

**PROJECT DONE ON BEHALF OF  
NINHAM SHAND (PTY) LTD**

# **VULNERABILITY STUDY FOR THE PROPOSED COAL FIRED POWER STATION & ASSOCIATED INFRASTRUCTURE IN THE WITBANK GEOGRAPHICAL AREA**

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# **VULNERABILITY STUDY FOR THE PROPOSED COAL FIRED POWER STATION & ASSOCIATED INFRASTRUCTURE IN THE WITBANK GEOGRAPHICAL AREA**

## **EXECUTIVE SUMMARY**

### **1 INTRODUCTION**

A power plant, operating on coal, is planned for construction in the Witbank area. As part of the project, flammable and toxic process chemicals will be stored on site and used during the operation of the process. As the consequence from hazardous chemicals may extend beyond the boundary of the site, a risk assessment was required to determine the impact on the public.

Riscom (Pty) Ltd was commissioned to conduct a Vulnerability Study to determine the extent of impact from accidental fires, explosions and toxic releases and to determine if any fatal flaw will prevent the approval of the project.

#### **1.1 Terms of Reference**

This study was limited to the hazards posed by process chemicals stored and transported on site but did not cover mechanical failures such as turbines.

The main aim of the investigation was to determine the extent of impact from accidental fires and toxic releases with regards to hazardous process chemicals stored and transported on the proposed Power Plant.

This Vulnerability study does not replace a quantitative risk assessment as required by the MHI Regulations (July 2001).

#### **1.2 Purpose and Main Activities**

The main activity of the power plant is the generation of electricity that will be incorporated into the national electrical grid.

#### **1.3 Main Hazard Due To Substance and Process**

The main hazards of the proposed power plant are:

- Exposure to toxic fumes from process chemicals; and,
- Thermal radiation from fires/explosions due to the flammability/explosively of the process chemicals.

## **2 ENVIRONMENT**

### **2.1 General Background**

The proposed site for the new power plant in the Witbank area is still to be finalised and would be located on either site X or Y with the respective positions indicate below in Fig 1. Both sites are located between the N12 and N4 motorways, the main routes to Witbank from Johannesburg and Pretoria respectively. The sites are rural with residential areas some distance away.

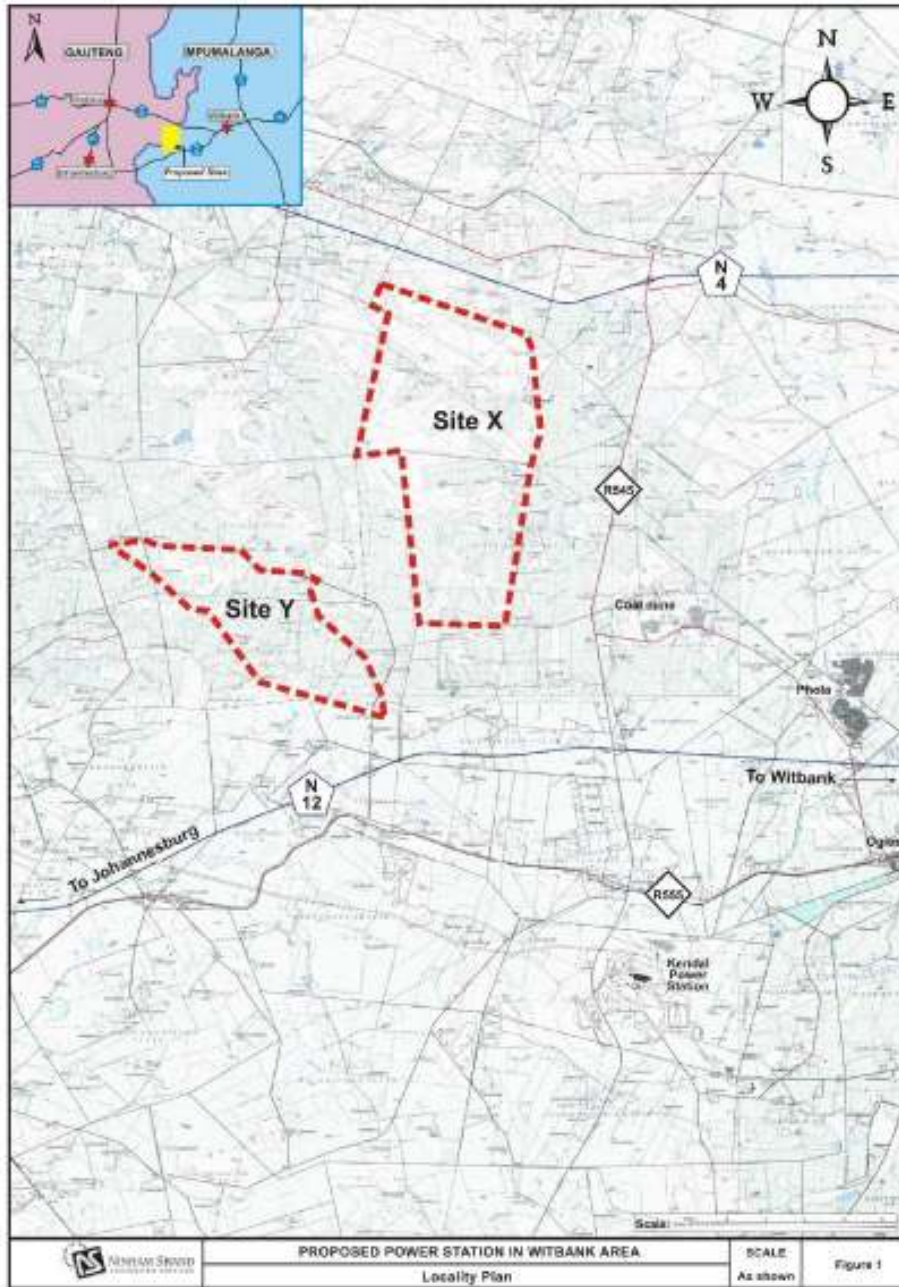


Fig 1 Proposed location of the new Power Plant in the Witbank area (Courtesy Ninham Shand)

### **3 PROCESS DESCRIPTION**

#### **3.1 Project Scope**

The proposed project comprises:

- A 5 400 MW greenfield, coal-fired power station west of Witbank; and,
- Associated infrastructure such as a high-voltage yard, water treatment and supply facilities, ash management systems, coal transportation, storage and handling facilities, service roads etc.

#### **3.2 Site Layout**

The extent of the site required for such a power plant and associated infrastructure is approximately 2500 ha, although the structure themselves would only occupy a small portion thereof.

#### **3.3 Electricity Generation**

Coal, which would be supplied from a coal mine in the vicinity, would be fed into pulverising mills to be crushed into fine dust. This would then be fed into the boilers where it is burnt at high temperatures. The boilers would operate within Original Equipment Manufacturer (OEM) design parameters, the most important of which are pressure and temperature. Each of the six boilers would heat water to produce steam within a pressure and temperature range of 17 MPa – 26 MPa and 535°C – 566°C respectively. There is no significant impact on cost across this range although operation at the higher pressure and temperature range allows for increased efficiency (reduction in coal consumption and associated emissions by some 5%). Superheated steam from the boilers would drive turbines coupled to generators, which convert mechanical energy into electrical energy. The generated electricity would be transformed from 22 kV to 400 kV via a generator transformer and thereafter transported from the HV yard into the national grid via HV transmission lines.

### **4 HAZARD IDENTIFICATION**

The first step in any risk assessment is to identify all hazards. The merits of including the hazard for further investigation are subsequently determined by its significance, normally using a cut-off or threshold quantity. The evaluation methodology assumes that the plant will perform as designed in the absence of unintended events such as component and material failures, human errors, external events and process unknowns.

Once a hazard has been identified, it is necessary to evaluate it in terms of the risk it presents to the employees and the neighbouring community. In principle, both probability and consequence should be considered, but there are occasions where if either the probability or the consequence can be shown to be sufficiently low or sufficiently high, decisions can be made on just one factor.

During the hazard identification component, the following considerations are taken into account:

- Chemical identities;
- Location of facilities that use, produce, process, transport or store hazardous materials;
- The type and design of containers, vessels or pipelines;

- The quantity of material that could be involved in an airborne release; and,
- The nature of the hazard (e.g. airborne toxic vapours or mists, fire, explosion, large quantities stored or processed handling conditions) most likely to accompany hazardous materials spills or releases.

The hazardous substances included in the study included; chlorine, ammonia, petrol, diesel and LPG.

## **5 CONCLUSIONS**

Risk calculations are not precise. The accuracy of the predictions is determined by the quality of base data and expert judgements.

The risk assessment was done on the assumption that the site will be maintained to an acceptable level and that all-statutory regulations are applied. It was also assumed that the detailed engineering designs will be done by competent people and are correctly specified for the intended duty. For example, it is assumed that the tank walls thicknesses will be correctly calculated, that the vents will be sized for emergency conditions, that the instrumentation and electrical components comply with the specified electrical area classification, that the material of construction is compatible with the products, etc. It is the responsibility of Eskom to ensure that all engineering designs will be completed and installed correctly.

A number of incident scenarios were simulated, taking into account the prevailing meteorological conditions and described in the sections above.

The following conclusions were reached.

### **5.1 Fires**

Pool fires from diesel and petrol would have predominantly onsite consequences. Jet fires from high pressure hydrogen could have substantial reach, but offsite consequences would be unlikely and dependant on the plant layout

### **5.2 Explosions**

Explosions from the bulk LPG storage would not generate sufficient overpressure to cause major damage and injuries, provided the tank is place in an unconfined area.

### **5.3 Vapour Clouds**

Toxic vapour clouds from a release of chlorine and ammonia could have substantial endpoints to a maximum distance of 5.6 km for a chlorine release. Thus a large release of chlorine or ammonia has a potential for an offsite consequences.

### **5.4 Major Hazardous Installation (MHI)**

A release of chlorine or ammonia could result in an offsite incident. As such, the facility has the potential to be classified as a Major Hazard Installation in accordance to the regulations.

However an accurate assessment of the risks from the facility can only be made when details designs have been completed.

## **6 RECOMMENDATIONS**

As a result of the risk assessment study, the following is recommended.

### **6.1 Site Recommendations**

Both the prospective sites are located in rural areas with no bordering residential communities. The hazardous material related risks at both sites can be mitigated to within acceptable limits or sufficient buffer zones can be applied between the hazardous materials and nearby communities. Thus, this study does not recommend one site above another.

### **6.2 Major Hazardous Installation Risk Assessment**

As offsite consequences are possible, a quantitative risk assessment would be required in terms of the Major Hazardous Installation (MHI) Regulations (July 2001) prior to project construction.

### **6.3 Project Approval**

Large coal based power plants have been installed around the world having acceptable risks. While consequences of the facility may extend beyond the sites boundary, the design and layout of the facility can be engineered to acceptable risks.

This study did not reveal any features with respect to the hazardous materials risks at the proposed development at either of the two sites that could be considered as fatal or other flaws preventing the further development of this project. The final designs must demonstrate engineering and organisational measures to reduce risks to acceptable levels. Final acceptance of risks will be done after the MHI risk assessment has been completed based on the detailed engineering designs and layouts.



## **ACKNOWLEDGEMENTS**

*The author would like to express his sincere appreciation for the assistance, effort in supplying all the necessary information from Brett Lawson and Kamal Govender of Ninham Shand as well as Suren Rajaruthnam of Eskom.*

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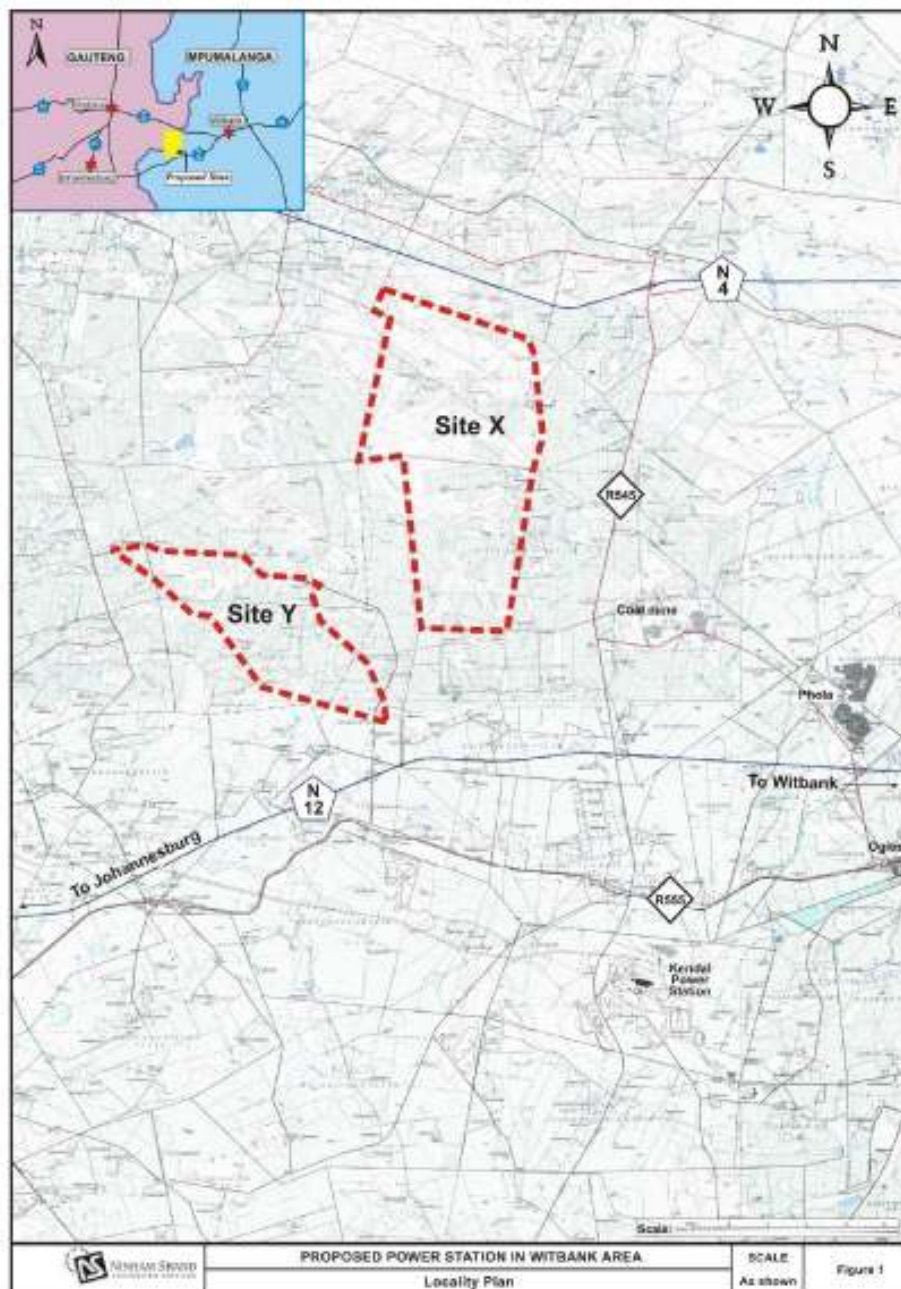


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The proposed project comprises:

- A 5 400 MW greenfield, coal-fired power station west of Witbank; and,
- Associated infrastructure such as a high-voltage yard, water treatment and supply facilities, ash management systems, coal transportation, storage and handling facilities, service roads etc.

#### **3.2 Site Layout**

The extent of the site required for such a power plant and associated infrastructure is approximately 2500 ha, although the structure themselves would only occupy a small portion thereof.

At this stage of the project, designs and have not been finalised and a typical expected plan layout shown below in Figure 3-1. The positions of the hazardous materials are indicated on the layout, but are subject to change prior to construction.

#### **3.3 Electricity Generation**

Coal, which would be supplied from a coal mine in the vicinity, would be fed into pulverising mills to be crushed into fine dust. This would then be fed into the boilers where it is burnt at high temperatures. The boilers would operate within Original Equipment Manufacturer (OEM) design parameters, the most important of which are pressure and temperature. Each of the six boilers would heat water to produce steam within a pressure and temperature range of 17 MPa – 26 MPa and 535°C – 566°C respectively. There is no significant impact on cost across this range although operation at the higher pressure and temperature range allows for increased efficiency (reduction in coal consumption and associated emissions by some 5%). Superheated steam from the boilers would drive turbines coupled to generators, which convert mechanical energy into electrical energy. The generated electricity would be transformed from 22 kV to 400 kV via a generator transformer and thereafter transported from the HV yard into the national grid via HV transmission lines.

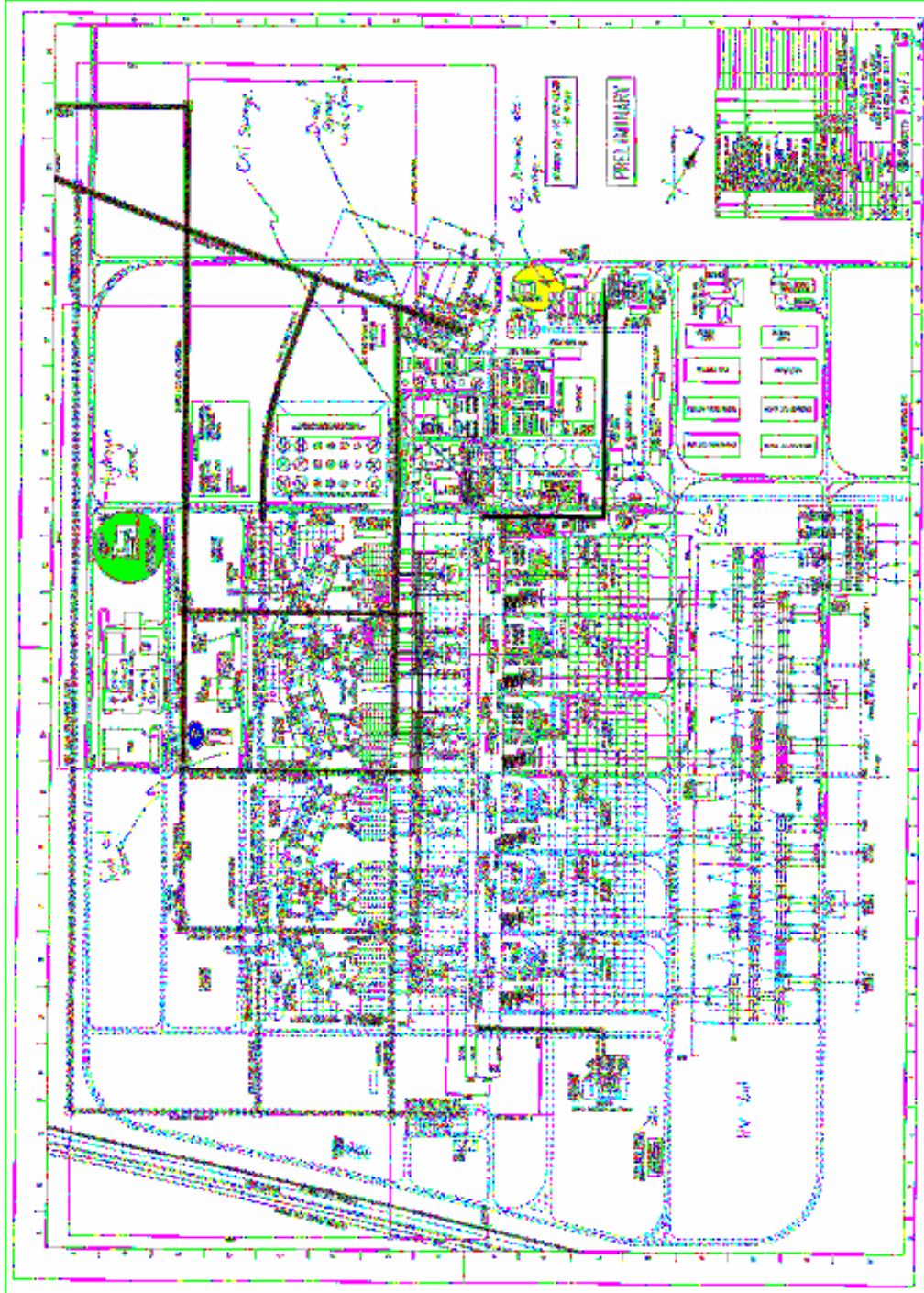


Figure 3-1 Typical layout of the proposed Power Plant indicating expected positions of hazardous materials



### 3.4 Hazardous Substances Stored on Site

The summary of potentially hazardous materials stored on site is given below in Table 3-1. The storage capacity was estimated by the author and based on expected 1 month's consumption and is subject to change with the final design.

**Table 3-1 Summary of potentially hazardous substances stored on site**

|   | <b>HAZARDOUS MATERIAL</b> | <b>STORAGE CAPACITY</b>           | <b>DESCRIPTION</b>                               |
|---|---------------------------|-----------------------------------|--|
| 1 | Chlorine                  | 2 x 925 kg drum                   |  |
| 2 | Ammonia                   | 1 x1500 ℓ                         |  |
| 3 | Caustic Soda              | Unknown                           |  |
| 4 | Sulphuric acid            | 70 m <sup>3</sup> bulk tank       | 98% Concentration                                |
| 5 | Petrol/gasoline           | 50 m <sup>3</sup> bulk tank       | Underground tank                                 |
| 6 | Bunker oil                | 275 m <sup>3</sup> total capacity |  |
| 7 | Diesel                    | 10 m <sup>3</sup>                 | Underground                                      |
| 8 | Hydrogen                  |                                   | Low pressure generation or high pressure trailer |
| 9 | LPG                       | 1x9 m <sup>3</sup>                |  |
| 8 | Illuminating paraffin     | 7.5 m <sup>3</sup>                |  |

## **4 HAZARD IDENTIFICATION**

The first step in any risk assessment is to identify all hazards. The merits of including the hazard for further investigation are subsequently determined by its significance, normally using a cut-off or threshold quantity. The evaluation methodology assumes that the plant will perform as designed in the absence of unintended events such as component and material failures, human errors, external events and process unknowns.

Once a hazard has been identified, it is necessary to evaluate it in terms of the risk it presents to the employees and the neighbouring community. In principle, both probability and consequence should be considered, but there are occasions where if either the probability or the consequence can be shown to be sufficiently low or sufficiently high, decisions can be made on just one factor.

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- Chemical identities;
- Location of facilities that use, produce, process, transport or store hazardous materials;
- The type and design of containers, vessels or pipelines;
- The quantity of material that could be involved in an airborne release; and,
- The nature of the hazard (e.g. airborne toxic vapours or mists, fire, explosion, large quantities stored or processed handling conditions) most likely to accompany hazardous materials spills or releases.

### **4.1 Notifiable Substances**

The General Machinery Regulation 8 and its Schedule A, on notifiable substances, requires any employer who has a substance equal or exceeding the quantity as listed in the regulation to notify the divisional director. A site is classified as a Major Hazardous Installation if it contains one or more notifiable substances or if the offsite risks are sufficiently high. The latter can only be determined from a quantitative risk assessment.

There would be no notifiable materials stored on the site, at this stage in the design.

### **4.2 Substance Hazards**

All components on the plant were assessed for potential hazards according to the criteria discussed below.

#### **4.2.1 Chemical Properties**

##### **4.2.1.1 Ammonia**

Ammonia is a colourless gas with a pungent, suffocating odour. It is easily liquefied under pressure, with a normal boiling point of -33.42 °C. Although classified as a non-flammable gas, it will burn in 16 to 25 percent vapour concentrations in air, when exposed to open flames.

Ammonia is incompatible with some other materials. It is corrosive to copper, brass, silver, zinc, and galvanized steel. Contact with strong oxidizers can result in fires and explosions. It forms explosive products when in contact with calcium, hypochlorite (household) bleaches, halogens, gold, mercury, and silver. Heat is generated when ammonia dissolves in water. At high temperatures, ammonia emits hydrogen and nitrogen. Products of combustion are nitrogen and water, which are harmless to life and the environment.

The effects of anhydrous ammonia upon the human body vary with size, weight, and to a lesser extent, temperature and humidity.

Contact with liquid ammonia can cause frostbite. Ammonia is soluble in water, forming a corrosive liquid. It is toxic if swallowed or inhaled and can irritate or burn the skin, eyes, nose, or throat at levels as low as 35 ppm, but normally a 100-125 ppm through inhalation or direct contact; and at 700 ppm can cause serious and permanent injury with extreme rapidity.

Upon contact with moist mucosal membranes (such as skin, eyes, and respiratory tract), ammonia reacts with water to form a strong alkali - ammonium hydroxide. This causes severe damage to the surface of tissues and thereby exposes more tissue to the effects of the alkali. Symptoms are rapid on contact due to the high water solubility of ammonia and include:

- Immediate burning of the eyes, nose, and throat;
- Coughing;
- Bronchospasm with wheezing; and,
- Pulmonary edema (fluid around the lungs).

Massive exposures can override the absorptive surface area of the upper respiratory tract and result in extensive injury to the lower airways and lung tissue.

There have been a number of major accidents involving ammonia involving storage tanks, pipelines as well as ammonia transported on trucks, railcars and ships.

The worst incident occurred in 1973 at Potchestroom, South Africa where a failure of an ammonia tank released approximately 39 t killing 18 people.

There have been a number on non-fatal releases of ammonia. A release of about 600 t of ammonia occurred from a pipeline in Floral Arkansas in 1971 resulted in a fish kill but no injuries. In another incident, 230 t of ammonia was released from a pipeline at McPherson, Kansas without fatalities.

#### **4.2.1.2 Chlorine**

Chlorine is a greenish-yellow gas with an irritating and suffocating odour. This gas is extremely toxic and a powerful oxidising agent and to be handled, stored and processed with caution.

Chlorine is very reactive and may ignite the following components on contact: methane and oxygen; hydrazine; hydroxylamine; calcium nitride; diethyl ether; diethylzinc; potassium, sodium and copper hydrides; boron; active carbon; silicon; phosphorus; arsenic powder; arsine; phosphine; silane; trialkyl boranes (lower homologues); dicopper acetylide; zirconium dicarbide (at 250°C); arsenic disulphide; boron trisulphide; mercuric sulphide; borondiodiphosphide; phosphorous trioxide; trimercury tetraphosphide. Trimagnesium diphosphide and trimanganese diphosphide ignite in warm chlorine. Metals such as tin,

aluminium, brass, calcium, copper, iron, manganese, potassium, antimony, bismuth, magnesium, sodium, zinc, thorium, tin, uranium, nickel, mercury, aluminium-titanium alloys and niobium ignite in chlorine under various conditions. Titanium is not suitable for components in contact with dry chlorine gas or liquid. Steel ignites in chlorine under various conditions (53-56). Ignition has occurred during continuous chlorination of polyisobutene.

Chlorine may react explosively with amidosulphuric acid ; antimony trichloride and tetramethylsilane (at 100°C); *tert*-butanol ; butyl rubber and naphtha ; carbon disulphide; 3-chloropropyne; dibutyl phthalate; dichloro(methyl)arsine ; disilyl oxide; glycerol ; white phosphorus (at -34°C); hexachlorodisilane; diborane; stibine; ethylphosphene; silicones ; synthetic rubber ; aluminium ; oxygen difluoride (on warming) ;benzene; tetraselenium tetranitride; dimethyl phosphoramidate; methanol and tetrepyridinecobalt(II) chloride ; methane (over yellow mercury oxide); ethylene; ethane; and gasoline. Explosive reactions with acetylene have occurred under a variety of conditions. Injection of liquid chlorine into a naphtha-sodium mixture caused a violent explosion; other incidents involving saturated hydrocarbons and chlorine have been reported, as have incidents involving organic auxiliary materials. Combination of chlorine and hydrogen may be explosive over a wide range of conditions, and equimolar mixtures of chlorine and hydrogen containing 0,1-0,2% nitrogen trichloride explode in the absence of light if the pressure is below a limiting value.

Acute (i.e. short-term) exposure to high levels (>30 parts per million (ppm)) of chlorine in humans results in chest pain, vomiting, toxic pneumonitis, pulmonary oedema, and eventually death. At lower levels, less than 3 ppm, chlorine is a potent irritant to the eyes, the upper respiratory tract, and lungs. Limited information is available on the long-term (chronic) effects of chlorine in humans, however, early literature professed that chronic exposure to concentrations of around 5 ppm caused respiratory complaints, corrosion of the teeth, inflammation of the mucous membranes of the nose, and increased susceptibility to tuberculosis.

No information is available on the developmental or reproductive effects of chlorine in humans or animals via inhalation exposure. A study reported no adverse effects on growth, life span, or fertility in rats exposed to 100 ppm chlorine in their drinking water for their entire life span, over seven generations (EPA's Integrated Risk Information System, IRIS). Furthermore no information is available on the carcinogenic effects of chlorine in humans from inhalation exposure, and chlorine has not been found to be carcinogenic in oral animal studies. The EPA has not classified chlorine for carcinogenicity.

Chlorine is extremely irritating to the skin and can cause severe burns. Acute animal tests in rats and mice have shown chlorine to have high acute toxicity. Chlorine is a potent irritant in humans to the eyes, the upper respiratory tract, and the lungs.

Information on the toxicity of chlorine was studied and the relations between toxicity and exposure shown in Figure 4-1 were produced. The hazard categories were then defined more closely in terms of toxic effects and the relationships shown in Figure 4-2 were derived. In assessing the effects of toxic substances, consideration needs to be given to members of the public who may be more susceptible than the average adult worker i.e. children and the elderly.

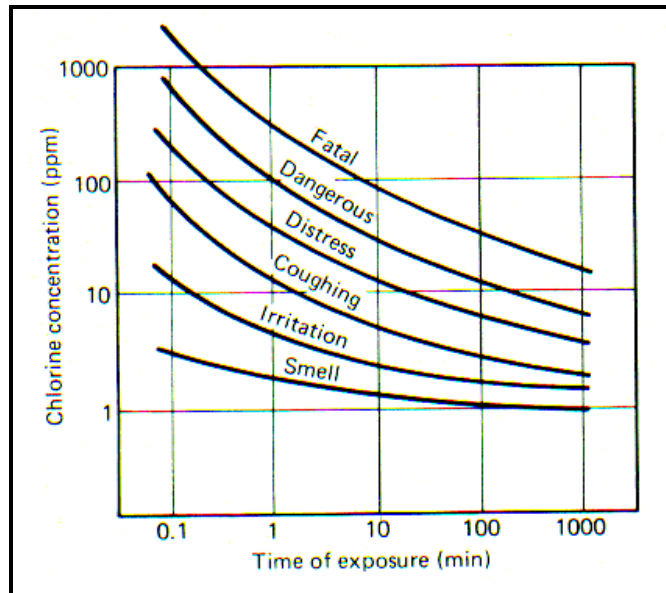


Figure 4-1 Effects of exposure to different concentrations of chronic vapour (Dicken, 1974).

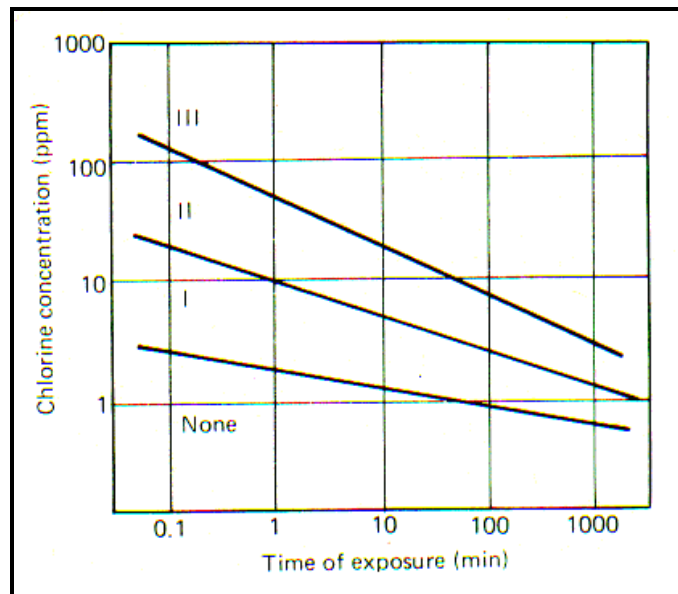


Figure 4-2 Categories of Chronic releases (Dicken, 1974). Four Categories of hazard were defined: *Category 0* involves no nuisance to the public; *Category I* = nuisance to the public (acceptable once per year); *Category II* = Could cause distress to people and damage to vegetation, could give rise to claim of compensation (acceptable once in 10 years); *Category III* = Could result in injury or loss of life (acceptable once in 100 years).

There have been a number of major accidents involving chlorine. Analysis has shown that, with one exception, fatalities occur within about 400m of the release and generally within 250m from the incident (Lees1994). Chlorine released from cylinders tends to have the

highest mortality index (fatalities/ t released). In this event, the amount of gas released is small but often occur within a building.

Chlorine accidents have involved storage tanks, portable cylinders as well as chlorine transported on trucks, railcars and ships. The worst incident occurred in 1939 at Zarnesti, Romania where a failure of a chlorine tank killed about 60 people.

#### **4.2.1.3 Diesel**

Diesel is a hydrocarbon mixture with variable composition with a boiling point range of between 252 and 371°C. It is a pale yellow liquid with a petroleum odour. Due to the flash point of diesel between 38 and 65°C, this material is not considered highly flammable but will readily ignite under suitable conditions.

Diesel is stable under normal conditions. It will react with strong oxidising agents and nitrate compounds may cause fires and explosions.

Diesel is not considered a toxic material. On contact with vapours may result in slight irritation to nose, eyes, skin. Vapours may cause headache, dizziness, loss of consciousness or suffocation; lung irritation with coughing, gagging, dyspnea, substernal distress and rapidly developing pulmonary oedema.

If swallowed, diesel may cause nausea or vomiting, swelling of the abdomen, headache, CNS depression, coma, death.

The long term effects of diesel exposure have not been determined, however this may affect lungs and may cause the skin to dry out and become cracked.

Diesel floats on water and can result in environmental hazards with large spills into waterways. It is harmful to aquatic life in high concentrations.

#### **4.2.1.4 Hydrogen**

Hydrogen is a colourless, odourless gas that is flammable gas over a wide range of vapour/air concentrations. Hydrogen vapour forms explosive mixture with air. Vapours or gases may travel considerable distances to ignition source and flash back.

Leaking hydrogen may ignite in the absence of any normally apparent source of ignition and if so, burns with a practically invisible flame that can instantly injure anyone coming in contact with it. Hydrogen gas is very light and rises rapidly in the air; concentrations may collect in the upper portions of buildings. Liquid hydrogen can solidify air and may create an explosion hazard.

Unlike hydrogen at normal temperatures, the very cold gas as it comes from the liquid is slightly heavier than air and may remain near ground level until it warms up. Fog formed when the cold gas contacts atmospheric moisture, indicates where the gas is spreading, but flammable mixtures may exist beyond the visible fog. Explosive atmospheres may linger. Under prolonged exposure to fire or intense heat the containers may rupture violently and rocket.

Hydrogen is incompatible with oxygen, oxidizing agents, air, lithium, and halogens. May react explosively at elevated temperatures or heating with alkali metals, halogens, oxygen, oxidizers, oxides, ozone, chlorides, di and trichlorides of nitrogen, and unsaturated hydrocarbons. Divided platinum and some other metals will cause a mixture of hydrogen and oxygen to explode at ordinary temperatures. Hydrogen embrittlement of steel and other metals such as nickel and copper-nickel alloys will occur at ambient temperatures on exposure to hydrogen gas at high pressures.

Hydrogen is not toxic but is a simple asphyxiate by the displacement of oxygen in the air. Exposure to liquid hydrogen may result in frostbite.

#### **4.2.1.5 LPG/Propane**

The primary constituent of Liquid Petroleum gas is propane. Propane is a colourless gas at room temperature with an odour of commercial natural gas. It has a low boiling point of -41.9°C and is often compressed and transported and sold as a liquid, primarily as a fuel.

Propane is a severe fire and explosion hazard with an invisible vapour that spreads easily and can be set on fire by many sources such as pilot lights, welding equipment, electrical motors, switches, etc. It is heavier than air and can travel along ground for some distance to an ignition source.

Propane is not compatible with strong oxidants and can result in fires and explosions.

Propane is not considered a carcinogenic material. The toxicology and the physical and chemical properties of propane suggest that overexposure is unlikely to aggravate existing medical conditions.

Overexposure to propane may cause dizziness & drowsiness. Effects of a single (acute) overexposure may result in asphyxiation due to lack of oxygen that could be fatal. Self-contained breathing apparatus may be required by rescue workers. Moderate concentrations may cause headache, drowsiness, dizziness, excitation, excess salivation, vomiting, and unconsciousness. Vapour contact with the skin will not cause any harm. However contact with liquid may cause frostbite due to low temperature of the liquid propane.

#### **4.2.1.6 Petrol/Gasoline**

Gasoline is a hydrocarbon mixture with variable composition with a boiling point range of between 20 and 215°C. It is a pale yellow liquid with strong petroleum odour. Due to the flash point of gasoline at minus 40°C, this material is considered highly flammable and will readily ignite under suitable conditions. The vapours of gasoline are heavier than air and may travel some distance to an ignition source.

Gasoline may contain up to 5% vol of benzene, a known animal carcinogen. It may also contain ethers and alcohols as oxygenates to a maximum concentration of 2%. Gasoline may also contain small quantities of multifunctional additives to enhance performance.

Gasoline is stable under normal conditions. It will react with strong oxidising agents and nitrate compounds may cause fires and explosions.

Although gasoline is of a low to moderate oral toxicity to adults, ingestion of small quantities may prove dangerous or fatal to small children.

Contact with vapours may result in slight irritation to nose, eyes, skin. Vapours may cause headache, dizziness, loss of consciousness or suffocation; lung irritation with coughing, gagging, dyspnea, subternal distress and rapidly developing pulmonary oedema.

If swallowed, gasoline may cause nausea or vomiting, swelling of the abdomen, headache, CNS depression, coma, death.

The long term effects of gasoline exposure have not been determined, however this may affect lungs and may cause the skin to dry out and become cracked.

Gasoline floats on water and can result in environmental hazards with large spills into waterways. It is harmful to aquatic life in high concentrations.

#### **4.2.2 Corrosive Liquids**

Corrosive liquids considered under this section are those chemicals that have a low or high pH that may burn if they comes into contact with people or they may attack and cause failure of equipment.

Substances that can be considered corrosive are; **ammonia, chlorine, caustic soda**

#### **4.2.3 Reactive Chemicals**

Reactive chemicals are chemicals that when mixed or exposed to one another react in a way that may cause a fire, explosion or release a toxic component.

Materials that react easily with other components include: **hydrogen, ammonia and chlorine. Chlorine will react with organic materials with a fire and explosion hazard**

#### **4.2.4 Flammable materials**

Flammable materials are those that can ignite to give a number of possible hazardous effects, depending on the actual material and conditions. These are flash fires, explosion, fireball, jet fire or pool fire.

The flammable and combustible materials on site are listed below. All these components have been analysed for fire risks.

**Table 4-1 Flammable and combustible materials on site**

| <b>Compound</b> | <b>Flash Pt. (°C)</b> | <b>Boil Pt. (°C)</b> | <b>Comment</b> |
|-----------------|-----------------------|----------------------|----------------|
| LPG/Propane     | -103.5                | -42                  | Flammable gas  |
| Petrol          | -40                   | ~87                  |                |
| Diesel          | 57                    | 290                  |                |
| Hydrogen        | N/A                   | N/A                  | Flammable gas  |



#### 4.2.5 Toxic materials

Toxic materials of interest to this study are those that could give dispersing vapour clouds upon release into the atmosphere. These could subsequently cause harm through inhalation or absorption through the skin. Typically the hazard posed by a toxic material will depend both on concentration of the material in the air and the exposure duration.

Materials as listed by EPA as Extremely Hazardous Substances are given in Table 4-2

**Table 4-2 Components classified by EPA as extremely hazardous**

| COMPOUND | ERPG-1<br>( mg/m <sup>3</sup> ) | ERPG-2<br>( mg/m <sup>3</sup> ) | ERPG-3<br>( mg/m <sup>3</sup> ) |
|----------|---------------------------------|---------------------------------|---------------------------------|
| Chlorine | 3                               | 7.5                             | 60                              |
| Ammonia  | 17.6                            | 105                             | 525                             |

**Emergency Response Planning Guidelines (ERPG's)** as developed by the **American Industrial Hygiene Association**

**ERPG-1:** Is the maximum airborne concentration below which it is believed 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 odour.

**ERPG-2:** Is the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

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

#### 4.3 Physical Properties

A summary of relevant physical properties for the identified hazardous substances are summarised in Appendix B.

#### 4.4 Materials Not Considered in this Study

Materials stored on site that were not considered in this study are listed below in Table 4-3. These materials are predominately small volume materials that will be kept in a store.

With a loss of containment of any of the listed components would not result in a major incident as they are difficult to ignite or would not release significant amounts of toxic gases.

**Table 4-3 Materials not considered in the study**

| Description                              | UMC            | On Hand QTY as at Aug 2006 | Reasons for Exclusion          |
|--|----------------|----------------------------|--------------------------------|
| CHEMICAL:ACETONE,LIQUID,5 L TIN          | L              | 100                        | Small quantities               |
| CHEMICAL: CAUSTIC SODA                   | M <sup>3</sup> | unknown                    | Non flammable, no toxic clouds |
| CHEMICAL:CHEMICIDE BCH,TABLET,25 KG      | KG             | 275                        | Small quantities               |
| CHEMICAL:SODIUM CARBONATE,GRANULAR,50 KG | KG             | 0                          | Small quantity, non flammable  |
| CHEMICAL:SODIUM CHLORIDE,CRYSTAL,50 KG   | KG             | 0                          | Small quantity, solid          |
| GAS:ACETYLENE,99.0 %,8.6 KG CYLINDER     | EA             | 22                         | Small quantity gas cylinders   |
| GAS:ARGON,INSTRUMENTAL,16.9 KG CYLINDER  | EA             | 4                          | Small quantity gas cylinders   |
| GAS:ARGON,TECH,14.5 KG CYLINDER          | EA             | 1                          | Small quantity gas cylinders   |

**VULNERABILITY STUDY FOR THE PROPOSED COAL FIRED POWER STATION & ASSOCIATED INFRASTRUCTURE IN THE WITBANK GEOGRAPHICAL AREA**

| Description                              | UMC | On Hand QTY as at Aug 2006 | Reasons for Exclusion            |
|--|-----|----------------------------|----------------------------------|
| GAS:ARGON/CARBON,17.8 KG CYLINDER        | EA  | 1                          | Small quantity gas cylinders     |
| GAS:CARBON DIOXIDE,TECH,31.5 KG          | EA  | 94                         | Small quantity gas cylinders     |
| GAS:HYDROGEN,TECH,0.62 KG CYLINDER       | EA  | 25                         | Small quantity gas cylinders     |
| GAS:LPG,50/50%, 19 KG CYLINDER           | EA  | 1                          | Small quantity gas cylinders     |
| GAS:LPG,50/50%,48KG CYLINDER             | EA  | 2                          | Small quantity gas cylinders     |
| GAS:NITROGEN,HIGH,11 KG CYLINDER         | EA  | 40                         | Small quantity gas cylinders     |
| GAS:NITROGEN,OXYGEN,98%,2%               | EA  | 2                          | Small quantity gas cylinders     |
| GAS:OXYGEN TECH,99.5%,11.8 KG CYLINDER   | EA  | 25                         | Small quantity gas cylinders     |
| GREASE,ALPHA GEL 370 15KG                | KG  | 0                          | Small quantity, high flash point |
| GREASE,CASTROL SPHEEROL EP2 15KG         | EA  | 32                         | Small quantity, high flash point |
| GREASE,IND:SHELL ALVANIA RL2,GEN PURPOSE | KG  | 68                         | Small quantity, high flash point |
| GREASE,IND:SHELL ALVANIA RL3,GEN PURPOSE | KG  | 54                         | Small quantity, high flash point |
| GREASE,OPEN GEAR & WIRE ROPE SPRAY 350G  | EA  | 120                        | Small quantity, high flash point |
| LUBRICANT:ANTI-SEIZE,LIQUID AEROSOL,400G | EA  | 80                         | Small quantities                 |
| LUBRICANT:ANTI-SEIZE,PASTE,500 GRAM TIN  | EA  | 86                         | Small quantities                 |
| LUBRICANT:GRAPHITE,1 KG PLASTIC BAG      | KG  | 10                         | Small quantities                 |
| LUBRICANT:GRAPHITE,325 ML AEROSOL CAN    | EA  | 56                         | Small quantities                 |
| LUBRICANT:NC,GEAR SHIELD,210 L DRUM      | L   | 2,100                      | Small quantities                 |
| LUBRICANT:NICKEL ANTI-SIEZE,PASTE        | EA  | 91                         | Small quantities                 |
| LUBRICANT:PENETRATING,650 ML             | EA  | 76                         | Small quantities                 |
| LUBRICANT:PENETRATING,800 ML             | EA  | 12                         | Small quantities                 |
| OIL,AUTO:AGIP DIESEL SIGMA HD30,ENGINE   | L   | 240                        | Small quantities                 |
| OIL,AUTO:AGIP SM0,SAE 20W50,20 L         | L   | 120                        | Small quantities                 |
| OIL,AUTO:SHELL HELIX SUPER,PETROL        | EA  | 220                        | Small quantities                 |
| OIL,HYDRAULIC TELLUS S100 20L            | L   | 160                        | Small quantities                 |
| OIL,HYDRAULIC TELLUS T37 20L             | L   | 220                        | Small quantities                 |
| OIL,INDUS:AGIP BLASIA100,20 L,GEAR       | L   | 80                         | Small quantities                 |
| OIL,INDUS:AGIP BLASIA220,20 L,GEAR       | L   | 340                        | Small quantities                 |
| OIL,INDUS:AGIP BLASIA220,210 L,GEAR      | L   | 1,050                      | Small quantities                 |
| OIL,INDUS:AGIP BLASIA320,20 L,GEAR       | L   | 1,000                      | Small quantities                 |
| OIL,INDUS:AGIP BLASIA460,20 L,GEAR       | L   | 580                        | Small quantities                 |
| OIL,INDUS:AGIP BLASIA68,20 L,GEAR        | L   | 300                        | Small quantities                 |
| OIL,INDUS:AGIP DICREA100,18 KG           | KG  | 36                         | Small quantities                 |
| OIL,INDUS:AGIP OSO32,20 L,HYDRAULIC      | L   | 620                        | Small quantities                 |
| OIL,INDUS:AGIP OSO68,20 L,HYDRAULIC      | L   | 1,560                      | Small quantities                 |
| OIL,INDUS:AGIP OTE46,180 KG,TURBINE      | KG  | 1,080                      | Small quantities                 |
| OIL,INDUS:BP ENERGOL THB32,210 L,TURBINE | L   | 0                          | Small quantities                 |
| OIL,INDUS:BP ENERGOL THZ32,210L          | L   | 2,940                      | Small quantities                 |
| OIL,INDUS:ENGEN GENGEAR 220 CODE 5133    | L   | 840                        | Small quantities                 |
| OIL,INDUS:ENGEN GENGEAR 320,210 L        | L   | 3,130                      | Small quantities                 |
| OIL,INDUS:TELLUS T37,210 L               | L   | 840                        | Small quantities                 |
| PAINT,AEROSOL WHITE 275G                 | EA  | 7                          | Small quantities                 |
| PAINT,ENAMEL L/BLUE VIP GLOSS 5L         | L   | 205                        | Small quantities                 |
| PAINT,PVA WHITE 5L                       | L   | 120                        | Small quantities                 |
| PAINT,STOEP GREEN CODE SP2 5L            | L   | 35                         | Small quantities                 |
| PAINT:ENAMEL,BLACK,HIGH GLOSS FINISH     | L   | 20                         | Small quantities                 |
| PAINT:ENAMEL,BLACK,HIGH GLOSS FINISH     | L   | 20                         | Small quantities                 |
| PAINT:ENAMEL,DARK GREY,5L TIN            | L   | 25                         | Small quantities                 |
| PAINT:ENAMEL,GOLDEN YELLOW,5 L TIN       | L   | 15                         | Small quantities                 |
| PAINT:ENAMEL,SIGNAL RED,5 L TIN          | L   | 10                         | Small quantities                 |
| PAINT:ENAMEL,WHITE,HIGH GLOSS,5L TIN     | L   | 95                         | Small quantities                 |
| PAINT:QUICK DRY,DARK ADMIRALTY GREY,MATT | L   | 10                         | Small quantities                 |
| SOLVENT:ELECTRICAL CLEANER               | EA  | 0                          | Small quantities                 |

**VULNERABILITY STUDY FOR THE PROPOSED COAL FIRED POWER STATION & ASSOCIATED INFRASTRUCTURE IN THE WITBANK GEOGRAPHICAL AREA**

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| Description                             | UMC | On Hand QTY as at Aug 2006 | Reasons for Exclusion                           |
|---|-----|----------------------------|---|
| SOLVENT:ENVIRO-FO655,ELECTRICAL CLEANER | L   | 2,250                      | Small quantity (limited individual containment) |
| SOLVENT:ICE113,DEGREASER,25 L DRUM      | L   | 900                        | Small quantities                                |

## **5 PHYSICAL AND CONSEQUENCE MODELLING**

On order to predict the impact following an accident, it is necessary to first estimate the physical process of the release (i.e. rate and size, and the subsequent atmospheric dispersion of the airborne cloud, or in the case of ignition, the burning rate, the resulting thermal radiation or the overpressures from an explosion.

The second step is then to estimate the consequences of a release on humans, fauna, flora and structures. The consequences would be due to the toxicity, thermal radiation and/or explosion overpressures. The consequences may be described in various formats. The simplest methodology follows a comparison of predicted concentrations (or thermal radiation, or overpressures) to short-term concentration (or radiation or pressure) guideline values.

### **5.1 Vapour Clouds**

The purpose of considering vapour clouds emanating from toxic material is to identify areas in the community that may be affected or exposed, or individuals in the community who may be subject to injury or death from an accidental release of toxic vapours from the facility.

A toxic vapour cloud can occur when:

- a toxic gas is released under pressure;
- when a toxic liquid spills and evaporates;
- when material combusts forming toxic gases; or,
- when products react forming toxic gases.

#### **5.1.1 Chlorine**

The chlorine is delivered to site in 925 liquid chlorine drums. A typical connection arrangement would ensure that only gaseous chlorine is delivered to the piping manifold. In the event of a leak in the piping gaseous chlorine will be released into the atmosphere.

In the event of liquid loss from the drum there would be a flashing of the liquid leaving the drum. The remaining liquid chlorine will evaporate over time with the rate of evaporation being a function of exposed surface area and ambient temperature.

A failure of a chlorine drum under worst case meteorological conditions could result in an endpoint distance to the ERPG-2<sup>1</sup> guidelines of 5.6 km from the release. This distance has potential to result in an offsite incident and may qualify the site as a Major Hazard Installation.

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1. **ERPG-2** is the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

### 5.1.2 Ammonia

Ammonia was assumed to be delivered to site in pressurised vessels. These vessels containing 1500 kg each of anhydrous ammonia are offloaded from a truck and placed in position by a crane located on the truck

The ammonia in the vessels is a liquid state with the pressure of the vessel determined by the atmospheric pressure and the temperature of the contained liquid. The vessel can be piped to deliver either liquid or vapour to the end user.

For this simulation 2 scenarios were considered.

i. Catastrophic failure of the vessel

The Catastrophic failure of one vessel assumes the entire loss of the vessel inventory in 900 seconds i.e. a liquid flow rate of 1.67 kg/s. The liquid pool would extend over an area of 150 m<sup>2</sup>. The total airborne rate was calculated at 2.38 kg/s. **The large endpoint from this scenario has potential to result in an offsite incident and may qualify the site as a Major Hazard Installation.**

ii. 5 mm Hole on a single vapour line

A 5mm hole is the most probable scenario and likely to occur at some point in the plant's lifetime. This is due to the fact that the vessels are coupled and uncoupled each time a new vessel is brought on site. The resulting airborne rate was calculated at 0.23 kg/s with an ERPG-2 endpoint of 130 m. Fatalities could occur at distances less than 16 m from the source of the leak.

**Table 5-1 Endpoint distances for accidental ammonia releases**

| Scenario                         | Airborne rate (kg/s) | Endpoint distance (m) |  |
|----------------------------------|----------------------|-----------------------|--|
|                                  |                      | ERPG-2 <sup>1</sup>   | LC <sub>50</sub> <sup>2</sup> (30 minutes) |
| Catastrophic failure of 1 vessel | 2.38                 | 1800                  | 170  |
| 5 mm Vapour hole                 | 0.023                | 130                   | 16   |

1. **ERPG-2**

Is the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

2. **Lethal concentration (LC).**

A concentration by which a given percentage of the exposed population will be fatally injured. The LC<sub>50</sub>, refers to the concentration of airborne material the inhalation of which results in death of 50% of the test group. The period of inhalation exposure could be from 30 min to a few hours (up to 4 hours).

### 5.2 Fires

Combustible materials within their flammable limits may ignite and burn if exposed to an ignition source of sufficient energy. On process plants, this normally occurs as a result of a leakage or spillage. Depending on the physical properties of the material and the operating parameters, the combustion of material in a plant may take on a number of forms i.e. pool fires, jet fires and flash fires.

### 5.2.1 Thermal Radiation

The effect of thermal radiation is very dependent on the type of fire and duration exposed to the thermal radiation. Codes such as API 520 and 2000 suggest the maximum heat absorbed on vessels for adequate relief designs to prevent the vessel from failure due to overpressure. Other codes such as API 510 and BS 5980 give guidelines for the maximum thermal radiation intensity as a guide to equipment layout.

The effect of thermal radiation on human health has been widely studied with many relations developed relating injuries to the time and intensity of the radiation exposed. Two values normally quoted is 1.5 kW/m<sup>2</sup> or “safe” value where people can be exposed for long period of time and 5 kW/m<sup>2</sup> for people performing emergency operation for short periods of time.

**Table 5-2 Thermal Radiation Guidelines (BS 5980 –1990)**

| <b>Thermal Radiation Intensity (kW/m<sup>2</sup>)</b> | <b>Limit</b>   |
|---|--|
| 1.5   | Will cause no discomfort for long exposure   |
| 2.1   | Sufficient to cause pain if unable to reach cover within 40 seconds                |
| 4.5   | Sufficient to cause pain if unable to reach cover within 20 seconds                |
| 12.5  | Minimum energy required for piloted ignition of wood and melting of plastic tubing |
| 25  | Minimum energy required to ignite wood at indefinitely long exposures              |
| 37.5  | Sufficient to cause serious damage to process equipment                            |

### 5.2.2 Bund and Pool Fires

The pool fires being either tank or bund fires consist of large volumes of flammable material at atmospheric pressure burning in an open space. The flammable material will be consumed at the burning rate depending on factors including the prevailing winds. During combustion heat will be released in the form of thermal radiation. Temperatures close to the flame centre will be high but will reduce rapidly to tolerable temperatures over a relatively short distance. Any plant building or persons close to the fire or within the intolerable zone will experience burn damage with the severity depending on the distance from the fire and the time exposed to the heat of the fire.

In the event of a pool fire the flames will tilt according to the wind speed and direction. The flame length and tilt angle affect the distance of thermal radiation generated.

Pool fires of petrol and diesel could occur with the loss of containment of the delivery tanker. Assuming the liquid spreads evenly to a depth of 1 cm on a large release before ignition, the fire would burn for approximately 3 minutes having a maximum flame height of 44 m. The burning pool will diminish rapidly during combustion, which was estimated to last

approximately 3 minutes, The maximum distance to 25 kW/m<sup>2</sup>, the closest approach distance of emergency personnel and vehicles, was calculated at 29 m from the edge of the flames. The distance to 5 kW/m<sup>2</sup>, the distance for emergency escape, was calculated at 76.5 m from the edge of the flame. Depending on the layout, a petrol/diesel fire would unlikely to result in an offsite incident.

### 5.2.3 Jet fires

Jet fires occur when flammable material of a high exit velocity ignites. In process industries this may be due to design (flares) or accidental. Ejection of flammable material from a vessel, pipe or pipe flange may give rise to a jet fire and in some instances the jet flame could have substantial “reach”. Depending on wind speed, the flame may tilt and impinge on pipelines, equipment or structures. The thermal radiation from these fires may cause injury to people or damage equipment some distance from the source of the flame.

#### 5.2.3.1 Hydrogen

Hydrogen is produced on site or delivered to site in high pressure containers. A loss of containment of hydrogen and a subsequent ignition could result in a jet fire . In the event of an ignition, hydrogen burns with an almost invisible flame. This hazard can remain undetected for some time or until an injury has occurred.

The following scenarios (listed below) have been considered:

##### 1. Jet fire from a low pressure pipe rupture

Assuming hydrogen is generated and piped to users at a low pressure of 54 kPa (g), the maximum flame length of 10.8 m will be reached. The maximum thermal radiation of 26 kW/m<sup>2</sup> will be reached and will damage plastics and equipment and injure people from direct impingement of the flame.

##### 2. Jet fire from a high pressure pipe rupture

Hydrogen cylinders have pressure typically of 165 bar. In the event of a loss of containment, the hydrogen will initially escape with critical velocity but may reduce as the inventory diminishes and the supply pressure drops.

Assuming the size of the hydrogen line is 20 mm, the maximum flame length of hydrogen flame is given in Table 5-3. The flame can be in any orientation on the line with some situations being more serious than others. It is expected that a horizontal flame will be more serious than flames in other orientations. The maximum radiation of any of the jet flames can result in equipment damage and injury to people from a direct impingement of the flame.

**Table 5-3 Jet fires from a loss of containment of high pressure hydrogen**

|   | Hole Size(mm)     | Flow Rate (kg/s) | Maximum Flame Length (m) | Max Thermal Radiation (kW/m <sup>2</sup> ) |
|---|-------------------|------------------|--------------------------|--|
| 1 | 5 mm              | 0.16             | 9.6                      | 47.5                                       |
| 2 | Full Bore Rupture | 1.82             | 34.7                     | 56.7                                       |

### **5.3 Vapour Cloud Explosion Consequences**

A release of combustible gases into the atmosphere could result in the formation of a vapour cloud. The concentration of the combustible component decreases from the point of release to the lower explosive limits (LEL), where the concentration of the component can no longer ignite. The material contained in the vapour cloud between the higher explosive limits (HEL) and the lower explosive limit (LEL), if ignites will form a flash fire or a fireball. The sudden detonation of the explosive mass of material causes an overpressure that can result in injury or damage to property.

An explosion may give rise to any of the following effects:

- Blast damage;
- Thermal damage;
- Missile damage;
- Ground tremors;
- Crater formation; and/or,
- Personal injury

These obviously depend on the pressure waves and proximity to the actual explosion. Of concern in this investigation are the “far distance” effects, such as limited structural damage and the breakage of windows, rather than crater formations. Table 5-4 gives a more detailed summary of the damage produced by an explosion for various over-pressures. The most commonly used overpressure is the “0.3 psi” value. This corresponds to a “Safe Distance”, at which approximately 10% of glass windows are broken.



**Table 5-4 Summary of consequences of blast overpressure (Clancey 1972)**

| Pressure (gauge) |             | Damage   |
|------------------|-------------|--|
| Psi              | kPa         |  |
| 0.02             | 0.138       | Annoying noise (137 dB), if of low frequency (10 - 15 Hz).   |
| 0.03             | 0.207       | Occasional breaking of large glass windows already under strain.   |
| 0.04             | 0.276       | Loud noise (143 dB). Sonic boom glass failure.   |
| 0.1              | 0.69        | Breakage of windows, small, under strain.  |
| 0.15             | 1.035       | Typical pressure for glass failure.  |
| 0.3              | 2.07        | 'Safe distance' (probability 0.95 no serious damage beyond this value). Missile limit. Some damage to house ceilings; 10% window glass broken.                               |
| 0.4              | 2.76        | Limited minor structural damage.   |
| 0.5 – 1.0        | 3.45 – 6.9  | Large and small windows usually shattered; occasional damage to window frames.   |
| 0.7              | 4.83        | Minor damage to house structures.  |
| 1.0              | 6.9         | Partial demolition of houses, made uninhabitable.  |
| 1.0 – 2.0        | 6.9 – 13.8  | Corrugated asbestos shattered. Corrugated steel or aluminium panels, fastenings fail, followed by buckling. Wood panels (standard housing) fastenings fail, panels blown in. |
| 1.3              | 8.97        | Steel frame of clad building slightly distorted.   |
| 2.0              | 13.8        | Partial collapse of walls and roofs of houses.   |
| 2.0 – 3.0        | 13.8 - 20.7 | Concrete or cinderblock walls, not reinforced shattered.   |
| 2.3              | 15.87       | Lower limit of serious structural damage.  |
| 2.5              | 17.25       | 50% destruction of brickwork of house.   |
| 3.0              | 20.7        | Heavy machines (1.4 tonne) in industrial building suffered little damage. Steel frame building distorted and pulled away from foundations.                                   |
| 3.0 – 4.0        | 20.7 – 27.6 | Frameless, self-framing steel panel building demolished.   |
| 4.0              | 27.6        | Cladding of light industrial buildings demolished.   |
| 5.0              | 34.5        | Wooden utilities poles (telegraph, etc.) snapped. Tall hydraulic press (18 tonne) in building slightly damaged.  |
| 5.0 – 7.0        | 34.5 – 48.3 | Nearly complete destruction of houses.   |
| 7.0              | 48.3        | Loaded train wagons, overturned.   |
| 7.0 – 8.0        | 48.3– 55.2  | Brick panels (20 – 30 cm) not reinforced, fail by shearing or flexure.   |
| 9.0              | 62.1        | Loaded train boxcars completely demolished.  |
| 10.0             | 69.0        | Probable total destruction buildings. Heavy (3 tonnes) machine tools moved and badly damaged. Very heavy (12 000 lb/5443 kg) machine tools survived.                         |
| 300              | 2070        | Limit of crater lip.   |

### **5.3.1 Un-Confined gas explosions**

A confined gas explosion is where the exploding gas is restricted from expanding by physical barriers such as walls or equipment and obstacles. An unconfined gas explosion is where the exploding gas is unrestricted from expanding by physical barriers such as walls or equipment and obstacles. The bulk LPG tank (as indicated in the plot plan) is located away from other activities. An accidental explosion would thus result in an unconfined explosion.

The unconfined explosion from the loss of containment of the full contents of the LPG vessel averaged over 10 minutes assuming 100% flash and subsequent detonation was simulated. The distance to safety (2 kPa) was calculated at 345 m. Maximum overpressure was calculated at 4.25 kPa which would be unlikely to result in an offsite incident.

### **5.3.2 BLEVE**

A Boiling Liquid Expanding Vapour Explosion (BLEVE) can occur when a flame impinges on a propane pressure vessel, particularly in the vapour space region where cooling by evaporation of the contained LPG does not occur. The vessel shell weakens, ruptures with a total loss of contents, and the issuing mass of propane burns as a massive fireball.

The simulations assumed an explosive amount of 8000 kg. The radius of the fireball was estimated to be 60 m, with duration of 8.8 seconds. The lift-off height was calculated to be 120 m.

The major consequences of a BLEVE are the intense thermal radiation from the fireball, a blast wave and fragments from the shattered vessel. These fragments may be projected to considerable distances. Analyses of the travel range of fragment missiles from a number of BLEVE's suggest that the majority land within 700 m from the incident. A blast wave from a BLEVE is fairly localised, but can cause significant damage to immediate equipment. A blast wave from a BLEVE would develop a maximum overpressure of 4.25 kPa. The distance to safety (2kPa) would extend 222 m.

## **6 RISKS**

Risk is the product of the severity of an incident and the likelihood of that incident occurring. In the previous section worst case consequences were simulated and discussed. This section addresses the likelihood of such events. As the detailed design has not been completed, the event trees for determining the frequencies of failure could not be developed, however a qualitative likelihood of incidents will be given, based on experience, engineering judgements guided by similar historical events.

Having characterised a risk and obtained a risk level, the investigator has to recommend whether the outcome is acceptable. In contrast to the employees in a plant, which may be assumed healthy, the adopted exposure assessment applies to an *average* population group that also includes sensitive sub-populations. Sensitive sub-population groups are those people that for reasons of age or medical condition have a greater than normal response to contaminants. Health guidelines and standards used to establish risk normally incorporate safety factors that address this group.

Among the most difficult tasks of risk characterisation is the definition of an *acceptable risk*. An attempt to account for risks in manner similar to those used in everyday life, using the "risk ALARP triangle". This involves deciding:

- Whether a risk is so high that something must be done about it;
- Whether the risk is, or has been made, so small that no further precautions are necessary; or
- If a risk falls between these two states, it has been reduced to levels as low as reasonably practical (ALARP).

Events as described in the previous section were ranked according to the severity and likelihood of these events occurring, and depicted in the Risk Ranking table below. The likelihood of the events are based on available design basis and judgement of the author. As such, the risks indicated in the table below should be used as a guide and hazard identification only. A quantitative risk assessment would be a more accurate and precise determination of the risks. At this point in the design, the risk matrix approach is satisfactory to identify risks and to determine where mitigation is necessary prior to the commencement of detail design.

From the risk matrix, some of considered scenarios have sufficiently high risks to consider mitigation with the most severe being a chlorine and ammonia release.



## **7 REDUCTION OF RISK**

Reduction of risks is an important part of risk assessments. As detailed design for the project has still to commence, only general remarks can be made.

From the risk analysis the most significant off-site consequences would be a large release of chlorine or ammonia.

In order to reduce the onsite and offsite risks and be compliant with the Major Hazard Installation, special attention must be given to the designs, layouts and emergency plans of all identified hazardous materials.

It is suggested that safety reviews such as Hazop studies or equivalent be done at various stages of the project in order to guide the design team to meet the legislative requirements.

## **8 CONCLUSIONS**

Risk calculations are not precise. The accuracy of the predictions is determined by the quality of base data and expert judgements.

The risk assessment was done on the assumption that the site will be maintained to an acceptable level and that all-statutory regulations are applied. It was also assumed that the detailed engineering designs will be done by competent people and are correctly specified for the intended duty. For example, it is assumed that the tank walls thicknesses will be correctly calculated, that the vents will be sized for emergency conditions, that the instrumentation and electrical components comply with the specified electrical area classification, that the material of construction is compatible with the products, etc. It is the responsibility of Eskom to ensure that all engineering designs will be completed and installed correctly.

A number of incident scenarios were simulated, taking into account the prevailing meteorological conditions and described in the sections above.

The following conclusions were reached.

### **8.1 Fires**

Pool fires from diesel and petrol would have predominantly onsite consequences. Jet fires from high pressure hydrogen could have substantial reach, but offsite consequences would be unlikely and dependant on the plant layout

### **8.2 Explosions**

Explosions from the bulk LPG storage would not generate sufficient overpressure to cause major damage and injuries, provided the tank is place in an unconfined area.

### **8.3 Vapour Clouds**

Toxic vapour clouds from a release of chlorine and ammonia could have substantial endpoints to a maximum distance of 5.6 km for a chlorine release. Thus a large release of chlorine or ammonia has a potential for an offsite consequences.

### **8.4 Major Hazardous Installation (MHI)**

A release of chlorine or ammonia could result in an offsite incident. As such, the facility has the potential to be classified as a Major Hazard Installation in accordance to the regulations. However an accurate assessment of the risks from the facility can only be made when details designs have been completed.

## **9 RECOMMENDATIONS**

As a result of the risk assessment study, the following is recommended.

### **9.1 Site Recommendations**

Both the prospective sites are located in rural areas with no bordering residential communities. The hazardous material related risks at both sites can be mitigated to within acceptable limits or sufficient buffer zones can be applied between the hazardous materials and nearby communities. Thus, this study does not recommend one site above another.

### **9.2 Major Hazardous Installation Risk Assessment**

As offsite consequences are possible, a quantitative risk assessment would be required in terms of the Major Hazardous Installation (MHI) Regulations (July 2001) prior to project construction.

### **9.3 Project Approval**

Large coal based power plants have been installed around the world having acceptable risks. While consequences of the facility may extend beyond the sites boundary, the design and layout of the facility can be engineered to acceptable risks.

This study did not reveal any features with respect to the hazardous materials risks at the proposed development at either of the two sites that could be considered as fatal or other flaws preventing the further development of this project.. The final designs must demonstrate engineering and organisational measures to reduce risks to acceptable levels. Final acceptance of risks will be done after the MHI risk assessment has been completed based on the detailed engineering designs and layouts.

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## **11 APPENDIX A: NOTIFICATION OF PROPOSED MAJOR HAZARD INSTALLATION**

Prior to the assessment of the potential impact of the various accidental spills, reference needs to be made to the legislation, regulations and guidelines governing the operation of the proposed development.

On 16 January 1998, the Major Hazard Installation Regulations was promulgated under the Occupational Health and Safety Act 1993 (Act No 85 of 1993), with a further amendment on 30 July 2001. The provisions of the regulations apply to installations, which have on their premises a quantity of a substance, which can pose a significant risk to the health, and safety of employees and the public.

The regulations essentially consists of six parts, namely

1. The duties for notification of a major hazard installation (existing or proposed), including
  - a. Fixed (see Box A.1); and,
  - b. Temporary installations.
2. The minimum requirements for a quantitative risk assessment (see Box A.2);
3. The requirements of an on-site emergency plan (see Box A.3);
4. The reporting steps of risk and emergency occurrences (see Box A.4);
5. The general duties required of suppliers; and,
6. The general duties required of local government.

### **BOX A.1 - NOTIFICATION OF INSTALLATION**

- Applications need to be made in writing to the relevant local authority and the provincial director for permission:
  - ▶ To erect any major hazard installation.
  - ▶ Prior to the modification of any existing installation, which may significantly increase the risk, related to it (e.g. increased storage or production capacity or alteration of process).
- Applications need to include the following information:
  - ▶ Physical address of installation;
  - ▶ Complete material safety data sheets of all hazardous substances;
  - ▶ Maximum quantity of each substance envisaged to be on the premises at any one time;
  - ▶ The risk assessment of the installation (see Box A.2); and,
  - ▶ Any further information that may be deemed necessary by an inspector in the interests of health and safety to the public.
- Applications need to be advertised in at least one newspaper serving the surrounding communities, and by way of notices posted within these communities.

**BOX A.2 - THE RISK ASSESSMENT**

- The risk assessment is the process of collecting, organising, analysing, interpreting, communicating and implementing information in order to identify the probable frequency, magnitude and nature of any major incident which could occur at a major hazard installation, and the measures required to remove, reduce or control the potential causes of such an incident.
- Risk assessments need to be undertaken at intervals not exceeding five years and need to be submitted to the relevant local emergency services.
- Copies of the risk assessment must be made available to the relevant health and safety committee, and give them 60 days within which to comment thereon and ensure that the results of the assessment be made available to the relevant representative or committee who may comment thereon.
- Risk assessments should be undertaken by competent person(s) and include the following:
  - ▶ General process description;
  - ▶ Description of major incidents associated with this type of installation and the consequences of such incidents (including potential incidents);
  - ▶ Estimate of the probability of a major incident;
  - ▶ The on site emergency plan;
  - ▶ Estimate the total result in the case of an explosion;
  - ▶ Estimate of the effects of thermal radiation in the case of fire;
  - ▶ Estimate concentration effects in the case of a toxic release;
  - ▶ Potential effect of a major incident at one major hazard installation on an adjacent major hazard installation or part thereof;
  - ▶ Potential effect of a major incident on any other installation, members of the public (including all persons outside the premises) and on residential areas;
  - ▶ Meteorological tendencies;
  - ▶ Suitability of existing emergency procedures for the risks identified;
  - ▶ Any requirements laid down in terms of the Environmental Conservation Act, 1989 (Act No. 73 of 1989); and,
  - ▶ Any organisational measures that may be required.
- The employer shall ensure that the risk assessment is of an acceptable standard and is reviewed should:
  - ▶ It be suspected that the preceding assessment is no longer valid;
  - ▶ Changes in the process affect hazardous substances;
  - ▶ Changes in the process involve a substance resulting in the installation being classified a major hazardous installation or in the methods, equipment or procedures in the sue, handling or processing of that substance; or,
  - ▶ Incidents that have brought the emergency plan into operation may affect the existing risk assessment.
- Risks assessment must be made available for scrutiny by any interested or affected person that may be affected by the activities, at a time, place and in a manner agreed upon between the parties.

**BOX A.3 – ON-SITE EMERGENCY PLAN**

- After submission of the notification, the following shall be established:
  - ▶ An on-site emergency plan must be available which is to be followed inside the premises of the installation or part of the installation classified as a major hazard installation in consultation with the relevant health and safety representative or the relevant health and safety committee.
  - ▶ The emergency plan must be discussed with the relevant local government taking into consideration any comment on the risk related to the health and safety of the public.
  - ▶ The on-site emergency plan has to be reviewed and, where necessary, update the plan, in consultation with the relevant local government, at least once every three years.
  - ▶ A copy of the on-site emergency plan shall be signed in the presence of two witnesses, who shall attest the signature.
  - ▶ Ensure that the on-site emergency plan is readily available at all times for implementation and use.
  - ▶ Ensure that all employees are conversant with the on-site emergency plan.
  - ▶ Cause the on-site emergency plan to be tested in practice at least once a year and keep a record of such test.
- Any employer, self-employed person and user owning or in control of a pipeline that could pose a threat to the general public shall inform the relevant local government and shall be jointly responsible with the relevant government for the establishment and implementation of an on-site emergency plan.

**BOX A.4 – Reporting of Risk and Emergency Occurrences**

- Following an emergency occurrence, the user of the installation shall:
  - ▶ Subject to the provisions of regulation 6 of the General Administrative Regulations, within 48 hours by means of telephone, facsimile or similar means of communication inform the chief inspector, the provincial director and relevant local government of the occurrence of a major incident or an incident that brought the emergency plan into operation or any near miss.
  - ▶ Submit a report in writing to the chief inspector, provincial director and local government within seven days.
  - ▶ Investigate and record all near misses in a register kept on the premises, which shall at all times be available for inspection by an inspector and the local government.

The duties of the supplier refer specifically to

- The supply of material safety data sheets for the hazardous substances employed or contemplated in the installation;
- Assess the circumstances and substance involved in an incident or potential incident and inform all persons being supplied with that substance, of the potential dangers surrounding it; and,
- Provide a service that shall be readily available on a 24-hour basis to all employers, self-employed persons and users, the relevant local government and any other body concerned, to provide information and advice in the case of a major incident with regard to the substance supplied.

The duties of local government are summarised as follows:

*“..... 9. (1) Without derogating from the provisions of the National Building Regulations and Building Standards Act, 1977 (Act No. 103 of 1977), no local government shall permit the erection of a new major hazard installation at a separation distance less than that which poses a risk to-*

- (a) Airports;*
- (b) Neighbouring independent major hazard installations;*
- (c) Housing and other centres of population; or*
- (d) Any other similar facility:*

Provided that the local government shall permit new property development only where there is a separation distance which will not pose a risk in terms of the risk assessment: Provided further that the local government shall prevent any development adjacent to an installation that will result in that installation being declared a major hazard installation.

*(2) Where a local government does not have facilities available to control a major incident or to comply with the requirements of this regulation, that local government shall make prior arrangements with a neighbouring local government, relevant provincial government or the employer, self-employed person and user for assistance.*

*(3) All off-site emergency plans to be followed outside the premises of the installation or part of the installation classified as a major hazard installation shall be the responsibility of the local government....”*

**12 APPENDIX B: PHYSICAL PROPERTIES**

A summary of relevant physical properties for the identified hazardous substances are summarised in **Error! Reference source not found.**

**Table 12-1 Physical properties.**

|             | MW    | State at 25°C | BP °C  | Flash Point °C | Vapor Press mm Hg | SG             | Gas Density @ 20C kg/m3 | Hc kJ/kg | Hv kJ/kg | Cp(l) kJ/kg K | LFL % v/v | UFL % v/v |
|-------------|-------|---------------|--------|----------------|-------------------|----------------|-------------------------|----------|----------|---------------|-----------|-----------|
| Ammonia     | 17.04 | G             | -33.3  | Gas            | >760              | 0              | 0.71                    | 18604.59 | 1186.03  | 4.65          | 15        | 28        |
| Hydrogen    | 2.02  | G             | -252.8 | Gas            | Gas               | 0.070 @ -253°C | 0.08                    | 119999.6 | #N/A     | #N/A          | 4         | 76        |
| Petrol      | 94    | L             | ~87    | -40            | 171.3             | 20             | ~4(Air=1)               | 47 600   | 550      | 2.09          | 1         | 8         |
| Diesel      | 224   | L             | ~290   | 57             | 0.52              | 20             | ~6(Air=1)               | 45 500   | 890      | 1.8           | 1.16      | 6         |
| Chlorine    | 70.91 | G             | -34    | N/A            | 5063              | 20             | 2.98                    | N/A      | N/A      | N/A           | N/A       | N/A       |
| LPG/Propane | 44.09 | G             | -42    | -105.5         | Gas               | 582@-42°C      | 1.86                    | 46 300   | 430      | 2.02          | 2.15      | 9.6       |