downwind distance, the centerline concentrations are decreasing. For release of pressurized gas, the gas should forms a jet, however, the jet is terminated as the occurrence of leak or rupture. This condition is due to properties of ammonia that forming gas at atmosphere temperature and pressure. Therefore the gas disperses as plume as soon as the occurrence of leak or rupture at certain fraction.

For Figures 4-4 and 5, the graphs produce unique trends. In Figure 4-4, the centerline concentration is decreasing until it reaches 4.132km downwind distance at 3493 seconds. At distance 176.69m downwind distance with 689.2 seconds, the centerline concentration increases back showing the similar trend (decreasing centerline concentration as increasing downwind distance) but with lower centerline concentration that is 789,574 ppm instead of 1,000,000 ppm. This phenomenon is due to initial ammonia in liquid form that is spilt start to vaporize.

Figure 4-5 show the similar phenomenon as Figure 4-4. However, the centerline concentration increases back at 230.63 m of the downwind distance at 30.5 second, 113.31 seconds, 150.95 seconds, and 181.79 seconds. This is due to the larger continuous mass flow rate of the leak that is 1.17E2 kg/s for 3 inches leak. For 2 inches and 1 inch, the continuous mass flow rates are 5.2E+1 kg/s and 1.3E+1 kg/s respectively. The large pool form will produce multiple cloud segments.

That phenomenon is known as pool vaporization behavior. After the occurrences of leak or rupture, the releases lead to multiple pool segments and multiple cloud segments. When there is rainout after the release, the pool will vaporize and contribute to the vapor cloud. As the cloud move downwind the pool vaporization will continue contributing to the cloud and when the cloud moves past the edge of the pool, the pool vaporization create another cloud behind it (DNV et al, 2003).

4.2.2 Probability of Fatality for Ammonia

Figures 4-7, 8, 9 and 10 show the probability of fatality as a function of distance downwind, where the probability is obtained from the probit value. The probability of fatality is calculated for both indoor and outdoor exposures. The value of each location is calculated using SAFETI by considering the time history of the concentration profile as the cloud passes over the point.

In general, for Figures 4-7, 8 and 9, with the increasing downwind distance, the probability of fatality are decreases. From those three graphs it can be deduced that weather I is the worst case. At weather I the probability of fatality is higher and it reach longer distance than other weather condition as in section 4.3.1. Looking at the probability of fatality value, leak with 1 inch have the highest value than 2 inches and 3 inches leaks.

For rupture case in Figure 4-10, as the vessel containing liquefied gas under pressure ruptures, the results is a violent ejection (J.R. Taylor et al, 1994). This can be clearly observed that the probability of fatality not only covers population downwind distance but including the negative distance as far as 14000 m.

Overall, people have probability of fatality located as far as 1500 m of the downwind distance from the hazard source.

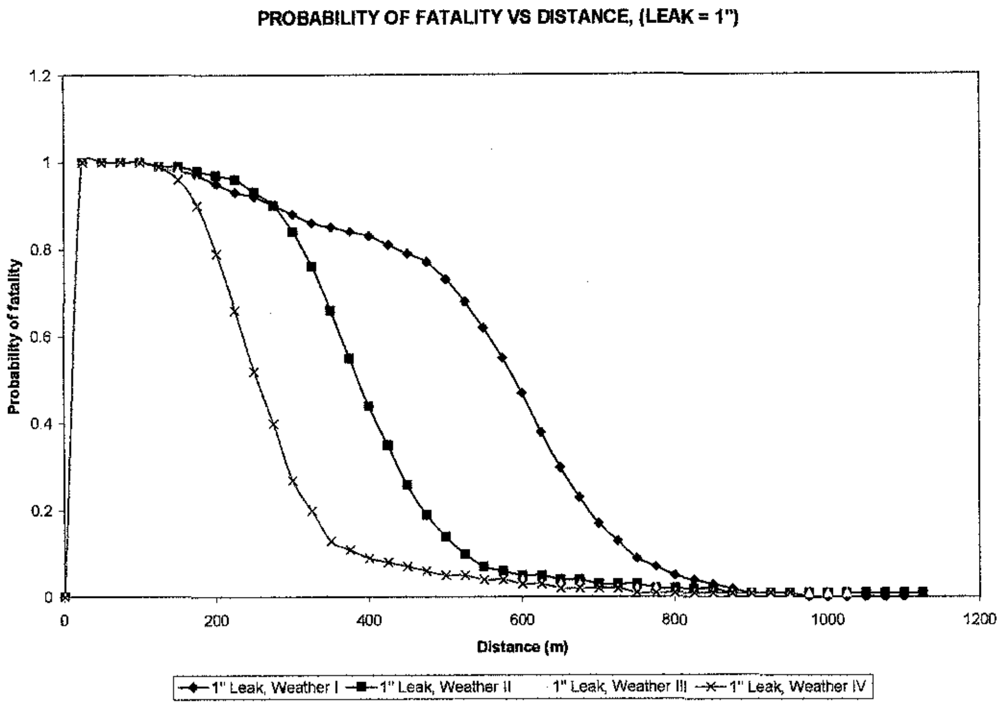

Figure 4-7: Probability of fatality vs. downwind distance for 1" leak at four weathers

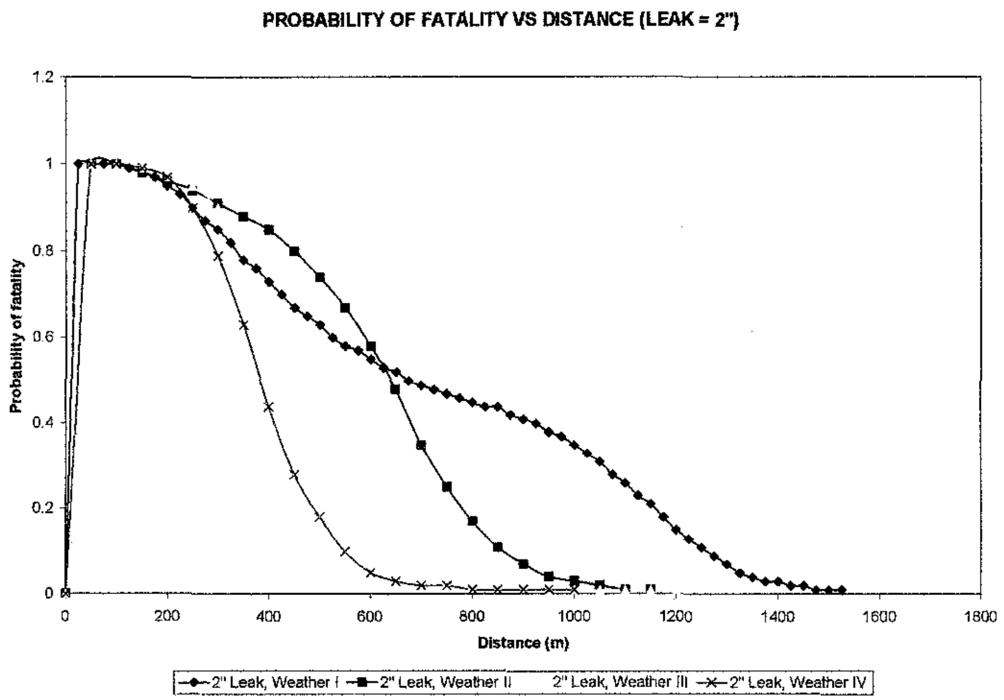

Figure 4-8: Probability of fatality vs. downwind distance for 2" leak at four weathers

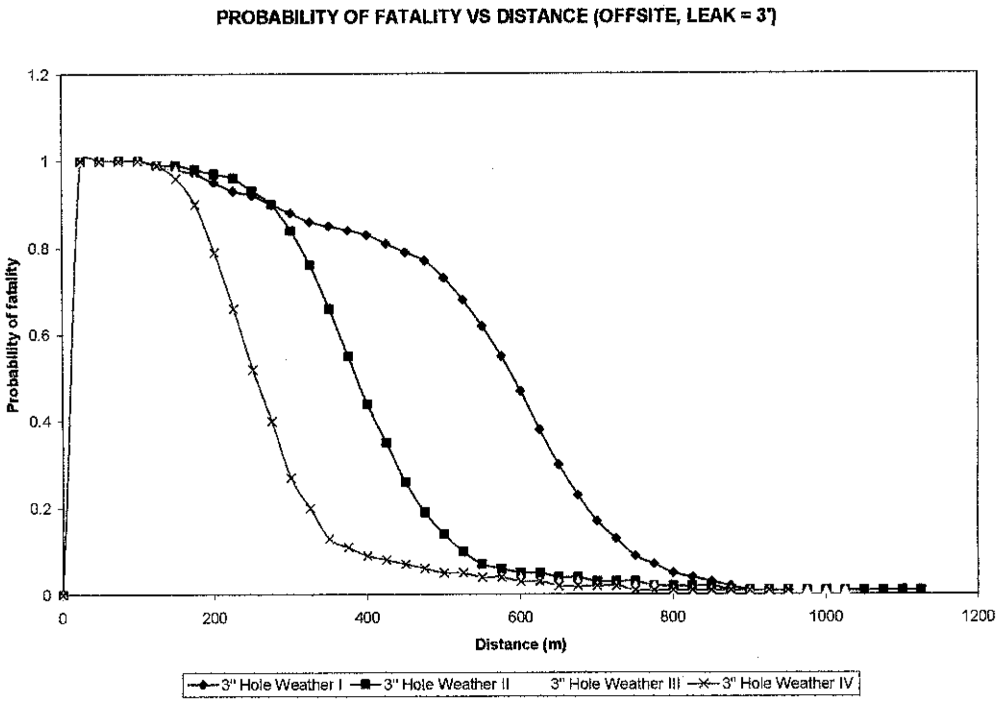

Figure 4-9: Probability of fatality vs. downwind distance for 3" leak at four weathers

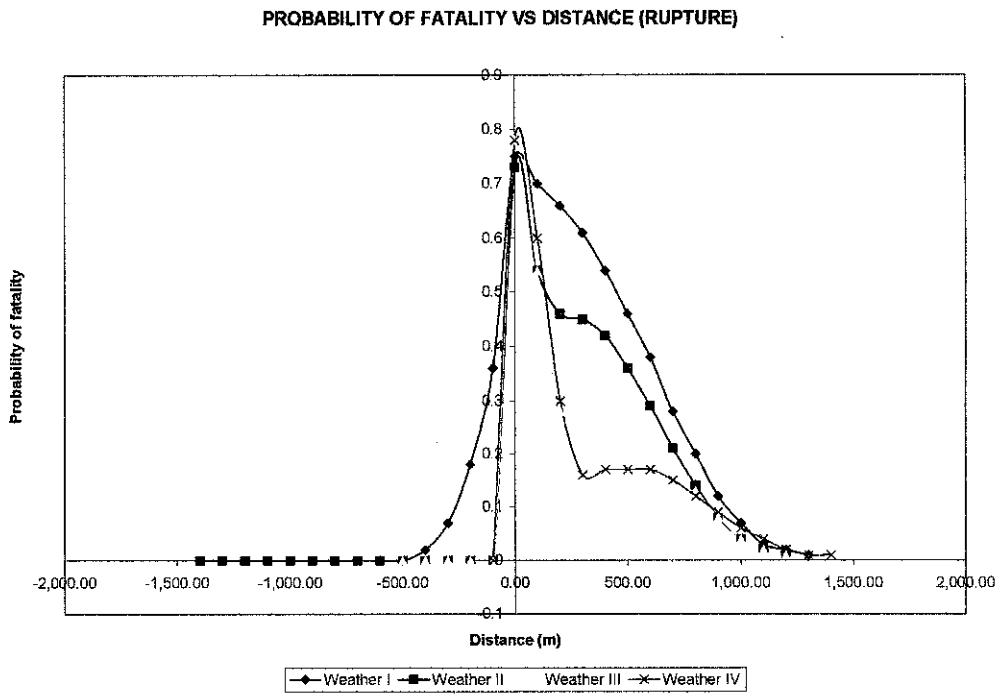

Figure 4-10: Probability of fatality vs. downwind distance for rupture at four weathers

4.2.3 Discharge Properties for Ammonia

Variation of the weather does not affect the discharge properties. The discharge properties values are constant as the changes of the weather at a fix leaks diameter. However there are few properties changes as the leaks diameter increases. Table 4-1 shows the summary of the dispersion properties for small leak with respective leak diameter.

LEAK DIAMETER	**1"**		**2"**		**3"**	
Liquid Fraction	0.85	fraction	0.85	fraction	0.85	fraction
Final Temperature	-33.4	°C	-33.4	°C	-33.4	°C
Final Velocity	225.69	m/s	225.69	m/s	225.69	m/s
Droplet Diameter	7.31E-03	mm	7.31E-03	mm	7.31E-03	mm
Continuous Release Data:						
Mass Flowrate	1.30E+01	kg/s	5.20E+01	kg/s	1.17E+02	kg/s
Release Duration	2,623.02	s	655.75	s	291.45	s
Orifice Velocity	70.12	m/s	70.12	m/s	70.12	m/s
Exit Pressure	1.01	bar	1.01	bar	1.01	bar
Exit Temperature	19.62	°C	19.62	°C	19.62	°C
Discharge Coefficient	0.6		0.6		0.6	

Table 4-1: Summary of dispersion properties for 1 inch, 2 inches and 3 inches leak diameter.

Only the mass flowrate and release duration of continuous release data are varied. When the size of leak diameter increases, the mass flowrate increases due to the size of the opening applying the volume flowrate equal to leak diameter times with velocity of the fluids. The continuous release duration decreases as the leak diameter increase, that is the ammonia escape from storage tank is faster when the leak diameter is larger.

4.3 Explosion Assessment for Methane

The affected area of explosion from ammonia reactor is small. The cloud radius reaches 16.3 m and BLEVE radius is 29.81 m. Figure 4-11 shows the cover area, which is only a dot in the map.

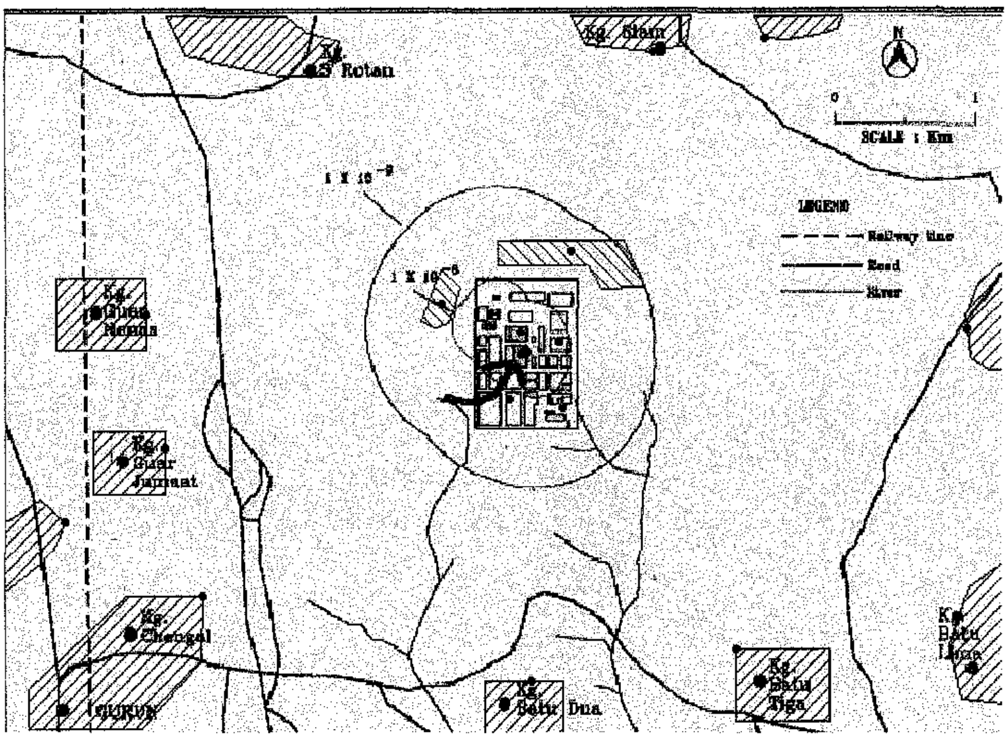

Figure 4-11: The map of the affected explosion area (at the green arrow)

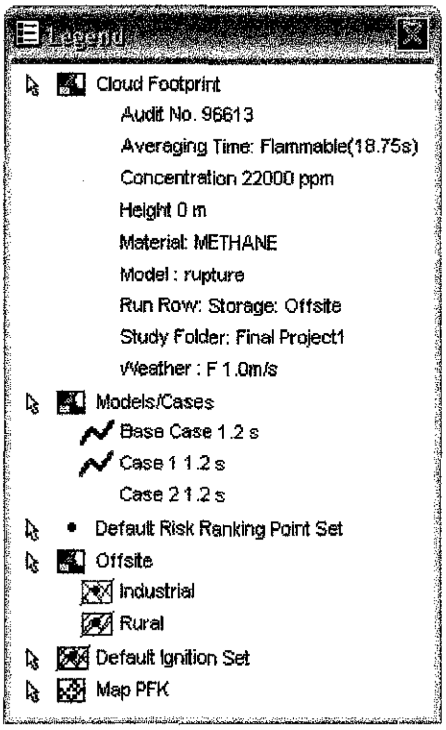

Figure 4-12: Legend for Figure 4-12

4.3.1 Dispersion Graph for Methane

As in Section 4.3.1, two areas of focus are developing a source model to describe how material are released and the rate of release, and estimating the downwind concentration of the toxic material using the a dispersion model.

The dispersion modelling is run at weather I and the result is in Figure 4-13.

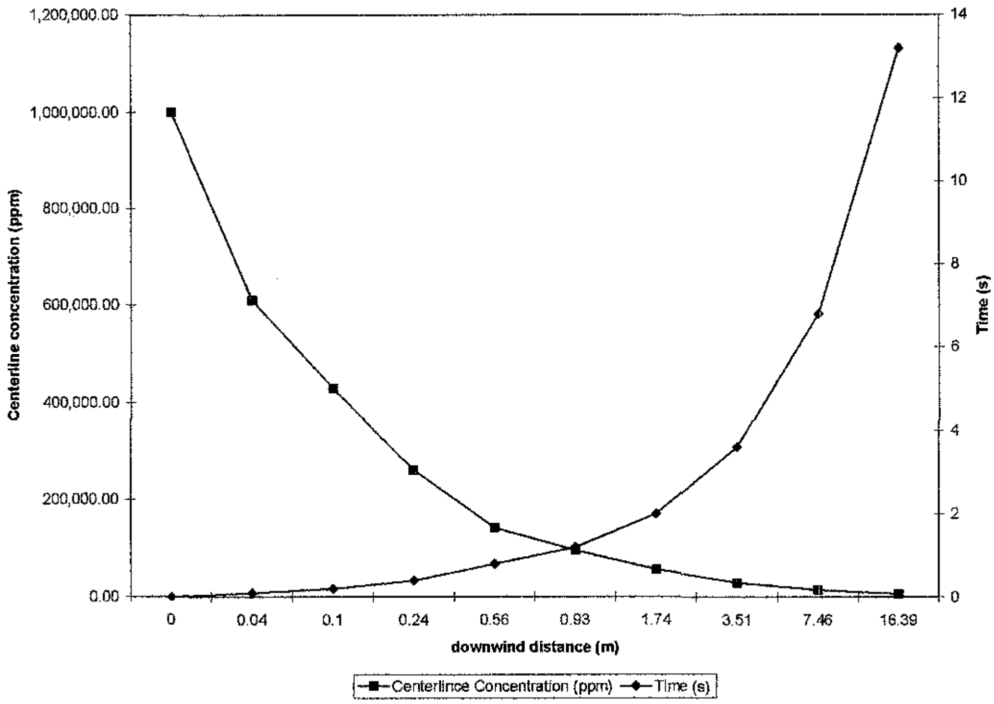

Figure 4-13: Dispersion of Methane, rupture, Weather I

The same phenomenon occur where the centerline concentration decreasing along the downwind distance. However with 1094 kg of methane inventory, the cloud covers as far as 16.3 m for 13.2 seconds. Therefore the population affected only those who are near the ammonia reactor, which are the personnel at the plant.

4.3.2 BLEVE Report

A BLEVE (boiling liquid expanding-vapor explosion) occurs if a vessel that contains liquid at a temperature above its atmospheric pressure boiling point ruptures. The subsequent BLEVE is the explosive vaporization of large fraction of the vessel contents followed by combustion or explosion. As the tank contents heats, the vapor pressure of the liquid increases and the tank strength is reduce because of the heating.

The BLEVE radius is 29.81 m with duration of 4.63 seconds. The flame emissive power is 400 kW/m^2.

The flames co-ordinates are given in Table 4-2 below.

X	**Z**	**R**	**Phi**
m	m	m	deg
0.00	0.00	0.00	0.00
0.00	1.80	10.20	0.00
0.00	6.97	19.16	0.00
0.00	14.91	25.82	0.00
0.00	24.64	29.36	0.00
0.00	34.99	29.36	0.00
0.00	44.72	25.82	0.00
0.00	52.65	19.16	0.00
0.00	57.83	10.20	0.00
0.00	59.62	0.00	0.00

Table 4-2: Flame coordinates

4.4 Mitigation Action

The purpose of modelling both toxic release and explosion model is to provide tool for performing release mitigation. Release mitigation is to lessen the risk of an incident by acting on the source either via a preventive way by reducing the likelihood of an event that could generate a hazardous vapor cloud or in a protective way be reducing the magnitude of the release and the exposure of local person.

4.4.1 Inherent Safety

An inherent safe plant relies on chemistry and physics to prevent accidents rather than on control systems, interlocks, redundancy, and special operating procedures to prevent accident.

Using a small amount of ammonia and methane in ammonia storage and ammonia reactor as required will minimize the hazards. When possible the substances should be produced and consumed in-situ, and as extra advantage it will minimize storage and transportation of the materials.

Another alternative is by moderation that is by reducing the process temperature and pressure to a less hazardous condition. Pressurized condition of the storage tank will give energy to ammonia to spread further distance and affect more people. Therefore lowering the pressure will reduce the distance. A few methods are available to achieve the less hazardous condition by diluting to a lower vapor pressure or by refrigerating to a lower a lower vapor pressure.

4.4.2 Engineering design

For spill containment, dikes are one of the possible solutions. This will reduce the pool radius. In the appendix there is a sample of detailed pool vaporization report that is the output of SAFETI. From the report, a distance to locate the dike can be found.

As in the detailed pool vaporization report, the maximum pool radius is larger with larger size of leak. However as the wind speed is increase from weather I to weather IV, the maximum pool radius will decrease. This phenomenon was discussed in Section 4.3.1. To locate the dikes, it must have capability to contain the amount of the spill.

Therefore the best maximum to be selected is the one with the largest pool radius. That is for weather I at 3 inches leak diameter. The best location of the dikes is at 0.52 m from the ammonia storage.

4.4.3 Emergency response

Site evacuation and offsite emergency plan is among the possible approaches. How fast people should react as the ammonia releases occur is summarized in the Appendix. The emergency response is for the worst case that is 3 inches leak diameter.

Other typical mitigation measure for reducing the hazards from toxic materials includes the following:

- Ventilation systems controls with appropriate detection that stop the flow of a contaminated air supply to the building.
- Appropriate preparation of personal protective equipment.
- Reduce number of people working at the hazardous area.
- A detection and alarm system for early notification of a release.

4.4.4 Preventing Explosion

A successful prevention of explosion requires a combination of many designs. A complete description of these techniques requires further study. Table 4-3 illustrates the feature for preventing explosion (John A. Davenport et al, 1977).

FEATURE	EXPLANATION
Maintenance programs	Preventive maintenance programs are designed to upgrade system before failure occurs
Control rooms	Design control rooms to withstand explosion
Utilities	Design steam, water, electricity, and air supplies to be available during emergencies, place substation away from process area.
Personnel areas	Locate personnel areas away from hazardous process and storage areas
Group units	Groups unit in a row. Design for a safe operation and maintenance. Create island of risk by concentrating hazardous process units in one area.
Isolation valves	Install isolation valve for a safe shutdowns. Install in safe and accessible location at edge of unit
Block valves	Automated block valves should be placed to stop and/or to control flows during emergencies. Ability to transfer hazardous material from one area to another should be considered.
On-line analyzer	Add appropriate on-line analyzer to monitor the status if the process to detect problems at incipient stage and to take appropriate action to minimize the effects of problems while still in initial phase of development.
Fail-safe design	All controls need to be designed to fail safely. Add safeguard for automated and safe shutdowns during emergencies.

Table 4-3: Miscellaneous Design for preventing explosion

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Based on the results of the study, it can be concluded that the risk values calculated for the surrounding population located approximately 0.43km to 2.43km away from the ammonia storage tank and ammonia reactor indicate a need for caution in the planning and operations. The risk level is decreasing as the moving away from both sources as in Figure 4-1. The maximum risk level is 1E-5/yr and the minimum is 1E-9/yr with the respective areas.

Study also shows a trend of the centerline concentration as opposed to downwind direction and its relation with the size of leak diameter and weather condition. As the distance moving away from the source, the centerline concentration is decreases. The increasing leak diameter will result in shorter distance for cloud. As for weather condition, the lowest wind speed will affect further distance as explain in Section 4.3.1. Table 5-1 below shows the ammonia concentration with its effect.

NH_3 CONCENTRATION (PPM)	EFFECT
20	Odor Detected
100	Irritation & complaint
500	Intolerable irritation
2500 - 5000	Fatalities for first 5 min (90 – 100% after 1 hr)
> 5000	100% fatalities

Table 5-1: Ammonia concentration and its effects

It also can be concluded that mitigation should be adopted, and should involve all relevant authorities of the communities in the affected area. Few relevant mitigation actions are reduce inventory, use lower energy material, passive barriers, produce the material when and where needed, and emergency plan for affected area.

5.2 Recommendations

The results presented above indicate the significance Quantitative Risk Assessment using SAFETI. Thus, some recommendations had been proposed as follows:

i. Study of the alternative to use lower energy material, at which pressure and temperature is suitable. This study should have interest for safety in the same time considering the plant requirement
ii. Analysis of the possibility of unusual wind condition that will drift the ammonia volume to residential areas
iii. Study of toxicology on long term effects to the agriculture activities and products

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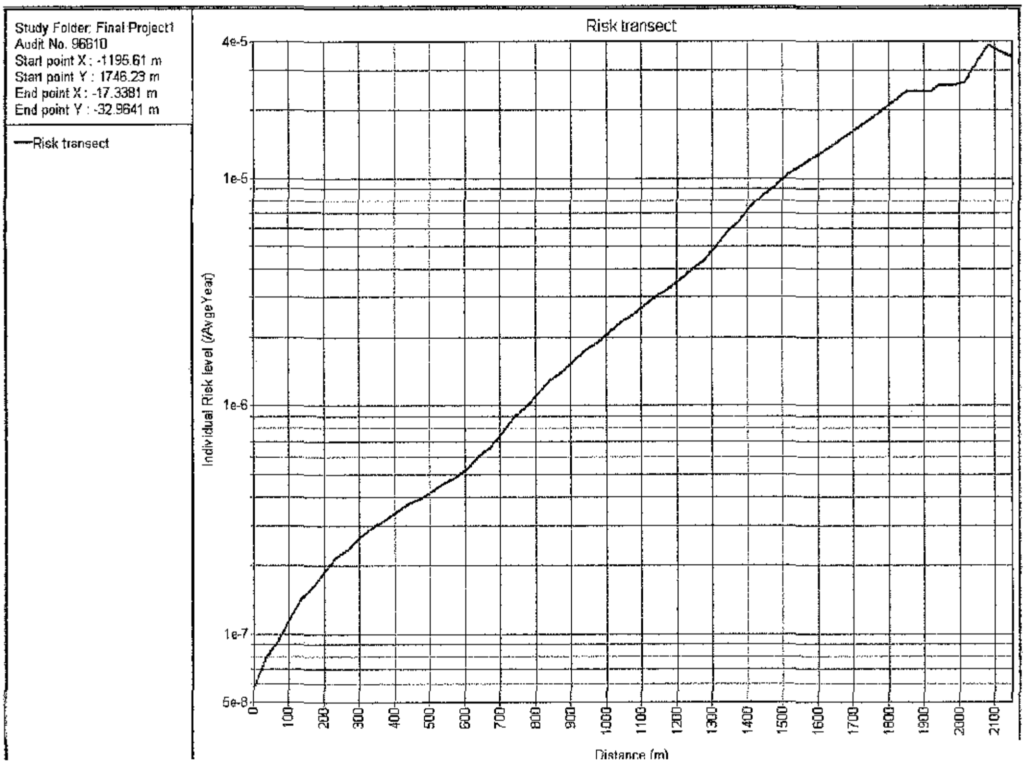
APPENDICES

RISK TRANSECT WITH RESPECTIVE LOCATION



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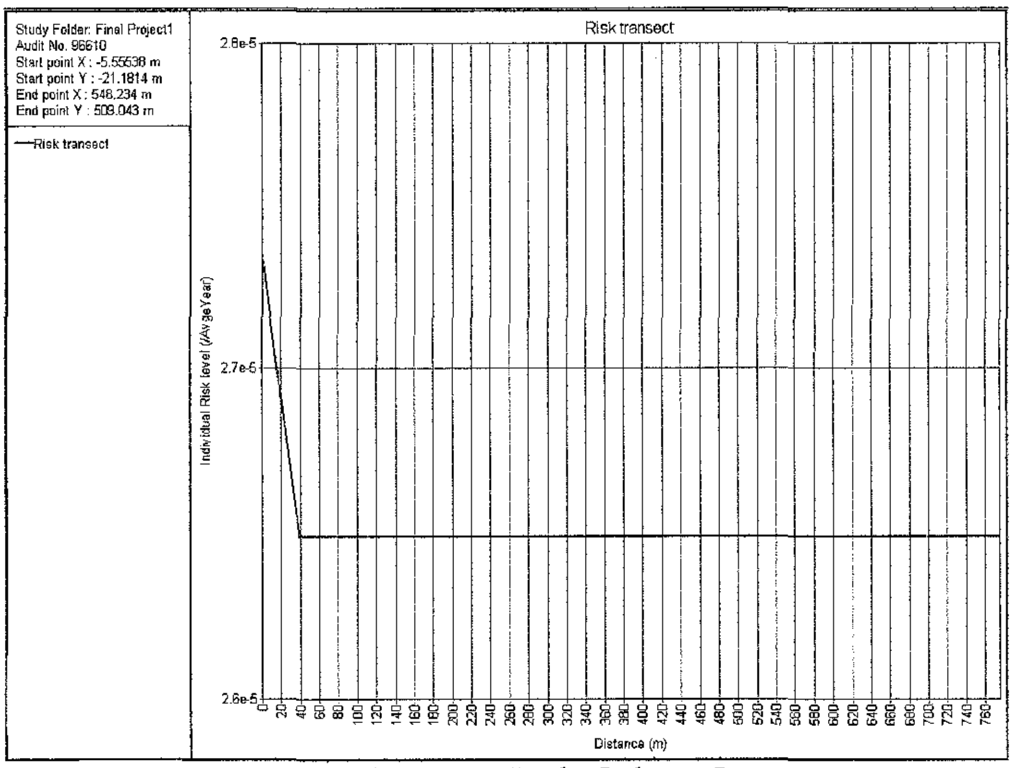
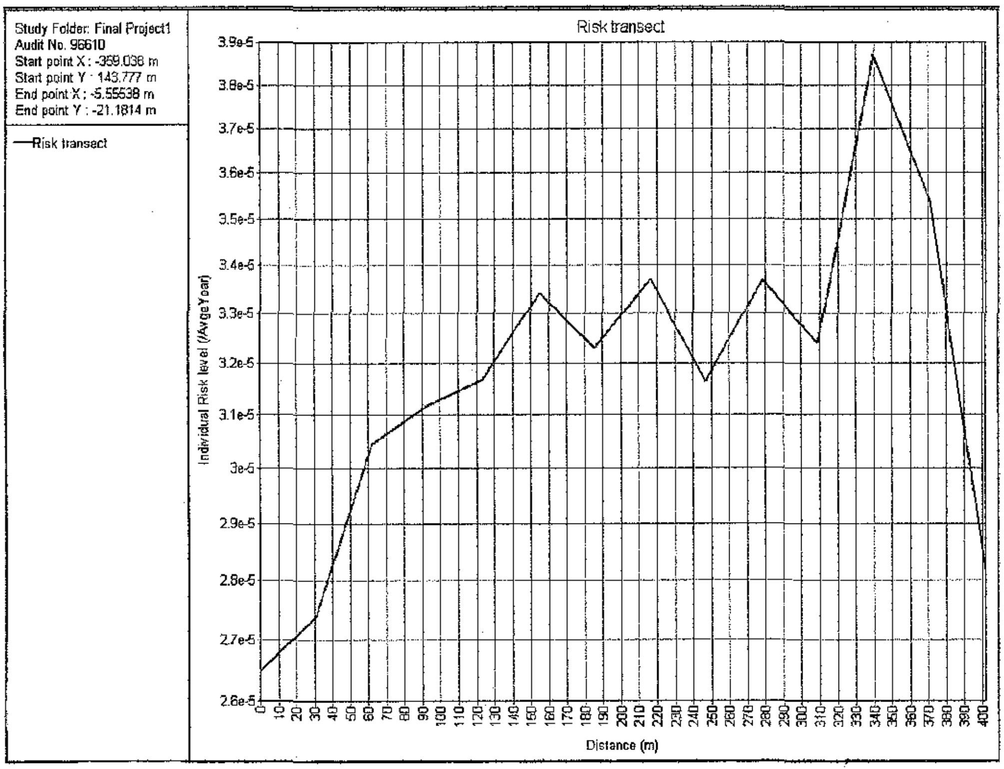
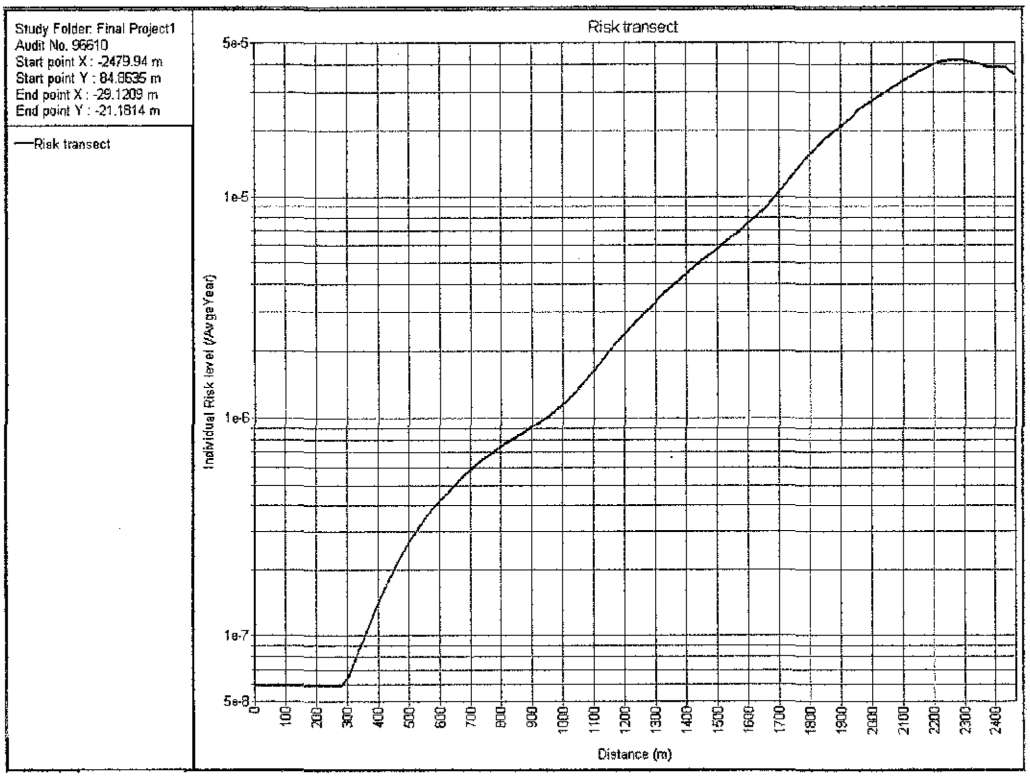


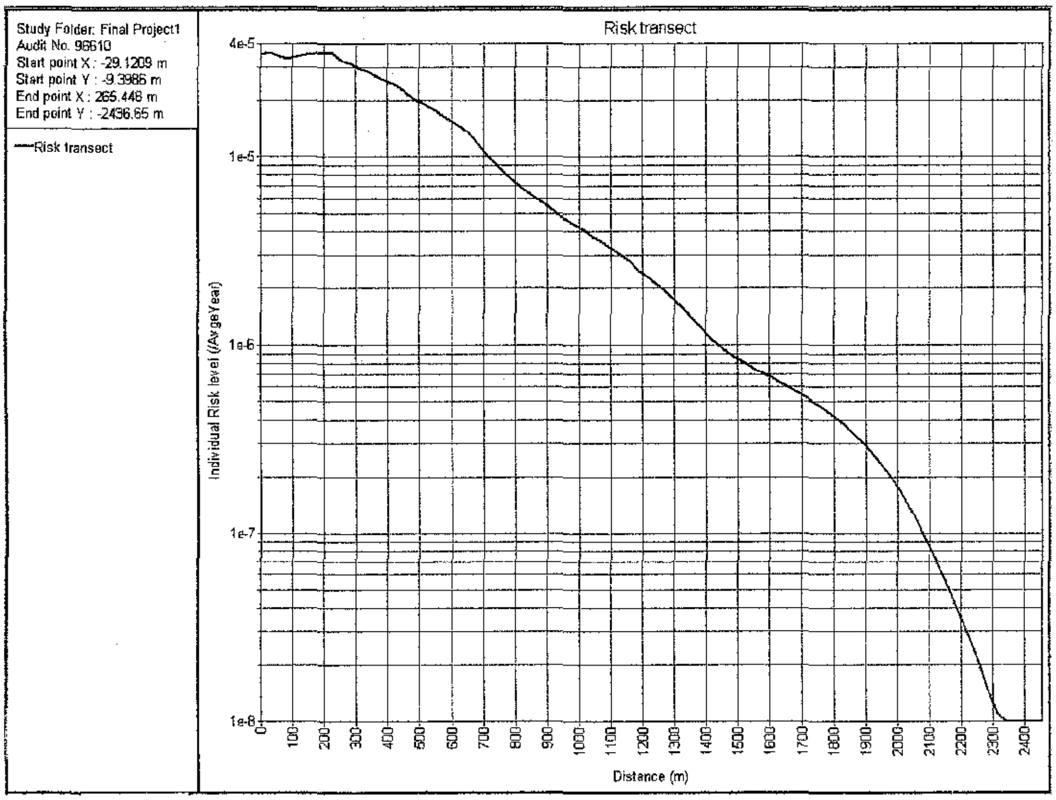
From Source to Nearby Industry I



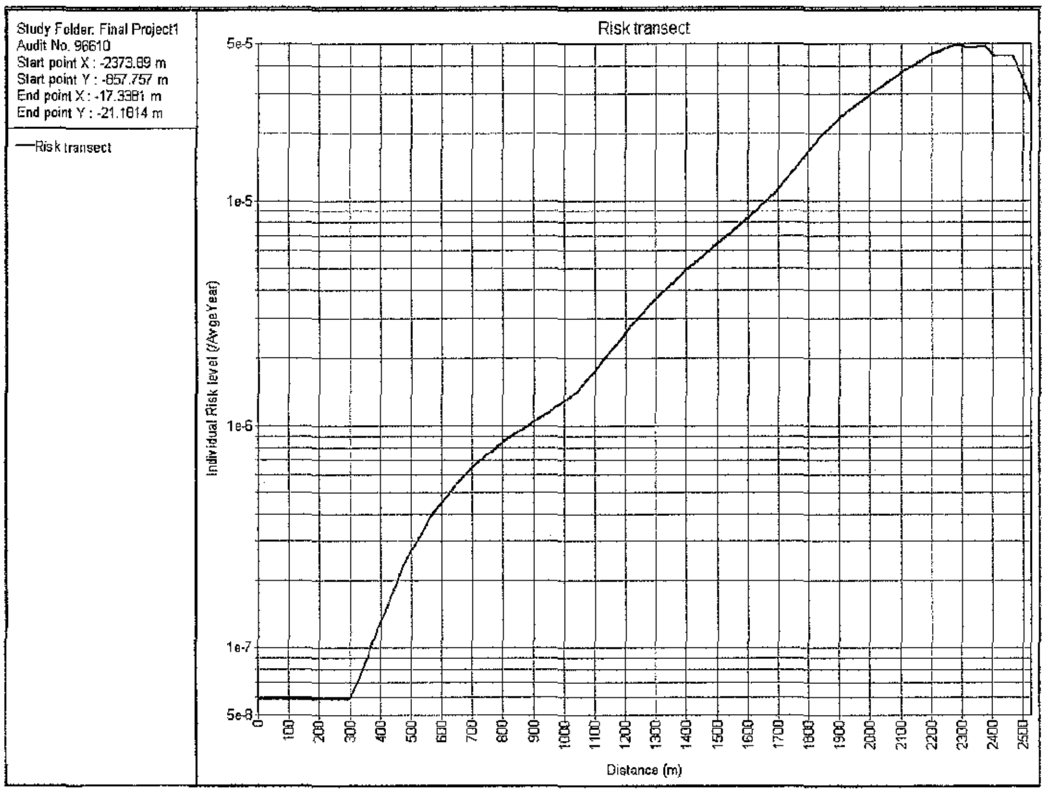
From Source to Nearby Industry II



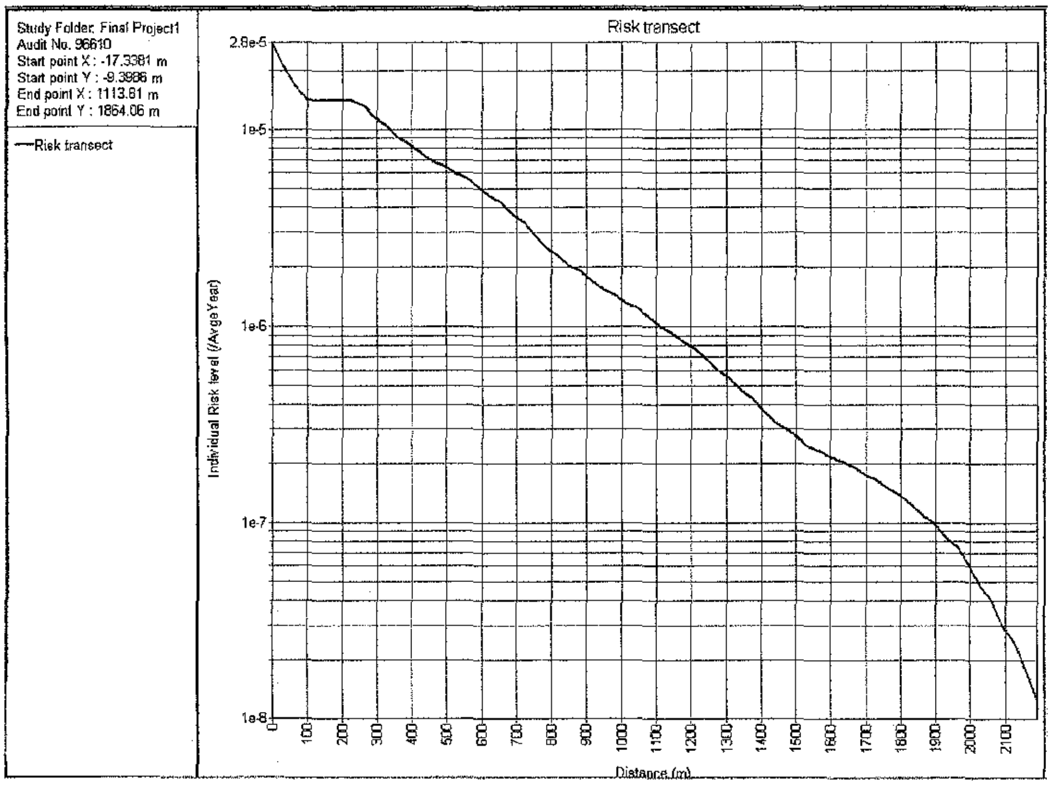
From Source to Kg Guar Nenas



From Source to Kg Batu Dua



From Source to Kg Guar Jumaat



From Source to Kg Siam

SAMPLE OF DETAILED POOL VAPORIZATION REPORT

Final Project1 (RunRow Storage: Offsite)

Ammonia Storage

at freq 3E-5
Hole Diameter
Case

Kedah Weather\F 1.0m/s

Weather:

Speed: **1.00 m/s** **Stability:** **F**

Final Project1\Ammonia Storage\small leak\at freq 3E-5\Hole Diameter\Case

Step Number	Time Spilt	Mass	Mass Vaporized	Mass Dissolved	Mass Left	Vaporization Rate	Solution Rate	Radius	Depth	Temperature
s		kg	kg	kg	kg	kg/s	kg/s	m	m	degC
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	-71.73
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	-71.35
3	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	-71.04
4	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	-71.10
5	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	-70.99
6	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	-70.85
7	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	-70.67
8	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	-70.47
9	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	-70.25
10	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	-70.02
11	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	-69.77
12	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	-69.51
13	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	-69.25
14	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	-68.97
15	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	-68.69
16	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	-68.40
17	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	-68.10
18	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	-67.80

19	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	-67.49
20	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	-67.18
21	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	-66.86
22	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	-66.53
23	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	-66.20
24	0.36	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.01	-65.87
25	0.39	0.01	0.00	0.00	0.01	0.00	0.00	0.02	0.01	-65.53
26	0.42	0.01	0.00	0.00	0.01	0.00	0.00	0.02	0.01	-65.19
27	0.46	0.01	0.00	0.00	0.01	0.00	0.00	0.02	0.01	-64.84
28	0.49	0.01	0.00	0.00	0.01	0.00	0.00	0.02	0.01	-64.50
29	0.53	0.01	0.00	0.00	0.01	0.00	0.00	0.02	0.01	-64.14
30	0.56	0.01	0.00	0.00	0.01	0.00	0.00	0.02	0.01	-63.79
31	0.60	0.01	0.00	0.00	0.01	0.00	0.00	0.02	0.01	-63.43
32	0.64	0.01	0.00	0.00	0.01	0.00	0.00	0.02	0.01	-63.07
33	0.68	0.01	0.00	0.00	0.01	0.00	0.00	0.02	0.01	-62.71
34	0.72	0.01	0.00	0.00	0.01	0.00	0.00	0.02	0.01	-62.34
35	0.77	0.01	0.00	0.00	0.01	0.00	0.00	0.02	0.01	-61.97
36	0.81	0.01	0.00	0.00	0.01	0.00	0.00	0.02	0.01	-61.60
37	0.86	0.01	0.00	0.00	0.01	0.00	0.00	0.02	0.01	-61.23
38	0.90	0.01	0.00	0.00	0.01	0.00	0.00	0.02	0.01	-60.85
39	0.95	0.01	0.00	0.00	0.01	0.00	0.00	0.02	0.01	-60.48
40	1.00	0.01	0.00	0.00	0.01	0.00	0.00	0.03	0.01	-60.10
41	1.05	0.01	0.00	0.00	0.01	0.00	0.00	0.03	0.01	-59.72
42	1.10	0.02	0.00	0.00	0.02	0.00	0.00	0.03	0.01	-59.34
43	1.16	0.02	0.00	0.00	0.02	0.00	0.00	0.03	0.01	-58.96
44	1.21	0.02	0.00	0.00	0.02	0.00	0.00	0.03	0.01	-58.58
45	1.27	0.02	0.00	0.00	0.02	0.00	0.00	0.03	0.01	-58.19
46	1.32	0.02	0.00	0.00	0.02	0.00	0.00	0.03	0.01	-57.81
47	1.38	0.02	0.00	0.00	0.02	0.00	0.00	0.03	0.01	-57.42
48	1.44	0.02	0.00	0.00	0.02	0.00	0.00	0.03	0.01	-57.04
49	1.50	0.02	0.00	0.00	0.02	0.00	0.00	0.03	0.01	-56.65
50	1.56	0.02	0.00	0.00	0.02	0.00	0.00	0.03	0.01	-56.26
51	1.63	0.02	0.00	0.00	0.02	0.00	0.00	0.03	0.01	-55.87
52	1.69	0.02	0.00	0.00	0.02	0.00	0.00	0.03	0.01	-55.49
53	1.76	0.02	0.00	0.00	0.02	0.00	0.00	0.03	0.01	-55.10
54	1.82	0.03	0.00	0.00	0.03	0.00	0.00	0.03	0.01	-54.71
55	1.89	0.03	0.00	0.00	0.03	0.00	0.00	0.03	0.01	-54.32

56	1.96	0.03	0.00	0.00	0.03	0.00	0.00	0.04	0.01	-53.93
57	2.03	0.03	0.00	0.00	0.03	0.00	0.00	0.04	0.01	-53.55
58	2.10	0.03	0.00	0.00	0.03	0.00	0.00	0.04	0.01	-53.16
59	2.18	0.03	0.00	0.00	0.03	0.00	0.00	0.04	0.01	-52.77
60	2.25	0.03	0.00	0.00	0.03	0.00	0.00	0.04	0.01	-52.38
61	2.33	0.03	0.00	0.00	0.03	0.00	0.00	0.04	0.01	-52.00
62	2.40	0.03	0.00	0.00	0.03	0.00	0.00	0.04	0.01	-51.61
63	2.48	0.04	0.00	0.00	0.04	0.00	0.00	0.04	0.01	-51.22
64	2.56	0.04	0.00	0.00	0.04	0.00	0.00	0.04	0.01	-50.84
65	2.64	0.04	0.00	0.00	0.04	0.00	0.00	0.04	0.01	-50.46
66	2.72	0.04	0.00	0.00	0.04	0.00	0.00	0.04	0.01	-50.07
67	2.81	0.04	0.00	0.00	0.04	0.00	0.00	0.04	0.01	-49.69
68	2.89	0.04	0.00	0.00	0.04	0.00	0.00	0.04	0.01	-49.31
69	2.98	0.04	0.00	0.00	0.04	0.00	0.00	0.04	0.01	-48.93
70	3.06	0.04	0.00	0.00	0.04	0.00	0.00	0.04	0.01	-48.55
71	3.15	0.04	0.00	0.00	0.04	0.00	0.00	0.04	0.01	-48.17
72	3.24	0.05	0.00	0.00	0.05	0.00	0.00	0.05	0.01	-47.80
73	3.33	0.05	0.00	0.00	0.05	0.00	0.00	0.05	0.01	-47.42
74	3.42	0.05	0.00	0.00	0.05	0.00	0.00	0.05	0.01	-47.05
75	3.52	0.05	0.00	0.00	0.05	0.00	0.00	0.05	0.01	-46.68
76	3.61	0.05	0.00	0.00	0.05	0.00	0.00	0.05	0.01	-46.31
77	3.71	0.05	0.00	0.00	0.05	0.00	0.00	0.05	0.01	-45.94
78	3.80	0.05	0.00	0.00	0.05	0.00	0.00	0.05	0.01	-45.57
79	3.90	0.06	0.00	0.00	0.05	0.00	0.00	0.05	0.01	-45.21
80	4.00	0.06	0.00	0.00	0.06	0.00	0.00	0.05	0.01	-44.85
81	4.10	0.06	0.00	0.00	0.06	0.00	0.00	0.05	0.01	-44.49
82	4.20	0.06	0.00	0.00	0.06	0.00	0.00	0.05	0.01	-44.13
83	4.31	0.06	0.00	0.00	0.06	0.00	0.00	0.05	0.01	-43.77
84	4.41	0.06	0.00	0.00	0.06	0.00	0.00	0.05	0.01	-43.42
85	4.52	0.06	0.00	0.00	0.06	0.00	0.00	0.05	0.01	-43.07
86	4.62	0.07	0.00	0.00	0.07	0.00	0.00	0.05	0.01	-42.72
87	4.73	0.07	0.00	0.00	0.07	0.00	0.00	0.06	0.01	-42.38
88	4.84	0.07	0.00	0.00	0.07	0.00	0.00	0.06	0.01	-42.03
89	4.95	0.07	0.00	0.00	0.07	0.00	0.00	0.06	0.01	-41.69
90	5.06	0.07	0.00	0.00	0.07	0.00	0.00	0.06	0.01	-41.36
91	5.18	0.07	0.00	0.00	0.07	0.00	0.00	0.06	0.01	-41.02
92	5.29	0.07	0.00	0.00	0.07	0.00	0.00	0.06	0.01	-40.69

93	5.41	0.08	0.00	0.00	0.08	0.00	0.00	0.06	0.01	-40.37
94	5.52	0.08	0.00	0.00	0.08	0.00	0.00	0.06	0.01	-40.04
95	5.64	0.08	0.00	0.00	0.08	0.00	0.00	0.06	0.01	-39.73
96	5.76	0.08	0.00	0.00	0.08	0.00	0.00	0.06	0.01	-39.41
97	5.88	0.08	0.00	0.00	0.08	0.00	0.00	0.06	0.01	-39.10
98	6.00	0.08	0.00	0.00	0.08	0.00	0.00	0.06	0.01	-38.79
99	6.13	0.09	0.00	0.00	0.09	0.00	0.00	0.06	0.01	-38.49
100	6.25	0.09	0.00	0.00	0.09	0.00	0.00	0.06	0.01	-38.19
101	6.38	0.09	0.00	0.00	0.09	0.00	0.00	0.06	0.01	-37.90
102	6.50	0.09	0.00	0.00	0.09	0.00	0.00	0.07	0.01	-37.61
103	6.63	0.09	0.00	0.00	0.09	0.00	0.00	0.07	0.01	-37.33
104	6.76	0.10	0.00	0.00	0.09	0.00	0.00	0.07	0.01	-37.05
105	6.89	0.10	0.00	0.00	0.10	0.00	0.00	0.07	0.01	-36.78
106	7.02	0.10	0.00	0.00	0.10	0.00	0.00	0.07	0.01	-36.52
107	7.16	0.10	0.00	0.00	0.10	0.00	0.00	0.07	0.01	-36.26
108	7.29	0.10	0.00	0.00	0.10	0.00	0.00	0.07	0.01	-36.01
109	7.43	0.10	0.00	0.00	0.10	0.00	0.00	0.07	0.01	-35.76
110	7.56	0.11	0.00	0.00	0.11	0.00	0.00	0.07	0.01	-35.53
111	7.70	0.11	0.00	0.00	0.11	0.00	0.00	0.07	0.01	-35.30
112	7.84	0.11	0.00	0.00	0.11	0.00	0.00	0.07	0.01	-35.09
113	7.98	0.11	0.00	0.00	0.11	0.00	0.00	0.07	0.01	-34.88
114	8.12	0.11	0.00	0.00	0.11	0.00	0.00	0.07	0.01	-34.69
115	8.27	0.12	0.00	0.00	0.12	0.00	0.00	0.07	0.01	-34.50
116	8.41	0.12	0.00	0.00	0.12	0.00	0.00	0.07	0.01	-34.33
117	8.56	0.12	0.00	0.00	0.12	0.00	0.00	0.07	0.01	-34.18
118	8.70	0.12	0.00	0.00	0.12	0.00	0.00	0.08	0.01	-34.04
119	8.85	0.13	0.00	0.00	0.12	0.00	0.00	0.08	0.01	-33.92
120	9.00	0.13	0.00	0.00	0.13	0.00	0.00	0.08	0.01	-33.81
121	9.15	0.13	0.00	0.00	0.13	0.00	0.00	0.08	0.01	-33.73
122	9.30	0.13	0.00	0.00	0.13	0.00	0.00	0.08	0.01	-33.66
123	9.46	0.13	0.00	0.00	0.13	0.00	0.00	0.08	0.01	-33.62
124	9.61	0.14	0.00	0.00	0.13	0.00	0.00	0.08	0.01	-33.59
125	9.77	0.14	0.00	0.00	0.13	0.00	0.00	0.08	0.01	-33.57
126	9.92	0.14	0.00	0.00	0.14	0.00	0.00	0.08	0.01	-33.56
127	10.08	0.14	0.00	0.00	0.14	0.00	0.00	0.08	0.01	-33.55
128	10.24	0.14	0.00	0.00	0.14	0.00	0.00	0.08	0.01	-33.55
129	10.40	0.15	0.00	0.00	0.14	0.00	0.00	0.08	0.01	-33.54

130	10.56	0.15	0.00	0.00	0.14	0.00	0.00	0.08	0.01	-33.54
131	10.73	0.15	0.00	0.00	0.15	0.00	0.00	0.08	0.01	-33.53
132	10.89	0.15	0.00	0.00	0.15	0.00	0.00	0.08	0.01	-33.53
133	11.06	0.16	0.01	0.00	0.15	0.00	0.00	0.08	0.01	-33.52
134	11.22	0.16	0.01	0.00	0.15	0.00	0.00	0.08	0.01	-33.52
135	11.39	0.16	0.01	0.00	0.16	0.00	0.00	0.09	0.01	-33.51
136	11.56	0.16	0.01	0.00	0.16	0.00	0.00	0.09	0.01	-33.51
137	11.73	0.17	0.01	0.00	0.16	0.00	0.00	0.09	0.01	-33.51
138	11.90	0.17	0.01	0.00	0.16	0.00	0.00	0.09	0.01	-33.50
139	12.08	0.17	0.01	0.00	0.16	0.00	0.00	0.09	0.01	-33.50
140	12.25	0.17	0.01	0.00	0.17	0.00	0.00	0.09	0.01	-33.50
141	12.43	0.18	0.01	0.00	0.17	0.00	0.00	0.09	0.01	-33.49
142	12.60	0.18	0.01	0.00	0.17	0.00	0.00	0.09	0.01	-33.49
143	12.78	0.18	0.01	0.00	0.17	0.00	0.00	0.09	0.01	-33.49
144	12.96	0.18	0.01	0.00	0.17	0.00	0.00	0.09	0.01	-33.49
145	13.14	0.19	0.01	0.00	0.18	0.00	0.00	0.09	0.01	-33.48
146	13.32	0.19	0.01	0.00	0.18	0.00	0.00	0.09	0.01	-33.48
147	13.51	0.19	0.01	0.00	0.18	0.00	0.00	0.09	0.01	-33.48
148	13.69	0.19	0.01	0.00	0.18	0.00	0.00	0.09	0.01	-33.48
149	13.88	0.20	0.01	0.00	0.19	0.00	0.00	0.09	0.01	-33.47
150	14.06	0.20	0.01	0.00	0.19	0.00	0.00	0.09	0.01	-33.47
151	14.25	0.20	0.01	0.00	0.19	0.00	0.00	0.09	0.01	-33.47
152	14.44	0.20	0.01	0.00	0.19	0.00	0.00	0.09	0.01	-33.47
153	14.63	0.21	0.01	0.00	0.19	0.00	0.00	0.10	0.01	-33.47
154	14.82	0.21	0.01	0.00	0.20	0.00	0.00	0.10	0.01	-33.47
155	15.02	0.21	0.01	0.00	0.20	0.00	0.00	0.10	0.01	-33.47
156	15.21	0.21	0.01	0.00	0.20	0.00	0.00	0.10	0.01	-33.46
157	15.41	0.22	0.01	0.00	0.20	0.00	0.00	0.10	0.01	-33.46
158	15.60	0.22	0.01	0.00	0.21	0.00	0.00	0.10	0.01	-33.46
159	15.80	0.22	0.02	0.00	0.21	0.00	0.00	0.10	0.01	-33.46
160	16.00	0.23	0.02	0.00	0.21	0.00	0.00	0.10	0.01	-33.46
161	16.20	0.23	0.02	0.00	0.21	0.00	0.00	0.10	0.01	-33.46
162	16.40	0.23	0.02	0.00	0.21	0.00	0.00	0.10	0.01	-33.46
163	16.61	0.23	0.02	0.00	0.22	0.00	0.00	0.10	0.01	-33.46
164	16.81	0.24	0.02	0.00	0.22	0.00	0.00	0.10	0.01	-33.46
165	17.02	0.24	0.02	0.00	0.22	0.00	0.00	0.10	0.01	-33.45
166	17.22	0.24	0.02	0.00	0.22	0.00	0.00	0.10	0.01	-33.45

EMERGENCY RESPONES, TIME TO REACT BASE ON WORST CASE, 3INCHES LEAK DIAMETER

Downwind Distance m	C/Line Height m	C/Line Conc ppm	Plume Half-width m	Plume Total Depth m	Vapor Temperature degC	Liquid Fraction fraction	Time s	Liquid Temperature degC	Centroid Velocity m/s	Cloud Density kg/m3
0	1	1,000,000.00	0.17	0.76	-33.4	0.85	0	-33.4	225.69	5.67
0	1	1,000,000.00	0.17	0.76	-33.4	0.85	0	-33.4	225.69	5.67
0.1	1	993,525.81	0.18	0.79	-31.07	0.84	0	-34.46	223.25	5.35
0.3	1	980,302.84	0.19	0.85	-28.42	0.84	0	-36.31	218.33	4.83
0.7	1	953,142.51	0.22	0.97	-22.87	0.83	0	-39.5	208.49	4.08
1.5	1	897,660.02	0.27	1.18	-30.35	0.81	0.01	-43.06	189.45	3.36
3.1	1	792,640.27	0.37	1.6	-41.71	0.77	0.02	-47.61	156.87	2.66
6.3	1	623,673.64	0.63	2.25	-51.27	0.69	0.04	-52.85	112.22	2.11
9.5	0.99	505,652.61	1.04	2.78	-53.71	0.62	0.07	-55.89	85.59	1.88
10.14	0.99	487,026.40	1.27	2.92	-54.61	0.61	0.08	-56.28	81.68	1.85
11.42	0.98	453,289.64	1.44	3.15	-55.11	0.58	0.1	-57.08	74.78	1.8
12.06	0.98	438,150.75	1.58	3.27	-56.39	0.56	0.11	-57.27	71.68	1.79
12.38	0.98	431,049.96	1.64	3.34	-56.13	0.56	0.11	-57.44	70.06	1.78
12.7	0.98	424,226.11	1.71	3.4	-56.15	0.55	0.11	-57.96	68.41	1.77
13.34	0.98	411,279.57	1.82	3.54	-55.15	0.54	0.12	-58.02	65.23	1.75
14.62	0.97	387,850.26	2.06	3.82	-55.07	0.51	0.15	-58.58	59.45	1.72
15.9	0.97	367,346.93	2.33	4.12	-55.19	0.49	0.17	-58.99	54.53	1.69
18.46	0.96	333,032.76	2.82	4.7	-56.91	0.43	0.22	-59.52	46.6	1.66
21.02	0.96	305,643.37	3.36	5.32	-56.08	0.39	0.28	-60.21	40.7	1.63
26.14	0.93	263,997.25	4.48	6.59	-49.59	0.33	0.42	-61.43	32.41	1.56
31.26	0.9	233,633.58	5.83	7.81	-52.46	0.24	0.59	-62.06	27.03	1.55
36.38	0.85	210,499.99	7.38	8.41	-50.33	0.17	0.79	-62.62	23.26	1.52
41.5	0.78	191,895.81	9.36	8.99	-45.05	0.13	1.03	-63.41	20.36	1.48
46.62	0.69	176,481.61	11.75	9.53	-40.82	0.09	1.29	-64.1	18.05	1.44
51.74	0.58	163,474.51	14.38	10.14	-34.42	0.07	1.59	-64.89	16.17	1.41
56.86	0.45	152,327.74	17.39	10.75	-28.85	0.06	1.93	-65.33	14.63	1.38
67.09	0.14	134,244.76	23.43	12.02	-18.74	0.04	2.69	-66.34	12.22	1.33
77.33	0	120,131.75	30.68	12.92	-11.68	0.03	3.59	-67.01	10.47	1.3

87.57	0	108,567.31	38.35	13.6	-6.26	0.02	4.64	-67.7	9.08	1.27	
97.81	0	98,788.57	46.54	14.25	-2.02	0.01	5.84	-68.06	7.98	1.26	
108.05	0	90,433.79	55.35	14.8	0.01	0.01	7.2	-68.69	7.09	1.25	
118.29	0	83,209.14	64.98	15.26	2.03	0	8.72	-69.41	6.35	1.24	
128.53	0	76,896.32	75.32	15.8	4.66	0	10.41	-69.47	5.74	1.23	
149.01	0	66,451.74	97.95	16.87	8.71	0	14.32	-70.02	4.76	1.22	
189.97	0	51,615.88	151.25	18.78	13.74	0	24.23	-71.03	3.51	1.2	
230.93	0	41,735.30	214.81	20.19	16.67	0	30.5		2.78	1.19	
230.93	0	41,738.61	215.17	20.24	16.67	0	30.5		2.78	1.19	0
251.41	0	38,033.21	250.54	20.79	17.7	0	38.22		2.52	1.19	7.72
271.89	0	34,875.83	288.05	21.2	18.55	0	46.68		2.32	1.19	16.18
312.85	0	29,819.00	368.88	21.97	19.87	0	65.69		1.99	1.18	35.19
394.77	0	23,008.32	550.49	22.88	21.57	0	111.45		1.59	1.18	80.95
476.69	0	18,743.48	750.47	23.01	22.6	0	166.86		1.37	1.17	136.36
576.69	0	15,386.13	1,011.91	22.83	23.43	0	244.86		1.2	1.17	214.36
676.69	0	13,180.09	1,284.58	22.33	23.99	0	332.52		1.09	1.17	302.02
776.69	0	11,655.20	1,563.91	21.74	24.41	0	428.09		1.01	1.17	397.59
876.69	0	10,562.62	1,846.30	21.07	24.74	0	530.44		0.95	1.17	499.94
976.69	0	9,759.92	2,128.88	20.41	25.15	0	638.67		0.9	1.16	608.17
1,076.69	0	9,161.73	2,395.83	19.87	25.97	0	752.11		0.86	1.16	721.61
1,176.69	0	8,713.60	2,638.96	19.4	26.64	0	870.02		0.83	1.16	839.52
1,276.69	0	8,376.69	2,858.72	18.98	27.18	0	991.66		0.81	1.16	961.16
1,376.69	0	8,049.29	3,051.46	18.76	27.65	0	1116.49		0.79	1.16	1,085.99
1,476.69	0	7,624.87	3,209.88	18.85	28.08	0	1243.79		0.78	1.15	1,213.29
1,576.69	0	7,079.93	3,328.99	19.26	28.45	0	1372.3		0.78	1.15	1,341.80
1,676.69	0	6,393.74	3,403.53	20.09	28.78	0	1500.45		0.78	1.15	1,469.95
1,776.69	0	5,551.35	3,426.33	21.54	29.07	0	1626.54		0.8	1.15	1,596.04
1,876.69	0	4,661.59	3,400.14	23.47	29.3	0	1748.52		0.84	1.15	1,718.02
1,976.69	0	3,864.76	3,412.01	25.51	29.47	0	1864.68		0.88	1.15	1,834.18
2,076.69	0	3,166.32	3,387.65	27.94	29.6	0	1974.38		0.94	1.15	1,943.88
2,126.69	0	2,886.96	3,369.80	28.03	29.64	0	2025.87		1	1.15	1,995.37
2,176.69	0	2,648.52	3,348.99	29.55	29.68	0	2075.38		1.02	1.15	2,044.88
2,226.69	0	2,383.08	3,307.69	30.84	29.72	0	2123.69		1.05	1.15	2,093.19

2,276.69	0	2,137.86	3,260.02	32.28	29.76	0	2170.29	1.09	1.15	2,139.79
2,376.69	0	1,747.85	3,164.04	35.87	29.81	0	2260.17	1.13	1.15	2,229.67
2,476.69	0	1,473.27	3,077.03	36.96	29.84	0	2344.73	1.23	1.15	2,314.23
2,576.69	0	1,275.48	2,998.84	38.55	29.87	0	2424.08	1.29	1.15	2,393.58
2,676.69	0	1,129.41	2,928.27	39.11	29.88	0	2499.72	1.36	1.15	2,469.22
2,776.69	0	1,018.39	2,863.02	39.53	29.9	0	2572.16	1.41	1.15	2,541.66
2,876.69	0	932.18	2,801.17	39.4	29.91	0	2642.09	1.45	1.15	2,611.59
2,976.69	0	864	2,740.72	38.98	29.92	0	2709.9	1.5	1.15	2,679.40
3,076.69	0	809.38	2,679.75	38.19	29.92	0	2775.97	1.53	1.15	2,745.47
3,176.69	0	765.22	2,616.16	37.1	29.93	0	2840.57	1.56	1.15	2,810.07
3,276.69	0	729.37	2,547.58	35.7	29.93	0	2903.94	1.59	1.15	2,873.44
3,376.69	0	700.26	2,471.08	33.99	29.93	0	2966.27	1.62	1.15	2,935.77
3,476.69	0	676.79	2,382.93	31.98	29.94	0	3027.74	1.64	1.15	2,997.24
3,576.69	0	658.12	2,277.99	29.65	29.94	0	3088.51	1.65	1.15	3,058.01
3,676.69	0	643.68	2,148.80	26.96	29.94	0	3148.69	1.67	1.15	3,118.19
3,776.69	0	632.93	2,011.64	24.48	29.94	0	3208.43	1.68	1.15	3,177.93
3,876.69	0	623.55	1,949.47	23.93	29.94	0	3267.83	1.69	1.15	3,237.33
3,976.69	0	614.5	1,886.46	23.35	29.95	0	3326.95	1.7	1.15	3,296.45
4,076.69	0	605.78	1,822.48	22.74	29.95	0	3385.79	1.7	1.15	3,355.29
4,176.69	0	597.35	1,757.37	22.1	29.95	0	3444.36	1.71	1.15	3,413.86
4,276.69	0	589.22	1,690.94	21.44	29.95	0	3502.68	1.72	1.15	3,472.18
4,376.69	0	581.35	1,622.98	20.73	29.95	0	3560.75	1.73	1.15	3,530.25
4,476.69	0	573.75	1,553.25	19.99	29.95	0	3618.56	1.73	1.15	3,588.06
4,576.69	0	566.38	1,481.43	19.21	29.95	0	3676.14	1.74	1.15	3,645.64
4,676.69	0	559.25	1,407.17	18.38	29.95	0	3733.48	1.75	1.15	3,702.98
4,776.69	0	552.34	1,330.00	17.5	29.95	0	3790.6	1.75	1.15	3,760.10
4,876.69	0	545.64	1,249.34	16.56	29.95	0	3847.49	1.76	1.15	3,816.99
4,976.69	0	539.14	1,164.40	15.54	29.96	0	3904.16	1.77	1.15	3,873.66
5,076.69	0	532.83	1,074.13	14.44	29.96	0	3960.63	1.77	1.15	3,930.13
5,176.69	0	526.7	977	13.22	29.96	0	4016.88	1.78	1.15	3,986.38
5,276.69	0	520.74	870.64	11.87	29.96	0	4072.93	1.79	1.15	4,042.43
5,376.69	0	514.96	751.1	10.31	29.96	0	4128.78	1.79	1.15	4,098.28
5,476.69	0	509.33	610.61	8.45	29.96	0	4184.44	1.8	1.15	4,153.94