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SAVANNAH ENVIRONMENTAL (PTY) LTD

QUANTITATIVE RISK ASSESSMENT FOR THE PROPOSED RICHARDS BAY COMBINED CYCLE POWER PLANT NEAR RICHARDS BAY, KWAZULU NATAL PROVINCE

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- RISCOM does not design equipment or processes.

Motlatsi Mabaso CEng MIChemE is a chartered engineer and member of the Institution of Chemical Engineers who holds a Bachelor of Science in Chemical Engineering. He has 10½ years' experience in safety & risk consulting, technical safety engineering and process engineering and has experience in the oil and gas (onshore and offshore), mining/ metal extraction, fast moving consumer goods manufacturing, and chemicals sectors.

Opinions and interpretations expressed herein this report are outside the scope of SANAS accreditation.

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QUANTITATIVE RISK ASSESSMENT FOR THE PROPOSED RICHARDS BAY COMBINED CYCLE POWER PLANT NEAR RICHARDS BAY, KWAZULU NATAL PROVINCE PROVINCE

EXECUTIVE SUMMARY

1 INTRODUCTION

Eskom Hodings SOC Ltd (hereinafter referred to as Eskom) proposes to construct a Combined Cycle Power Plant near Richards Bay, KwaZulu-Natal, South Africa.

Since off-site incidents may result due to hazards of some of the chemical components to be stored on or delivered to site, RISCOM (PTY) LTD was commissioned to conduct a quantitative risk assessment (QRA) to determine the impacts onto surrounding properties and communities as part of an environmental impact assessment (EIA).

At this stage of the project the detailed engineering designs are not yet available and there is not enough information to complete a formal Major Hazard Installation (MHI) risk assessment. Should an MHI risk assessment be completed based on this report, the risk assessment should be updated to the most current detailed engineering designs.

The purpose of this report is to convey the essential details, which include a short description of hazards, the receiving environment and current relevant design as well as risks and consequences of a major incident.

1.1 Terms of Reference

The main aim of the investigation was to quantify the risks to employees, neighbours and the public with regard to the proposed Eskom facility near Richards Bay.

The scope of the risk assessment included:

1. Development of accidental spill and fire scenarios for the facility;
2. Using generic failure rate data (for tanks, pressure vessels, pipelines/ pipework, valves, flanges, and so forth), determination of the probability of each accident scenario;
3. For each incident developed in Step 2, determination of consequences (such as thermal radiation, domino effects, toxic-cloud formation and so forth);
4. For scenarios with off-site consequences (greater than 1% fatality off-site), calculation of maximum individual risk (MIR), taking into account all generic failure rates, initiating events (such as ignition), meteorological conditions and lethality.

1.2 Purpose and Main Activities

The main activity of the power plant would be the generation of mid-merit power supply to the South African electricity grid. The fuel used to generate power would be natural gas with diesel proposed as a back-up fuel.

1.3 Main Hazards Due to Substance and Process

The main hazards that would occur with a loss of containment of hazardous components at the proposed Eskom facility in Richards Bay include exposure to:

- Toxic vapours;
- Asphyxiant vapours;
- Thermal radiation from fires;
- Overpressure from explosions.

2 ENVIRONMENT

The proposed Eskom facility, as shown in Figure 2.1, is located in Alton, Richards Bay.

The site is proposed to be located in Alton, west of Richards Bay Central in an area characterised by industrial land use. The proposed site lies directly south of the Mondi facility in the area and just north of the John Ross Highway (R34) and a railway line which runs east to west just north of the John Ross Highway. West of the proposed facility is the Nsezi Dam with the Nseleni River running into it.

The land use surrounding the Eskom facility:

- To the north is Mondi Richards Bay
- To the east is agricultural land and to the north-east is the industrial area of Alton approximately 1 kilometre away;
- To the south is a railway line and the train station of Bhizolo, and the John Ross Highway (R34) approximately 600 metres south of the site;
- To the west is agricultural land and the Nsezi Dam approximately 2 kilometres west-north-west.

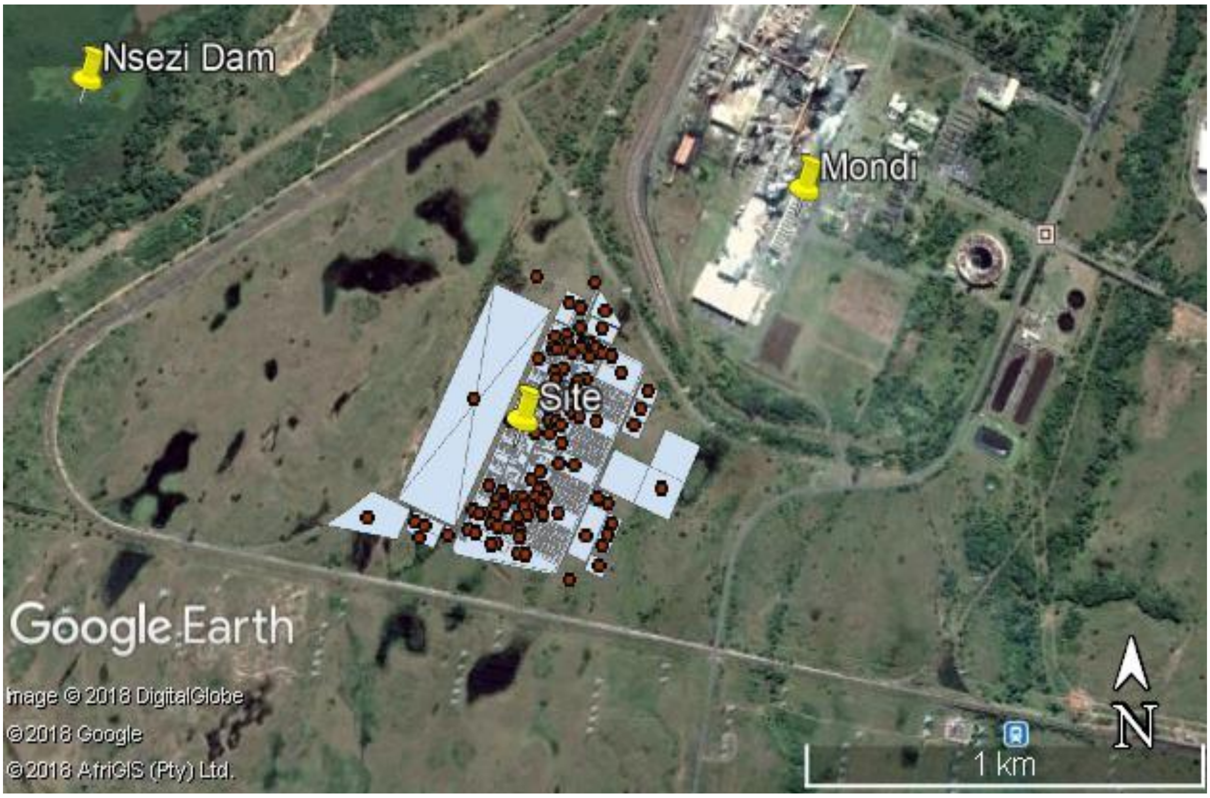

Figure 2.1: Location of the proposed Eskom facility in Richards Bay

3 PROCESS DESCRIPTION

3.1 Site

The proposed Eskom facility in Richards Bay is to consist of a natural gas supply line, gas receipt and processing area, 8 x gas turbines, steam turbines, transformers, substation, H V Yard, water treatment area and other facilities as given in the 'Richards Bay Combined Cycle Power Plant Proposed Site Layout' diagram.

4 METHODOLOGY

The first step in any risk assessment is to identify all hazards. The merit of including a hazard for further investigation is then determined by how significant it is, normally by using a cut-off or threshold value.

Once a hazard has been identified, it is necessary to assess 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 based on just one factor.

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

- Chemical identities;
- Location of on-site installations that use, produce, process, transport or store hazardous components;
- Type and design of containers, vessels or pipelines;
- Quantity of material that could be involved in an airborne release;
- Nature of the hazard most likely to accompany hazardous materials spills or releases, e.g. airborne toxic vapours or mists, fires or explosions, large quantities to be stored and certain handling conditions of processed components.

The evaluation methodology assumes that the facility will perform as designed in the absence of unintended events such as component and material failures of equipment, human errors, external events and process unknowns.

Due to the absence of South African legislation regarding determination methodology for quantitative risk assessment (QRA), the methodology of this assessment is based on the legal requirements of the Netherlands, outlined in CPR 18E (Purple Book; 1999) and RIVM (2009). The evaluation of the acceptability of the risks is done in accordance with the UK Health and Safety Executive (HSE) ALARP criteria that clearly cover land use, based on determined risks.

The QRA process is summarised with the following steps:

1. Identification of components that are flammable, toxic, reactive or corrosive and that have potential to result in a major incident from fires, explosions or toxic releases;
2. Development of accidental loss of containment (LOC) scenarios for equipment containing hazardous components (including release rate, location and orientation of release);
3. For each incident developed in Step 2, determination of consequences (such as thermal radiation, domino effects, toxic-cloud formation and so forth);
4. For scenarios with off-site consequences (greater than 1% fatality off-site), calculation of maximum individual risk (MIR), taking into account all generic failure rates, initiating events (such as ignition), meteorological conditions and lethality.

Scenarios included in this QRA have impacts external to the establishment. The 1% fatality from acute affects (thermal radiation, blast overpressure and toxic exposure) is determined as the endpoint (RIVM 2009). Thus, a scenario producing a fatality of less than 1% at the establishment boundary under worst-case meteorological conditions would be excluded from the QRA.

5 CONCLUSIONS

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

This risk assessment included the consequences of fires and explosions as well as toxic releases at the Eskom facility in Richards Bay. A number of well-known sources of incident data were consulted and applied to determine the likelihood of an incident to occur.

This risk assessment was performed with the assumption that the site would be maintained to an acceptable level and that all statutory regulations would be applied. It was also assumed that the detailed engineering designs would be done by competent people and would be correctly specified for the intended duty. For example, it was assumed that tank wall thicknesses have been correctly calculated, that vents have been sized for emergency conditions, that instrumentation and electrical components comply with the specified electrical area classification, that material of construction is compatible with the products, etc.

It is the responsibility of the owners and their contractors to ensure that all engineering designs would have been completed by competent persons and that all pieces of equipment would have been installed correctly. All designs should be in full compliance with (but not limited to) the Occupational Health and Safety Act 85 of 1993 and its regulations, the National Buildings Regulations and the Buildings Standards Act 107 of 1977 as well as local by-laws.

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

Furthermore, the following conclusions are made:

- The following installations were considered for analysis in the QRA:
  - Chlorine;
  - Natural gas;
  - Diesel;
  - Hydrogen;
  - LPG; and
  - Ammonia.
- Consequences for the installations were analysed and assessed, with several worst case scenarios having the potential to affect individuals located offsite. The largest of these was toxic vapour dispersion from the catastrophic rupture of a chlorine drum stored on-site.
- The likelihood of failure of these installations were assessed and the combination of consequence and likelihood being used to calculate the overall individual and societal risk.
- Overall individual and societal risk were found to be broadly acceptable according to the acceptability criteria for individual risk are detailed in Section 4.3.3.2. Societal risk was found to be negligible and therefore also broadly acceptable.
- No new land planning should be approved without consultation of the PADHI land-planning tables described in Appendix D.
- Impact Assessments of each installation assessed was performed and each was found to LOW SIGNIFICANCE, with and without mitigation. Cumulative Impact of all installations was assessed and the significance thereof was found to be LOW.

6 RECOMMENDATIONS

RISCOM did not find any fatal flaws that would prevent the project proceeding to the detailed engineering phase of the project.

RISCOM would support the project with the following conditions:

- Compliance with all statutory requirements, i.e. pressure vessel designs;
- Compliance with applicable SANS codes, i.e. SANS 10087, SANS 10089, SANS 10108, etc.;
- Incorporation of applicable guidelines or equivalent international recognised codes of good design and practice into the designs;
- Completion of a recognised process hazard analysis (such as a HAZOP study, FMEA, etc.) on the proposed facility prior to construction to ensure design and operational hazards have been identified and adequate mitigation put in place;
- Compliance with IEC 61508 and IEC 61511 (Safety Instrument Systems) standards or equivalent to ensure that adequate protective instrumentation is included in the design and would remain valid for the full life cycle of the tank farm:
    - Including demonstration from the designer that sufficient and reliable instrumentation would be specified and installed at the facility;
- Preparation and issue of a safety document detailing safety and design features reducing the impacts from fires, explosions and flammable atmospheres to the MHI assessment body at the time of the MHI assessment:
    - Including compliance to statutory laws, applicable codes and standards and world's best practice;
    - Including the listing of statutory and non-statutory inspections, giving frequency of inspections;
    - Including the auditing of the built facility against the safety document;
    - Noting that codes such as IEC 61511 can be used to achieve these requirements;
- Demonstration by Eskom or their contractor that the final designs would reduce the risks posed by the installation to internationally acceptable guidelines;
- Signature of all terminal designs by a professional engineer registered in South Africa in accordance with the Professional Engineers Act, who takes responsibility for suitable designs;
- Completion of an emergency preparedness and response document for on-site and off-site scenarios prior to initiating the MHI risk assessment (with input from local authorities);
- Permission not being granted for increases to the product list or product inventories without redoing part of or the full EIA;
- Final acceptance of the facility risks with an MHI risk assessment that must be completed in accordance to the MHI regulations:
    - Basing such a risk assessment on the final design and including engineering mitigation.

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QUANTITATIVE RISK ASSESSMENT FOR THE PROPOSED RICHARDS BAY COMBINED CYCLE POWER PLANT NEAR RICHARDS BAY, KWAZULU NATAL PROVINCE PROVINCE

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The purpose of this report is to convey the essential details, which include a short description of hazards, the receiving environment and current relevant design as well as risks and consequences of a major incident.

1.1 Legislation

Legislation discussed in this sub-section is limited to the health and safety of employees and the public.

Risk assessments are conducted when required to do so by law or by companies wishing to determine the risks of the facility for other reasons, such as insurance. In South Africa, risk assessments are carried out under the legislation of two separate acts, each with different requirements. These are discussed in the sub-sections that follow.

1.1.1 National Environmental Management Act (No. 107 of 1998) (NEMA) and its Regulations

The National Environmental Management Act (NEMA) contains South Africa’s principal environmental legislation. It has as its primary objective to make provision for cooperative governance by establishing principles for decision making on matters affecting the environment, on the formation of institutions that will promote cooperative governance and on establishing procedures for co-ordinating environmental functions exercised by organs of state as well as to provide for matters connected therewith (Government Gazette 1998).

Section 30 of the NEMA act deals with the control of emergency incidents where an "*incident*" is defined as an "*unexpected sudden occurrence, including a major emission, fire or explosion leading to serious danger to the public or potentially serious pollution of or detriment to the environment, whether immediate or delayed*".

The act defines "*pollution*" as *"any change in the environment caused by:*

(i) Substances;
(ii) Radioactive or other waves; or
(iii) Noise, odours, dust or heat…

Emitted from any activity, including the storage or treatment of waste or substances, construction and the provision of services, whether engaged in by any person or an organ of state, where that change has an adverse effect on human health or wellbeing or on the composition, resilience and productivity of natural or managed ecosystems, or on materials useful to people, or will have such an effect in the future... "

"*Serious*" is not fully defined but would be accepted as having long lasting effects that could pose a risk to the environment or to the health of the public that is not immediately reversible.

This is similar to the definition of a MHI as defined in the Occupational Health and Safety Act (OHS Act) 85 of 1993 and the associated MHI regulations.

Section 28 of NEMA makes provision for anyone who causes pollution or degradation of the environment being made responsible for the prevention of the occurrence, continuation or re-occurrence of related impacts and for the costs of repair of the environment. In terms of the provisions under Section 28 that are stated as:

" Every person who causes, has caused or may cause significant pollution or degradation of the environment must take reasonable measures to prevent such pollution or degradation from occurring, continuing or recurring, or, in so far as such harm to the environment is authorised by law or cannot reasonably be avoided or stopped… "

1.1.2 The Occupational Health and Safety Act No. 85 of 1993

The Occupation Health and Safety Act 85 (1993) is primarily intended for the health and safety of the employees, whereas the associated MHI regulations are intended for the health and safety of the public.

The OHS Act shall not apply in respect of:

"
- *a) A mine, a mining area or any works as defined in the Minerals Act, 1991 (Act No. 50 of 1991), except in so far as that Act provides otherwise;*
- *b) Any load line ship (including a ship holding a load line exemption certificate), fishing boat, sealing boat and whaling boat as defined in Section 2 (1) of the Merchant Shipping Act, 1951 (Act No. 57 of 1951), or any floating crane, whether or not such ship, boat or crane is in or out of the water within any harbour in the Republic or within the territorial waters thereof, (date of commencement of paragraph (b) to be proclaimed.), or in respect of any person present on or in any such mine, mining area, works, ship, boat or crane. "*

1.1.2.1 Major Hazard Installation Regulations

The MHI regulations (July 2001) published under Section 43 of the OHS Act require employers, self-employed persons and users who have on their premises, either permanently or temporarily, a major hazard installation or a quantity of a substance which may pose a **risk** (our emphasis) that could affect the health and safety of employees and the public, to conduct a risk assessment in accordance with the legislation.

In accordance with legislation, the risk assessment must be done **prior to construction of the facility** by an approved inspection authority (AIA; see Appendix A and Appendix B), registered with the Department of Labour and accredited by the South African Accreditation Systems (SANAS).

Similar to Section 30 of NEMA as it relates to the health and safety of the public, the MHI regulations are applicable to the health and safety of employees and the public in relation to the operation of a facility and specifically in relation to sudden or accidental major incidents involving substances that could pose a risk to the health and safety of employees and the public.

It is important to note that the MHI regulations are applicable to the risks posed and not merely the consequences. This implies that both the consequence and likelihood of an event need to be evaluated, with the classification of an installation being determined on the risk posed to the employees and the public.

The notification of the MHI is described in the regulations as an advertisement placement and specifies the timing of responses from the advertisement. It should be noted that the regulation does not require public participation.

The regulations, summarised in Appendix C, essentially consists of six parts, namely:

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

As this is not an MHI risk assessment, the application of the above legislation is not mandatory but the legislation is described to give a background to this report.

1.2 Terms of Reference

The main aim of the investigation was to quantify the risks to employees, neighbours and the public with regard to the proposed Eskom facility near Richards Bay.

The scope of the risk assessment included:

1. Development of accidental spill and fire scenarios for the facility;
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- Toxic vapours;
- Asphyxiant vapours;
- Thermal radiation from fires;
- Overpressure from explosions.

1.5 Facility Inspection

The Eskom site near Richards Bay was inspected on the 1st of March 2018, with the objective of with the objective of familiarisation with the environment of the proposed project.

The inspector representing RISCOM during the site visit was Mr M P Oberholzer.

1.6 Software

Physical consequences were calculated with DNV's PHAST v. 6.7 and TNO's EFFECTS v.9.0.23 and the data derived was entered into TNO's RISKCURVES v. 9.0.23. All calculations were performed by Mr M G Mabaso.

2 ENVIRONMENT

2.1 General Background

The proposed Eskom facility[1], as shown in Figure 2.1, is located in Alton, Richards Bay.

The site is proposed to be located in Alton, west of Richards Bay Central in an area characterised by industrial land use. The proposed site lies directly south of the Mondi facility in the area and just north of the John Ross Highway (R34) and a railway line which runs east to west just north of the John Ross Highway. West of the proposed facility is the Nsezi Dam with the Nseleni River running into it.

The land use surrounding the Eskom facility:

- To the north is Mondi Richards Bay
- To the east is agricultural land and to the north-east is the industrial area of Alton approximately 1 kilometre away;
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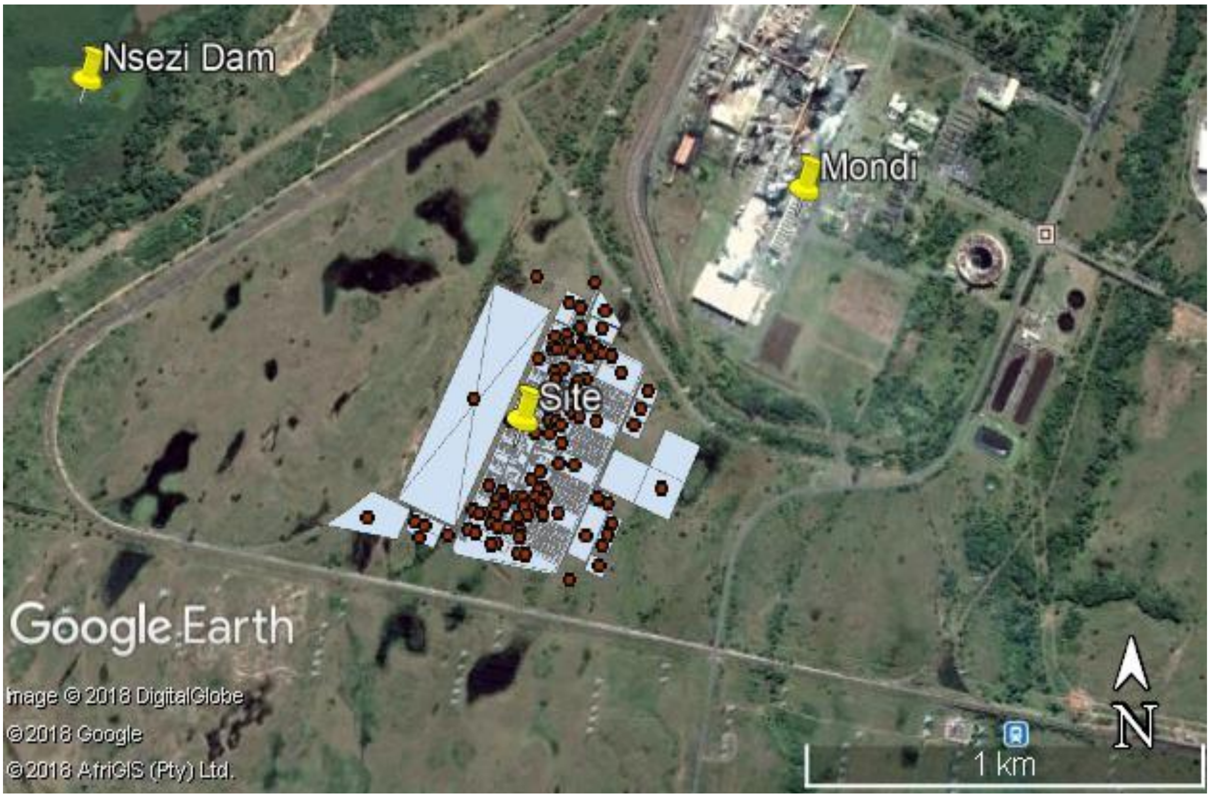


Figure 2.1: Location of the proposed Eskom facility in Richards Bay

1 An updated layout is available which does not differ significantly from that shown in the Figure provided. The overall findings of the report will remain the same.

2.2 Meteorology

Meteorological mechanisms govern the dispersion, transformation and eventual removal of hazardous vapours from the atmosphere. The extent to which hazardous vapours will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. Dispersion comprises of vertical and horizontal components of motion. The stability of the atmosphere and the depth of the surface, i.e. the mixing layer, define the vertical component. The horizontal dispersion of hazardous vapours in the boundary layer is primarily a function of wind field. Wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume stretching. Similarly, the generation of mechanical turbulence is a function of the wind speed in combination with surface roughness. Wind direction and variability in wind direction both determine the general path hazardous vapours will follow and the extent of crosswind spreading. Concentration levels of hazardous vapours therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth and to shifts in the wind field.

Meteorological data was analysed to characterise the atmospheric dispersion potential for the Richards Bay area. Meteorological parameters that were taken into account included hourly wind speed as well as direction and were supplied by the South African Weather Service as measured at the Richards Bay airport for the period from the 1st of January 2013 to the 31st of December 2017.

The long-term rainfall, humidity and temperature used a 30 year average for Richards Bay, as measured by the South African Weather Service.

2.2.1.1 Surface winds

The predominant winds blow from the north, north east and southwest quadrants, with calm conditions occurring up to 2.4% of the time. Low to medium wind speeds are predominant, with wind speeds of more than 8.7 m/s occurring about 1.4% of the time.

Although wind shifts between the northeasterly and southwesterly sectors occur all the months of the year, the frequency with which such wind shifts occur varies seasonally as a function of synoptic climatology. The predominant weather directions for summer and winter months is the north and north northeasterly winds with westerly and easterly winds occurring less frequently, as shown in Figure 2.2.

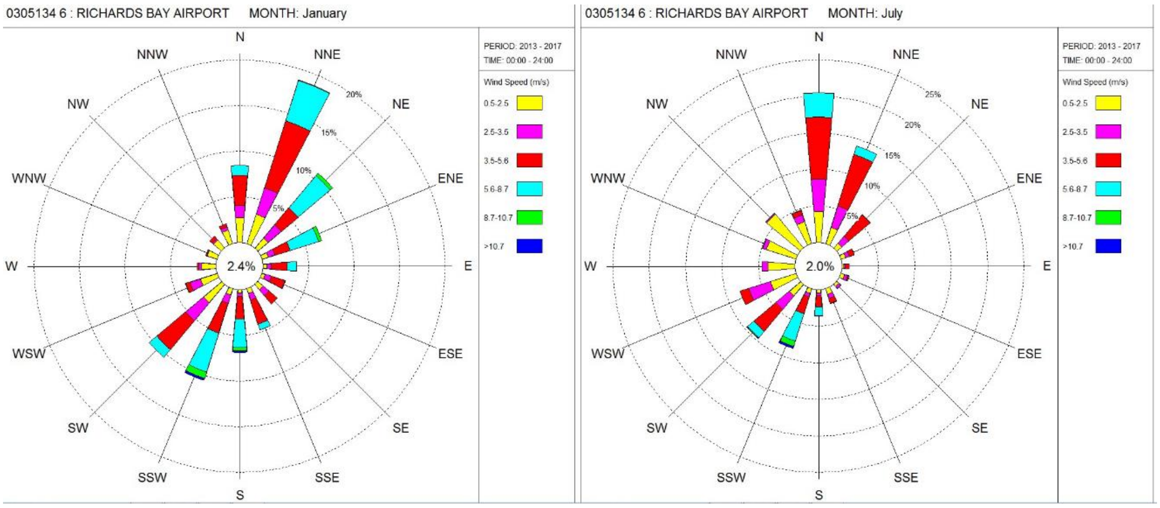


Figure 2.2: Wind analysis for winter and summer variations

2.2.1.2 Precipitation and relative humidity

Relative humidity, the amount of water that is contained in the atmosphere, influences the extent of fires and toxic clouds. The warmer the air, the more moisture it can hold. Should the relative humidity reach 100%, precipitation occurs. The long-term average precipitation and humidity supplied by the South African Weather Service is given in Table 2.1, indicating an average annual relative humidity in excess of 50%.

Table 2.1: Long-term average precipitation and relative humidity for Richards Bay

Month	Average Precipitation (mm)	Relative Humidity at 14H00 (%)	Relative Humidity at 20H00 (%)
January	172	70	79
February	167	71	79
March	107	71	78
April	109	71	81
May	109	63	79
June	57	61	72
July	60	59	74
August	65	59	74
Sept	77	66	73
October	105	67	79
November	114	70	80
December	86	69	79
Year	**1228**	**67**	**79**

2.2.1.3 Temperature

Air temperature is important for determining the effect of plume buoyancy (the larger the temperature difference between the plume and the ambient air, the higher the plume is able to rise), for estimating evaporation rates and for determining the development of the mixing and inversion layers.

The long-term average temperatures supplied by the South African Weather Service are given in Table 2.2. Extreme temperatures frequently occur due to *berg wind* conditions, during which temperatures over 40°C are reported for all months of the year.

Table 2.2: Long-term temperature averages for Richards Bay

Month	Average Maximum (°C)	Average Minimum (°C)	Mean Average (°C)
January	29.2	21.2	25.2
February	28.9	21.2	25
March	28.9	20.4	24.6
April	27	18.1	22.5
May	24.8	15.2	20
June	23.1	12.3	17.7
July	23	12.3	17.6
August	24	14.1	19
September	24.9	16	20.3
October	25.4	17.3	21.3
November	26.7	18.6	22.7
December	28.7	20.4	24.5
Year	**26.2**	**17.3**	**21.7**

2.2.1.4 Atmospheric stability

Atmospheric stability is frequently categorised into one of six stability classes. These are briefly described in Table 2.3. The atmospheric stability, in combination with the wind speed, is important in determining the extent of a particular hazardous vapour from a release. A very stable atmospheric condition, typically at night, would have low wind speeds and produce the greatest endpoint for a dense gas. Conversely, a buoyant gas would have the greatest endpoint distance due to high wind speeds.

Table 2.3: Classification scheme for atmospheric stability

Stability Class	Stability Classification	Description
A	Very unstable	Calm wind, clear skies, hot daytime conditions
B	Moderately unstable	Clear skies and daytime conditions
C	Unstable	Moderate wind, slightly overcast daytime conditions
D	Neutral	Strong winds or cloudy days and nights
E	Stable	Moderate wind, slightly overcast night-time conditions
F	Very stable	Low winds, clear skies, cold night-time conditions

Figure 2.3 depicts the atmospheric stability distribution for each wind direction as calculated from the hourly weather measurements recorded at the Richards Bay airport for the period from the 1st of January 2013 to the 31st of December 2017.

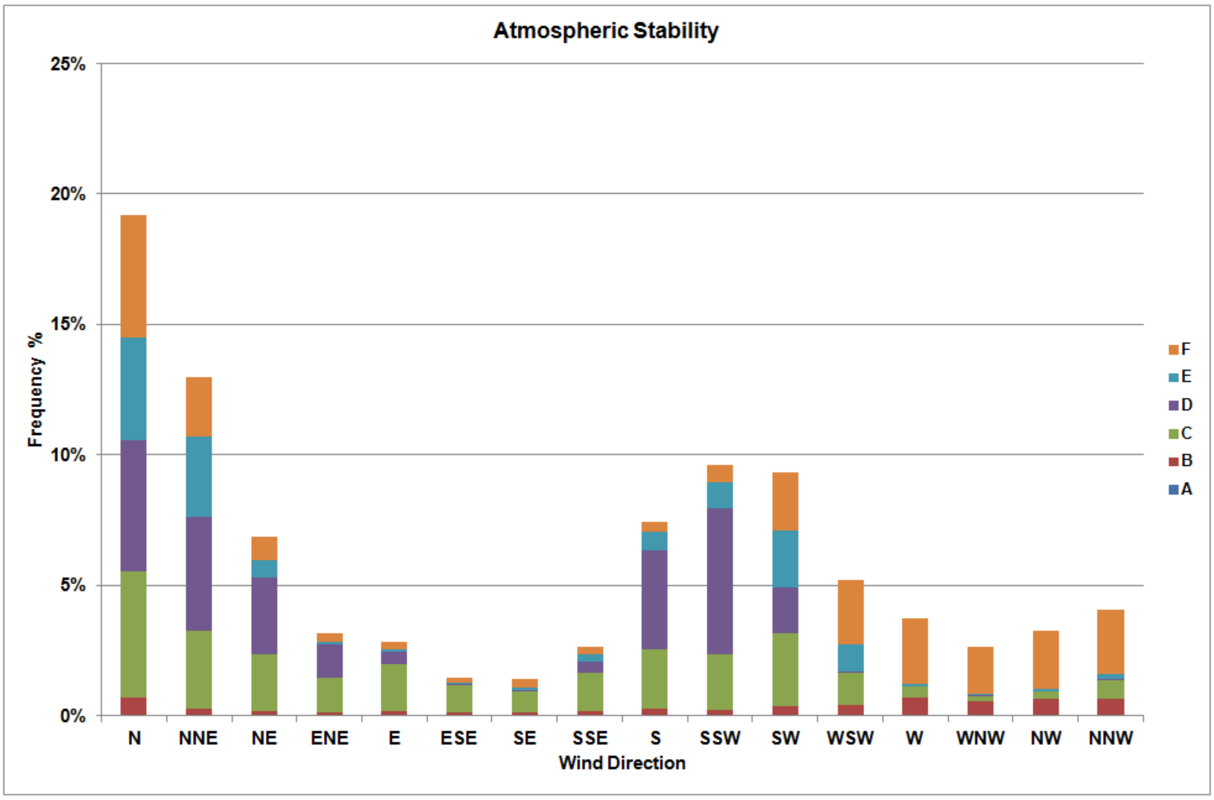


Figure 2.3: Atmospheric stability as a function of wind direction in Richards Bay

This risk assessment's calculations are based on six representative weather classes covering the stability conditions of stable, neutral and unstable as well as low and high wind speeds. In terms of Pasquill classes, the representative conditions are given in Table 2.4.

Table 2.4: Representative weather classes

Stability Class	Wind (m/s)
B	3
D	1.5
D	5
D	9
E	5
F	1.5

The allocation of observations into the six weather classes is summarised in Table 2.5, with the representative weather classes for Richards Bay given in Figure 2.4.

Table 2.5: Allocation of observations into six weather classes

<table>
<tr><th>Wind Speed</th><th>A</th><th>B</th><th>B/C</th><th>C</th><th>C/D</th><th>D</th><th>E</th><th>F</th></tr>
<tr><td>< 2.5 m/s</td><td colspan="3" rowspan="3">B 3 m/s</td><td colspan="3">D 1.5 m/s</td><td colspan="2">F 1.5 m/s</td></tr>
<tr><td>2.5 - 6 m/s</td><td colspan="3">D 5 m/s</td><td colspan="2" rowspan="2">E 5 m/s</td></tr>
<tr><td>> 6 m/s</td><td colspan="3">D 9 m/s</td></tr>
</table>

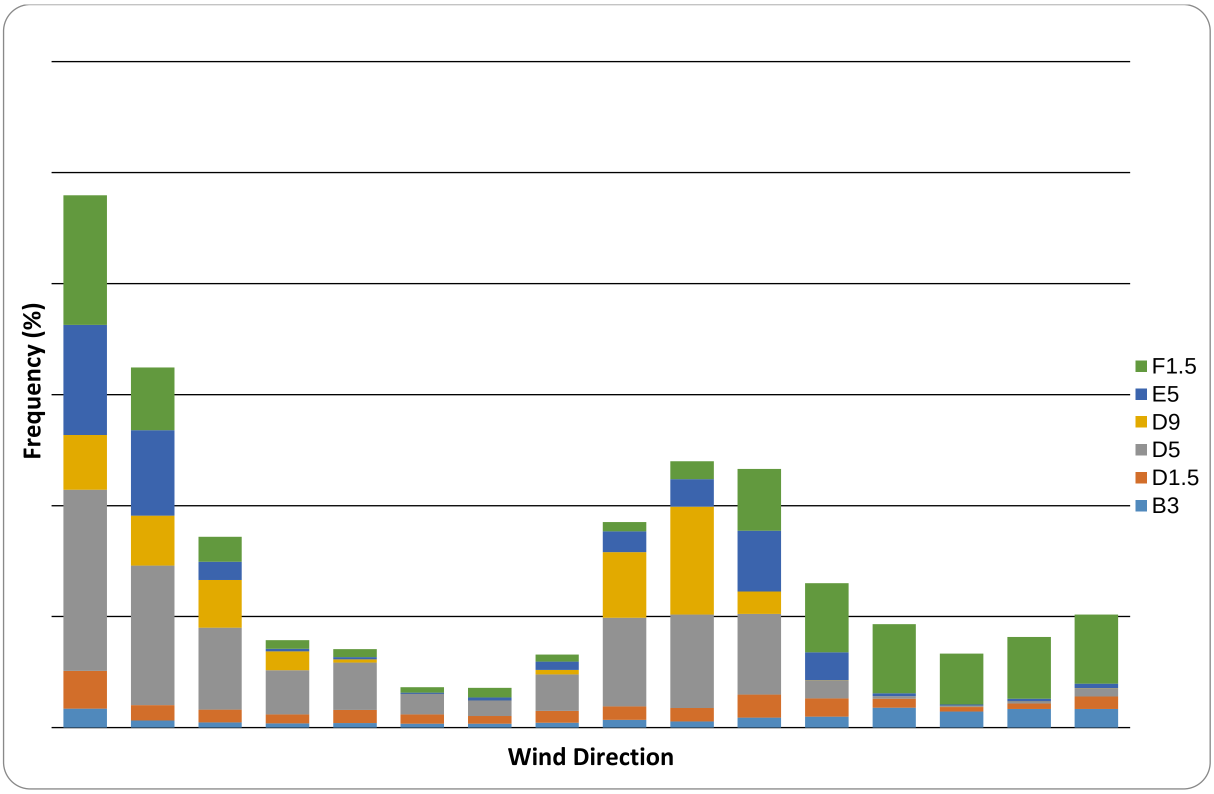


Figure 2.4: Representative weather classes for Richards Bay (2013-2017)

2.2.1.5 Meteorological simulation values

The default meteorological values used in the simulations, based on local conditions, are given in Table 2.6.

Table 2.6: The meteorological values used in the simulation, based on local conditions

Parameter	Default Value Daytime	Default Value Night-time
Ambient temperature (°C)	26	17
Substrate/bund temperature (°C)	22	22
Water temperature (°C)	22	22
Air pressure (bar)	1.013	1.013
Humidity (%)	67	78
Fraction of a 24-hour period	0.5	0.5
Mixing height	[1]	[1]

1 The default values for the mixing height, which are included in the model, are 1500 m for weather category B3, 300 m for weather category D1.5, 500 m for weather category D5 and D9, 230 m for weather category E5 and 50 m for weather category F1.5.

3 PROCESS DESCRIPTION

3.1 Site

The proposed Eskom facility in Richards Bay is to consist of a natural gas supply line, gas receipt and processing area, 8 x gas turbines, steam turbines, transformers, substation, H V Yard, water treatment area and other facilities as given in the 'Richards Bay Combined Cycle Power Plant Proposed Site Layout' diagram.

3.2 Process Description

3.2.1 Project Description

The Richards Bay Combined Cycle Power Plant (CCPP) involves the construction of a gas-fired power station which will provide mid-merit4 power supply to the electricity grid. The weekly mid-merit power supply will be between a range of 20% to 70% of the total electricity supply produced by the Richards Bay CCPP. The power station will have an installed capacity of up to 3 000MW, to be operated on natural gas, with diesel as a back-up fuel. The natural gas is to be supplied via a gas pipeline to the CCPP from the supply take-off point at the Richards Bay Harbour by potential gas suppliers. The Liquefied Natural Gas (LNG) terminal infrastructure at the port and the gas supply pipeline to the boundary fence of the Richards Bay CCPP does not form part of the scope of this assessment.

The main infrastructure associated with the facility includes the following:

- Gas turbines for the generation of electricity through the use of natural gas or diesel.
- Heat recovery steam generators (HRSG) to capture heat from high temperature exhaust gases to produce high temperature and high pressure dry steam to be utilised in the steam turbines.
- Steam turbines for the generation of additional electricity through the use of dry steam generated by the HRSG.
- Condensers for the conversion of steam back to water through a cooling process.
- Bypass stacks associated with each gas turbine.
- Dirty Water Retention Dams.
- Exhaust stacks for the discharge of combustion gases into the atmosphere.
- A water treatment plant for the treatment of potable water and the production of demineralised water (for steam generation).
- Water pipelines and water tanks to transport and store water of both industrial quality and potable water to be supplied by the Local Municipality.
- Dry-cooled system consisting of air-cooled condenser fans situated in fan banks.
- Closed Fin-fan coolers to cool lubrication oil for the gas and steam turbines.
- A gas pipeline and a gas pipeline supply conditioning process facility for the conditioning and measuring of the natural gas prior to being supplied to the gas turbines. It must be noted however that the environmental permitting processes for the gas pipeline construction and operation will be undertaken under a separate EIA Process

4 Mid-merit electricity generation capacity refers to the generation of electricity which is adjusted according to the fluctuations in demand in the national grid.

- Diesel off-loading facility and storage tanks.
- Diesel off-loading facility and storage tanks.
- Ancillary infrastructure including access roads, warehousing, buildings, access control facilities and workshop area, storage facilities, emergency back-up generators, firefighting systems, laydown areas and 132kV and 400kV switchyards.
- A power line to connect the Richards Bay CCPP to the national grid for the evacuation of the generated electricity. It must be noted however that the due environmental permitting processes for the development of the power line component are being undertaken under a separate EIA Process.

3.2.1.1 Utilities Expected at the Facility

The following utilities have been provided for in the study. Options using the most hazardous substances are assumed and inventories are estimated. The hazardous inventories assumed are conservative estimations and inventories should be less in the installed facility.

- **Process Water Systems**

Water would not be used as a cooling function and would be replaced by air condensers. Process water would be used for potable water, fire water and for the steam boiler.

It would be sanitised by either direct injection of chlorine or by the production of low concentration sodium hypochlorite.

Gaseous chlorine would be drawn through an inductor into the water at the required rate.

- **Sewage and Wastewater System**

Provision has been made for a sewerage and wastewater system. Water would be cleaned prior to discharge.

This study assumes the use of chlorine and ammonia in a common facility as that for seawater.

- **Ammonia Installation**

Anhydrous ammonia may be used to condition water for use in the boiler. It is assumed that it would be delivered to site in 8–10 t trucks and offloaded into 2 x 20 m^3 storage vessels.

- **Hydrogen Installation**

Hydrogen is expected to be used as a coolant for the mechanical bearings and to be produced on-site by splitting water into hydrogen and oxygen in an electrolyser.

Oxygen would be vented to the atmosphere, while the hydrogen from the electrolysers would be compressed and stored in three 20 m^3 vessels at a maximum pressure of 25 bar.

- **Diesel Storage for Turbines**

Provision has been made to provide 10 800 m^3 of diesel as back-up fuel for the turbines. In order to prevent dirt blocking the burners, the diesel would be required to stand in the storage vessel for 24 hours to allow particles to settle. Two storage tanks are proposed each with a volume of 5,400 m^3. Both tanks would have a diameter of 21 metres and a height of 18.5 metres and secondary containment equal to 110% of the largest vessel with a bund wall height limited to 1.8 m in height.

Diesel would be delivered to site via road or rail, offloaded in a dedicated area and pumped to the storage area.

- **Nitrogen Installation**

Nitrogen is an inert gas and would be used to purge lines and equipment prior to maintenance. It is expected that nitrogen would be stored in gas cylinders or a cryogenic storage vessel or would be produced on site by removing the nitrogen from the air. One 18 m^3 nitrogen vessel is proposed.

- **Flare System**

Vapours from vents, pressure safety valves, storage and compressors would be directed to the flare manifold where it would be released via the flare.

The flare would not always be in use but would require a small pilot flame fuelled by LPG. This would typically be stored as LPG in cylinders or a bulk storage vessel.

- **Potable Water**

It is expected that potable water would be supplied by the municipality.

3.3 Summary of Bulk Materials to be Stored on Site

A summary of bulk materials that can give hazardous effects that are to be stored or conveyed and used on-site is given in Table 3.1.

Table 3.1: Summary of hazardous components to be stored/ conveyed/ used on site

No.	Component	CAS No.	Inventory
1	Chlorine	7782-50-5	3 x 925 kg drums
2	Ammonia (anhydrous)	7664-41-7	2x 20 m^3 vessels
3	Liquefied Petroleum Gas (LPG)	68476-85-7	3 x 11 m^3 vessels
4	Hydrogen	1333-74-0	3 x 20 m^3 vessels
5	Diesel	68334-30-5	2 x 5,400 m^3 tanks
6	Sulphuric acid (98%)	7664-93-9	2 x 100 ton vessels
7	Natural Gas (predominantly methane)	74-82-8	200 mm pipeline
8	Nitrogen	7727-37-9	1 x 18 m^3 vessel

4 METHODOLOGY

4.1 Hazard Identification

The first step in any risk assessment is to identify all hazards. The merit of including a hazard for further investigation is then determined by how significant it is, normally by using a cut-off or threshold value.

Once a hazard has been identified, it is necessary to assess 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 based on just one factor.

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

- Chemical identities;
- Location of on-site installations that use, produce, process, transport or store hazardous components;
- Type and design of containers, vessels or pipelines;
- Quantity of material that could be involved in an airborne release;
- Nature of the hazard most likely to accompany hazardous materials spills or releases, e.g. airborne toxic vapours or mists, fires or explosions, large quantities to be stored and certain handling conditions of processed components.

The evaluation methodology assumes that the facility will perform as designed in absence of unintended events, such as component and material failures of equipment, human errors, external events and process unknowns.

4.1.1 Substance Hazards

All components on site were assessed for potential hazards according to the criteria discussed in this section.

4.1.1.1 Chemical Properties

A short description of bulk hazardous components to be stored on, produced at or delivered to site is given in the following subsections. The material safety data sheets (MSDSs) of the respective materials are attached in Appendix C.

- **Natural Gas**

The composition of natural gas is primarily methane (±95% v/v), with other components including ethane, propane and nitrogen.

Given the flammable and potentially explosive nature of natural gas, fires and VCEs represent the primary hazards associated with transfer of the gas. The gas is a fire and explosion hazard when it is exposed to heat and flame. The lower explosive limit (LEL) is 5% v/v (meaning 5%

gas to 95% air, measured by volume) and the higher explosive limit (HEL) is 15% v/v. In unconfined atmospheric conditions, the likelihood of an explosion is expected to be small.

It is not compatible with strong oxidants and could result in fires and explosions in the presence of such materials.

It is non-toxic and would be considered as an asphyxiant only. Chronic and long-term effects are low and are not listed.

It is in the gaseous state at atmospheric temperatures and pressures. Economical transportation would require either liquefying or compressing the gas so that it would occupy less volume per weight. LNG has a low temperature of -162°C (at atmospheric pressure). The critical pressure of methane is 46 bar; compressed natural gas (CNG) would be above the critical pressure and would be a supercritical gas having a density similar to that of the liquid.

- **Chlorine**

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

It is very reactive and may cause ignition on contact with the following components: methane; oxygen; hydrazine; hydroxylamine; calcium nitride; diethyl ether; diethyl zinc; potassium, sodium and copper hydrides; boron; active carbon; silicon; phosphorus; arsenic powder; arsine; phosphine; silane; trialkylboranes (lower homologues); dicopper acetylide; zirconium dicarbide (at 250°C); arsenic disulphide; boron trisulphide; mercuric sulphide; boron diiodophosphide; phosphorus trioxide; and, trimercury tetraphosphide. Trimagnesium diphosphide and trimanganese diphosphide would 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 components would not be suitable for contact with dry chlorine gas or liquid. Steel ignites in chlorine under various conditions. Ignition has occurred during continuous chlorination of polyisobutene.

It may react explosively with amidosulphuric acid, antimony trichloride and tetramethylsilane (at 100°C), tert-butanol, butyl rubber, naphtha, carbon disulphide, 3-chloropropyne, dibutyl phthalate, dichloride (methyl) arsine, disilyl oxide, glycerol, white phosphorus (at -34°C), hexachlorodisilane (9), diborane, stibine, ethylphosphene; silicones, synthetic rubber, aluminium, oxygen difluoride (on warming), benzene, tetraselenium tetranitride, dimethyl phosphoramidate, methanol and tetrepyridine cobalt (II) chloride, methane (over yellow mercury oxide), ethylene, ethane and petrol. Explosive reactions with acetylene have occurred under a variety of conditions. Injection of liquid chlorine into a naphtha-sodium mixture may cause a violent explosion. Other incidents involving saturated hydrocarbons and chlorine have been reported, as have incidents involving organic auxiliary materials. Combination with 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 absence of light if the pressure is below a limiting value.

In humans, short-term (acute) exposure to high levels (> 30 ppm) results in chest pain, vomiting, toxic pneumonitis, pulmonary oedema and eventually death. At lower levels (< 3 ppm), it is a potent irritant to eyes, the upper respiratory tract and lungs.

Limited information is available on long-term (chronic) effects of exposure on humans. However, early literature shows that chronic exposure to concentrations of around 5 ppm causes respiratory complaints, corrosion of teeth, inflammation of mucous membranes of the nose and increased susceptibility to tuberculosis.

No information is available on developmental or reproductive effects on humans or animals via inhalation exposure. A study reported no adverse effects on growth, life span or fertility in rats exposed to 100 ppm in drinking water for their entire life span, over seven generations according to the US Environmental Protection Agency (EPA) Integrated Risk Information System (IRIS). Furthermore, no information is available for carcinogenic effects on humans from inhalation exposure, and it has not been found to be carcinogenic in oral studies with animals.

It is extremely irritating to skin and can cause severe burns. Acute tests on rats and mice have shown high acute toxicity. It is a potent irritant in humans to eyes, the upper respiratory tract and lungs. Several studies have reported the effects shown in Table *4.1*.

Table 4.1: Acute toxicological effects of chlorine

Concentrations		Effect
(ppm)	**(mg/m³)**	
0.014–0.054	0.041–0.157	Tickling of the nose (odour threshold)
0.040–0.097	0.116–0.281	Tickling of the throat
0.060–0.3	0.174–0.870	Itching of the nose, coughing, stinging or dryness of the nose and throat
0.35–0.72	1.015–2.088	Burning of the conjunctiva and pain after 15 minutes
0.5	1.45	Temporary emergency exposure level TEEL-0
1.0	2.9	Threshold level value – time weighted average (TLV-TWA)
1.0	3	Emergency response planning guideline ERPG-1
> 1.0	> 2.9	Discomfort ranging from ocular and respiratory irritation to coughing, shortness of breath and headaches
1.0–3.0	2.9–8.7	Mild mucous membrane irritation
3.0	8.7	Short-term exposure level (STEL)
3.0	7.5	ERPG-2
14	40	Concentration which causes immediate irritation
34	98.9	Lowest reported median lethal concentration LC_{50} (human, 30 min)
20	60	ERPG-3
25	72.7	Immediately dangerous to life or health (IDLH)
30	87	Chest pain, vomiting, dyspnoea, coughing
46–60	133.4–174	Toxic pneumonitis and pulmonary oedema
430	1247	Highest reported LC_{50} (human, 30 min)
500	1454	Lowest recorded lethal concentration (mammal, 5 min)
873	2538	Lethal concentration (human, 30 min)
1000	2900	Lethal after a few breaths

Information on toxicity of chlorine was studied, and the relationship between toxicity and exposure were produced, as shown in Figure 4.1. Hazard categories were then defined more closely in terms of toxic effects, and the relationships shown in Figure 4.2 were derived. In assessing effects of toxic substances, consideration needs to be given to members of the public who may be more susceptible than the average adult worker, such as children and the elderly.

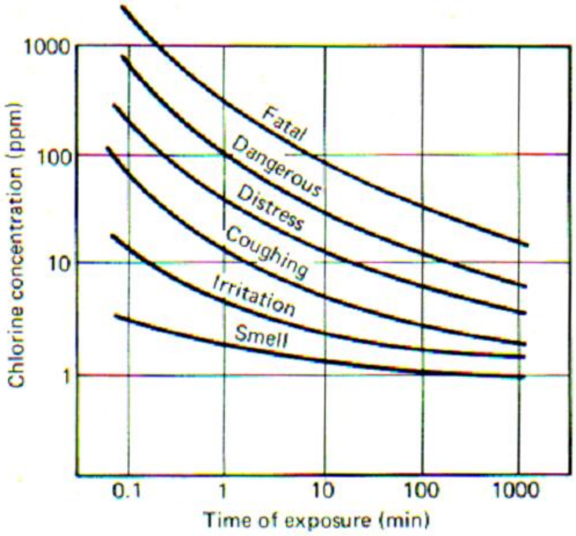


Figure 4.1: Effects of chronic exposure to different concentrations of chlorine vapour (Dicken 1974)

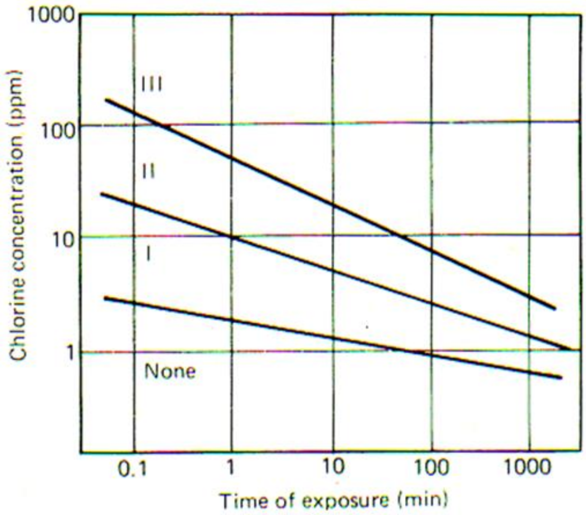


Figure 4.2: Categories of chronic releases (Dicken, 1974) with four categories of hazard defined: Category 0 involves no nuisance to the public; Category I could cause nuisance to the public (acceptable once per year); Category II could cause distress to people, damage to vegetation and could give rise to claim of compensation (acceptable once in 10 years); and, 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 400 m of the release and generally within 250 m from the incident (Lees, 1994). Chlorine released from cylinders tends to have the highest mortality index (fatalities per tonnes released). In this event, the amount of gas released is small but often occurs within a building.

Accidents have involved storage tanks and 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.

- **Ammonia**

Ammonia is a colourless gas with a pungent and suffocating odour. It liquefies easily under pressure, with a normal boiling point of -33°C. Although classified as a non-flammable gas, it will burn in 16–25% vapour concentrations in air when exposed to open flames.

It is incompatible with certain 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 include nitrogen and water, which are harmless to life and the environment.

The effects of anhydrous ammonia upon the human body vary with the size and weight of the subject 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 skin, eyes, the nose or the throat at levels as low as 35 ppm but normally at 100–125 ppm, through inhalation or direct contact. At 700 ppm it can cause serious and permanent injury with extreme rapidity.

Upon contact with moist mucosal membranes (such as those in the 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, thereby exposing 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 and coughing and bronchospasm with wheezing and pulmonary oedema (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 and pipelines as well as ammonia transported on trucks, railcars and ships.

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

There have been a number of nonfatal releases of ammonia. A release of about 600 t of ammonia occurred from a pipeline in Floral, Arkansas, in 1971 and 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.

- **Hydrogen**

Hydrogen is a colourless odourless gas that is flammable over a wide range of air or vapour concentrations. The vapour forms an explosive mixture with air. Vapours or gases may travel considerable distances to an 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. The liquid can solidify air and may create an explosion hazard.

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.

It is incompatible with oxygen, oxidising agents, air, lithium and halogens. It may react explosively at elevated temperatures or with heating, alkali metals, halogens, oxygen, oxidizers, oxides, ozone, chlorides, dichlorides 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. Embrittlement of steel and other metals such as nickel and copper-nickel alloys will occur at ambient temperatures on exposure to the gas at high pressures.

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

- **Diesel**

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

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

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

If swallowed, it may cause nausea or vomiting, swelling of the abdomen, headache, central nervous system depression, coma and death.

The long-term effects of exposure have not been determined. However, this may affect the 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.

- **Sulphuric Acid**

Sulphuric acid is a colourless substance that may emit choking fumes when hot. It is non-flammable, but when it comes in contact with other flammable materials it may react resulting in fires.

It can have violent reactions with water and strong bases, generating heat. It is not compatible with organic materials, chlorates, carbides, fulminates and powdered metals. In contact with metal, it releases flammable hydrogen gas that will explode if ignited in enclosed spaces.

Sulphuric acid is hazardous for skin contact, inhalation, or ingestion. It is corrosive to the skin, eyes, nose, mucous membranes, respiratory and gastrointestinal tracts or any tissue with which it comes in contact. Severe burns can occur, with necrosis and scarring, and may result in death. Milder exposures can cause irritation of the eyes, skin, mucous membranes and respiratory as well as digestive tracts.

Chronic exposure may be associated with changes in pulmonary function, chronic bronchitis, conjunctivitis and overt symptoms resembling acute viral respiratory tract infection. Discoloration and erosion of dental enamel can occur. Long-term exposure may cause mutations in living cells, bronchitis, emphysema, erosion and pitting of teeth, running nose, upset stomach and tearing of the eyes.

4.1.1.2 Flammable and Combustible Components

Flammable and combustible components are those that can ignite and give a number of hazardous effects, depending on the nature of the component and conditions. These effects may include pool fires, jet fires and flash fires as well as explosions and fireballs.

The flammable and combustible components to be stored on, produced at or delivered to site are listed in Table 4.2. These components have been analysed for fire and explosion risk.

Table 4.2: Flammable and combustible components to be stored on, produced at or delivered to site

Component	Flashpoint (°C)	Boiling Point (°C)	LFL (vol. %)	UFL (vol. %)
Natural gas	-188	-161	5	15
Hydrogen	N/A	-253	4	75
LPG	-103.5	-42	2.1	9.5
Diesel or fuel oil	> 55	290	0.6	7.5

Ammonia will burn in 16–25% vapour concentrations in air when exposed to open flames. However, due to its low reactivity, it is classified as a non-flammable gas and is only assessed on toxicity (RIVM, 2009).

4.1.1.3 Toxic and Asphyxiant Components

Toxic or asphyxiant components of interest to this study are those that could produce 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 toxic or asphyxiant components will depend on both concentration of the material in the air and the exposure duration.

Ammonia, chlorine and sulphuric acid are considered acutely toxic components.

The acute exposure guideline level (AEGL) / emergency response planning guideline (ERPG) values are given in Table 4.3.

Table 4.3: Guideline levels for toxic and asphyxiant components

Component	AEGL-1		AEGL-2		AEGL-3	
	mg/m³	ppm	mg/m³	ppm	mg/m³	ppm
Sulphuric acid	0.2	0.06	8.7	2.7	160	50
Chlorine	1.45	0.5	5.8	2	58	20
Ammonia	20.9	30	111	160	766	1100

AEGL values correspond to a one-hour exposure.

Sulphuric acid has a very low vapour pressure and significant amounts of toxic vapour would not be released.

4.1.2 Physical Properties

For this study, LPG, natural gas and diesel were modelled as pure components, as given in Table 4.4. The physical properties used in the simulations were based on the DIPPR[1] data base.

Table 4.4: Representative components

Component	Modelled as
LPG	Modelled as propane
Natural gas	Modelled as methane
Diesel	Modelled as dodecane

4.1.3 Components Excluded from the Study

The following installations were not considered in this study, as the site inventories would be very small in comparison to the relatively large natural gas, LPG and diesel inventory:

- Diesel storage for gensets;
- Petrol and diesel filling station;
- Workshop gases;
- Flammable store;
- Laboratory reagents.

Turbine oil, lube oils and greases were excluded from the study as they have very high flashpoints making ignition extremely remote.

1 Design Institute for Physical Properties

It is assumed that corrosive liquids would be stored sufficiently far from the site boundary that a release would not affect the public. The toxic effects of vapours released from sulphuric acid were not considered due its low vapour pressure.

4.2 Physical and Consequence Modelling

In order to establish which impacts follow an accident, it is first necessary to estimate the physical process of the spill (i.e. rate and size), spreading of the spill, evaporation from the spill, subsequent atmospheric dispersion of the airborne cloud and, in the case of ignition, the burning rate and resulting thermal radiation from a fire and the overpressures from an explosion.

The second step is then to estimate the consequences of a release on humans, fauna, flora and structures in terms of the significance and extent of the impact in the event of a release. The consequences could be due to toxic or asphyxiant vapours, thermal radiation or explosion overpressures. They may be described in various formats.

The simplest methodology would show a comparison of predicted concentrations, thermal radiation or overpressures to short-term guideline values.

In a different but more realistic fashion, the consequences may be determined by using a dose-response analysis. Dose-response analysis aims to relate the intensity of the phenomenon that constitutes a hazard to the degree of injury or damage that it can cause. Probit analysis is possibly the method mostly used to estimate probability of death, hospitalisation or structural damage. The probit is a lognormal distribution and represents a measure of the percentage of the vulnerable resource that sustains injury or damage. The probability of injury or death (i.e. the risk level) is in turn estimated from this probit (risk characterisation).

Consequence modelling gives an indication of the extent of the impact for selected events and is used primarily for emergency planning. A consequence that would not cause irreversible injuries would be considered insignificant, and no further analysis would be required. The effects from major incidents are summarised in the following sub-sections.

4.2.1 Toxic Vapour Clouds

The purpose of considering vapour clouds emanating from toxic components is to identify sections of the surrounding community that may be affected by exposure or individuals in the community who may be subject to injury or death from an accidental release.

A toxic vapour cloud can occur when:

- Toxic gas is released under pressure;
- Toxic liquid spills and evaporates;
- Components combust forming toxic gases;
- Components react forming toxic gases.

In the case of a toxic liquefied gas, the rate of the component becoming airborne must be estimated as input for dispersion modelling. The pressure of contained liquefied gas is dependent on its temperature, and it remains liquefied due to the pressure inside the tank.

Quantification of the adverse impacts associated with a substance is made possible through dose-response analysis and exposure assessment. A large release of a toxic, flammable or explosive substance may result in death, non-lethal injury or irritation to humans and in damage to property. The characterisation of such impacts would be based on the calculation of down-wind distances to various acute exposure guidelines.

Limits for brief exposure to potentially lethal levels are given in terms of lethal concentration and lethal dose. Lethal concentration and lethal dose are determined by tests on animals. Lethal concentration LC_{50} refers to the concentration of airborne material 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 (normally up to 4 hrs.). Lethal dose LD_{50} refers to the quantity of material administered, either orally or by skin adsorption, which results in death of 50% of the test group.

An approach that may be adopted involves comparison of predicted concentrations to exposure guidelines. These guidelines may include the following occupational exposure limits: the threshold limit values (TLVs); the immediately dangerous to life or health (IDLH) values; or, the acute exposure guideline level (AEGL) values.

AEGL values were developed by the US Environmental Protection Agency (EPA) and are defined as the maximum concentrations that individuals could be exposed to for a period of one hour before certain health effects would occur in sensitive populations. In the event that AEGL values are not yet available for a particular component, emergency response planning guideline (ERPG) values or temporary emergency exposure limits (TEELs) could be used.

This study refers to the AEGL values for the assessing of emergency response plans and LC_1 (1% fatality based on inhaled dosages derived from probit values) for determining the significance and extent off-site impacts. In this report all AEGL values are based on one hour.

4.2.2 Fires

Combustible and flammable components within their flammable limits may ignite and burn if exposed to an ignition source of sufficient energy. On process plants releases with ignition normally occur as a result of a leakage or spillage. Depending on the physical properties of the component and the operating parameters, combustion may take on a number of forms, such as pool fires, jet fires, flash fires and so forth.

4.2.2.1 Thermal Radiation

The effect of thermal radiation is very dependent on the type of fire and duration of exposure. Certain codes, such as the American Petroleum Institute API 520 and API 2000 codes, suggest values for the maximum heat absorbed by vessels to facilitate adequate relief designs in order to prevent failure of the vessel. Other codes, such as API 510 and the British Standards BS 5980 code, give guidelines for the maximum thermal radiation intensity and act as a guide to equipment layout, as shown in Table 4.5.

The effect of thermal radiation on human health has been widely studied, relating injuries to the time and intensity of exposure.

Table 4.5: Thermal radiation guidelines (BS 5980 of 1990)

Thermal Radiation Intensity (kW/m^2)	Limit
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

For pool fires, jet fires and flash fires CPR 18E (Purple Book; 1999) suggests the following thermal radiation levels be reported:

- 4 kW/m^2, the level that glass can withstand, preventing the fire entering a building, and that should be used for emergency planning;
- 10 kW/m^2, the level that represents the 1% fatality for 20 seconds of unprotected exposure and at which plastic and wood may start to burn, transferring the fire to other areas;
- 35 kW/m^2, the level at which spontaneous ignition of hair and clothing occurs, with an assumed 100% fatality, and at which initial damage to steel may occur.

4.2.2.2 Bund and Pool Fires

Pool fires, either tank or bund fires, consist of large volumes of a flammable liquid component burning in an open space at atmospheric pressure.

The flammable component will be consumed at the burning rate, depending on factors including 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 building or persons close to the fire or within the intolerable zone will experience burn damage with severity depending on the distance from the fire and 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.

4.2.2.3 Jet Fires

Jet fires occur when a flammable component is released with high exit velocity ignites.

In process industries this may be due to design (such as flares) or due to accidental releases. Ejection of a flammable component 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 other pipelines, equipment or structures. The thermal radiation from these fires may cause injury to people or damage equipment some distance away from the source of the flame.

4.2.2.4 Flash Fires

A loss of containment of a flammable component may mix with air, forming a flammable mixture. The flammable cloud would be defined by the lower flammable limit (LFL) and the upper flammable limit (UFL). The extent of the flammable cloud would depend on the quantity of the released and mixed component, physical properties of the released component, wind speed and weather stability. An ignition within a flammable cloud can result in an explosion if the front is propagated by pressure. If the front is propagated by heat, then the fire moves across the flammable cloud at the flame velocity and is called a flash fire. Flash fires are characterised by low overpressure, and injuries are caused by thermal radiation. The effects of overpressure due to an exploding cloud are covered in the subsection dealing with vapour cloud explosions (VCEs).

A flash fire would extend to the lower flammable limit; however, due to the formation of pockets, it could extend beyond this limit to the point defined as the ½ LFL. It is assumed that people within the flash fire would experience lethal injuries while people outside of the flash fire would remain unharmed. The ½ LFL is used for emergency planning to evacuate people to a safe distance in the event of a release.

4.2.3 Explosions

The concentration of a flammable component would decrease from the point of release to below the lower explosive limits (LEL), at which concentration the component can no longer ignite. The sudden detonation of an explosive mass would cause overpressures that could result in injury or damage to property.

Such an explosion may give rise to any of the following effects:

- Blast damage;
- Thermal damage;
- Missile damage;
- Ground tremors;
- Crater formation;
- Personal injury.

Obviously, the nature of these effects depends on the pressure waves and the 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 4.6 and Table 4.7 give a more detailed summary of the damage produced by an explosion due to various overpressures.

CPR 18E (Purple Book; 1999) suggests the following overpressures be determined:

- 0.03 bar overpressure, corresponding to the critical overpressure causing windows to break;
- 0.1 bar overpressure, corresponding to 10% of the houses being severely damaged and a probability of death indoors equal to 0.025:
    - No lethal effects are expected below 0.1 bar overpressure on unprotected people in the open;
- 0.3 bar overpressure, corresponding to structures being severely damaged and 100% fatality for unprotected people in the open;
- 0.7 bar overpressure, corresponding to an almost entire destruction of buildings.

Table 4.6: 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 small under strain windows
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 t) 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 t) 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 t) machine tools moved and badly damaged; very heavy (12 000 lb. / 5443 kg) machine tools survived
300	2070	Limit of crater lip

Table 4.7: Damage caused by overpressure effects of an explosion (Stephens 1970)

Equipment	Overpressure (psi)																								
	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	12	14	16	18	20
Control house steel roof	A	C	V				N																		
Control house concrete roof	A	E	P	D			N																		
Cooling tower	B			F			O																		
Tank: cone roof		D				K							U												
Instrument cubicle			A			LM						T													
Fire heater				G	I					T															
Reactor: chemical				A				I				P						T							
Filter				H					F									V			T				
Regenerator						I				IP					T										
Tank: floating roof						K							U												D
Reactor: cracking							I							I							T				
Pine supports							P					SO													
Utilities: gas meter									Q																
Utilities: electric transformer									H					I						T					
Electric motor										H								I							V
Blower										Q										T					
Fractionation column											R			T											
Pressure vessel horizontal												PI						T							
Utilities: gas regulator												I								MQ					
Extraction column													I							V	T				
Steam turbine															I						M	S			V
Heat exchanger															I			T							
Tank sphere																I						I	T		
Pressure vessel vertical																					I	T			
Pump																					I		Y		

A	Windows and gauges break
B	Louvers fall at 0.3–0.5 psi
C	Switchgear is damaged from roof collapse
D	Roof collapses
E	Instruments are damaged
F	Inner parts are damaged
G	Bracket cracks
H	Debris-missile damage occurs
I	Unit moves and pipes break
J	Bracing fails
K	Unit uplifts (half filled)
L	Power lines are severed
M	Controls are damaged
N	Block wall fails
O	Frame collapses
P	Frame deforms
Q	Case is damaged
R	Frame cracks
S	Piping breaks
T	Unit overturns or is destroyed
U	Unit uplifts (0.9 filled)
V	Unit moves on foundations

4.2.3.1 Vapour Cloud Explosions (VCEs)

The release of a flammable component into the atmosphere could result in formation of a flash fire, as described in the subsection on flash fires, or a vapour cloud explosion (VCE). In the case of a VCE, an ignited vapour cloud between the higher explosive limits (HEL) and the lower explosive limit (LEL) could form a fireball with overpressures that could result in injury or damage to property.

4.2.3.2 Boiling Liquid Expanding Vapour Explosions (BLEVEs)

A boiling liquid expanding vapour explosion (BLEVE) can occur when a flame impinges on a pressure cylinder, particularly in the vapour space region where cooling by evaporation of the contained material does not occur; the cylinder shell would weaken and rupture with a total loss of the contents, and the issuing mass of material would burn as a massive fireball.

The major consequences of a BLEVE are \ intense thermal radiation from the fireball, a blast wave and propelled 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 BLEVEs 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 BLEVE occurs sometime after the vessel has been engulfed in flames. Should an incident occur that could result in a BLEVE, people should be evacuated to beyond the 1% fatality line.

4.3 Risk Analysis

4.3.1 Background

It is important to understand the difference between hazard and risk.

A hazard is anything that has the potential to cause damage to life, property and the environment. Furthermore, it has constant parameters (like those of petrol, chlorine, ammonia, etc.) that pose the same hazard wherever present.

On the other hand, risk is the probability that a hazard will actually cause damage, and goes along with how severe that damage will be (consequence). Risk is therefore the probability that a hazard will manifest itself. For instance, the risks of a chemical accident or spill depends upon the amount present, the process the chemical is used in, the design and safety features of its container, the exposure, the prevailing environmental and weather conditions and so on.

Risk analysis consists of a judgement of probability based on local atmospheric conditions, generic failure rates and severity of consequences, based on the best available technological information.

Risks form an inherent part of modern life. Some risks are readily accepted on a day-to-day basis, while certain hazards attract headlines even when the risk is much smaller, particularly in the field of environmental protection and health. For instance, the risk of one-in-ten-thousand chance of death per year associated with driving a car is acceptable to most people, whereas the much lower risks associated with nuclear facilities (one-in-ten-million chance of death per year) are deemed unacceptable.

A report by the British Parliamentary Office of Science and Technology (POST), entitled ‘Safety in Numbers? Risk Assessment and Environmental Protection’, explains how public perception of risk is influenced by a number of factors in addition to the actual size of the risk. These factors were summarised as follows in Table 4.8.

Table 4.8: Influence of public perception of risk on acceptance of that risk, based on the POST report

Control	People are more willing to accept risks they impose upon themselves or they consider to be ‘natural’ than to have risks imposed upon them
Dread and Scale of Impact	Fear is greatest where the consequences of a risk are likely to be catastrophic rather than spread over time
Familiarity	People appear more willing to accept risks that are familiar rather than new risks
Timing	Risks seem to be more acceptable if the consequences are immediate or short term, rather than if they are delayed (especially if they might affect future generations)
Social Amplification and Attenuation	Concern can be increased because of media coverage, graphic depiction of events or reduced by economic hardship
Trust	A key factor is how far the public trusts regulators, policy makers or industry; if these bodies are open and accountable (being honest as well as admitting mistakes and limitations and taking account of differing views without disregarding them as emotive or irrational), then the public is more likely consider them credible

A risk assessment should be seen as an important component of ongoing preventative action, aimed at minimising or hopefully avoiding accidents. Re-assessments of risks should therefore follow at regular intervals and after any changes that could alter the nature of the hazard, so contributing to an overall prevention programme and emergency response plan of the facility. Risks should be ranked with decreasing severity and the top risks reduced to acceptable levels.

Procedures for predictive hazard evaluation have been developed for the analysis of processes when evaluating very low probability accidents with very high consequences (for which there is little or no experience) as well as more likely releases with fewer consequences (for which there may be more information available). These address both the probability of an accident as well as the magnitude and nature of undesirable consequences of that accident. Risk is usually defined as some simple function of both the probability and consequence.

4.3.2 Predicted Risk

Physical and consequence modelling addresses the impact of a release of a hazardous component without taking into account probability of occurrence. This merely illustrates the significance and the extent of the impact in the event of a release. Modelling should also analyse cascading or knock-on effects due to incidents in the facility and the surrounding industries and suburbs.

During a risk analysis, the likelihood of various incidents is assessed, the consequences calculated and finally the risk for the facility is determined.

4.3.2.1 Generic Equipment Failure Scenarios

Because of the coarse nature of this study and the general lack of detailed information, only major failures of equipment were included, and pig receiver, pump/ compressor and transport scenarios such as road tanker failures were not included due to their effects likely being surpassed by those of the larger vessels on-site. Unless otherwise stated, analysis was completed using published failure rate data (RIVM 2009). Equipment failures can occur in tanks, pipelines and other items handling hazardous chemical components. These failures may result in:

- Release of combustible, flammable and explosive components with fires or explosions upon ignition;
- Release of toxic or asphyxiant components.

- **Storage Vessels**

Scenarios involving storage vessels can include catastrophic failures that would lead to leakage into the bund with a possible bund fire. The fracture of a nozzle or transfer pipeline could also result in leakage into the bund.

Typical failure frequencies for atmospheric and pressure vessels are listed, respectively, in Table 4.9 and Table 4.10.

Table 4.9: Failure frequencies for atmospheric vessels

Event	Leak Frequency (per item per year)
Small leaks	$1x10^{-4}$
Severe leaks	$3x10^{-5}$
Catastrophic failure	$5x10^{-6}$

Table 4.10: Failure frequencies for pressure vessels

Event	Failure Frequency (per item per year)
Small leaks	$1x10^{-5}$
Severe leaks	$5x10^{-7}$
Catastrophic failure	$5x10^{-7}$

- **Process Piping**

Piping may fail as a result of corrosion, erosion, mechanical impact damage, pressure surge (water hammer) or operation outside the design limitations for pressure and temperature. Failures caused by corrosion and erosion usually result in small leaks, which are easily detected and corrected quickly. For significant failures, the leak duration may be from 10–30 minutes before detection.

Generic data for leak frequency for process piping is generally expressed in terms of the cumulative total failure rate per year for a 10 m section of pipe for each pipe diameter. Furthermore, failure frequency normally decreases with increasing pipe diameter. Scenarios and failure frequencies for a pipeline apply to pipelines with connections, such as flanges, welds and valves.

The failure data given in Table 4.11 represents the total failure rate, incorporating all failures of whatever size and due to all probable causes. These frequencies are based on an assumed environment where no excessive vibration, corrosion, erosion or thermal cyclic stresses are expected. For incidents causing significant leaks (such as corrosion), the failure rate will be increased by a factor of 10.

Table 4.11: Failure frequencies for process pipes

Description	Frequencies of Loss of Containment for Process Pipes (per meter per year)	
	Full Bore Rupture	Leak
Nominal diameter < 75 mm	$1x10^{-6}$	$5x10^{-6}$
75 mm < nominal diameter < 150 mm	$3x10^{-7}$	$2x10^{-6}$
Nominal diameter > 150 mm	$1x10^{-7}$	$5x10^{-7}$

- **Ammonia Installation Failure Rates**

Stress corrosion from ammonia is a well-known issue and contributes to the failure of storage vessels and equipment. Therefore, the failure frequencies relating to ammonia installations, as given in Table 4.12, are different to other installations for less corrosive components. Failure frequencies of instrumentation and other equipment (not given in the table) was sourced from the equipment tables listed earlier in this section.

Table 4.12: Estimated frequency of releases at ammonia installations and carriers (Lees 2001)

Incident	No. of Incidents	Estimated Frequency
Major failure of storage vessel	2	1.67×10^{-5} vessel years
Major release from storage vessel	1	1×10^{-4} storage area years
Serious release on site	12	5×10^{-4} plant years
Release from refrigeration facility	15	1×10^{-5} plant years
Release on transfer point		
Flexible hose failure	11	1×10^{-3} transfer point years
Movement while still connected		
Major release	3	2.5×10^{-4} transfer point years
Other release	8	6.57×10^{-4} transfer point years
Major releases in transport		
Road	6	5×10^{-4} tanker years
Rail	18	3.33×10^{-4} tanker years
Pipeline	8	3.33×10^{-3} mile years
Sea	1	5×10^{-3} ship years
Total	**79**	

- **Ignition Probability of Flammable Gases and Liquids**

Estimation of probability of an ignition is a key step in assessment of risk for installations where flammable liquids or gases are stored. There is a reasonable amount of data available relating to characteristics of ignition sources and effects of release type and location.

Probability of ignition for stationary installations is given in Table 4.13 (along with classification of flammable substances in Table 4.14). These can be replaced with ignition probabilities related to surrounding activities. For example, probability of a fire from a flammable release at an open flame would increase to a value of 1.

Table 4.13: Probability of direct ignition for stationary installations (RIVM 2009)

Substance Category	Source-Term Continuous	Source-Term Instantaneous	Probability of Direct Ignition
Category 0 Average to high reactivity	< 10 kg/s 10 – 100 kg/s > 100 kg/s	< 1000 kg 1000 – 10 000 kg > 10 000 kg	0.2 0.5 0.7
Category 0 Low reactivity	< 10 kg/s 10 – 100 kg/s > 100 kg/s	< 1000 kg 1000 – 10 000 kg > 10 000 kg	0.02 0.04 0.09
Category 1	All flow rates	All quantities	0.065
Category 2	All flow rates	All quantities	0.0043[1]
Category 3 Category 4	All flow rates	All quantities	0

Table 4.14: Classification of flammable substances

Substance Category	Description	Limits
Category 0	Extremely flammable	Liquids, substances and preparations that have a flashpoint lower than 0°C and a boiling point (or the start of the boiling range) less than or equal to 35°C Gaseous substances and preparations that may ignite at normal temperature and pressure when exposed to air
Category 1	Highly flammable	Liquids, substances and preparations that have a flashpoint of below 21°C
Category 2	Flammable	Liquids, substances and preparations that have a flashpoint equal to 21°C and less than 55°C
Category 3		Liquids, substances and preparations that have a flashpoint greater than 55°C and less than or equal to 100°C
Category 4		Liquids, substances and preparations that have a flashpoint greater than 100°C

1 This value is taken from the CPR 18E (Purple Book; 1999). RIVM (2009) gives the value of delayed ignition as zero. RISCOM (PTY) LTD believes the CPR 18E is more appropriate for warmer climates and is a conservative value.

4.3.3 Risk Calculations

4.3.3.1 Maximum Individual Risk Parameter

Standard individual risk parameters include: average individual risk; weighted individual risk; maximum individual risk; and, the fatal accident rate. The lattermost parameter is more applicable to occupational exposures.

Only the maximum individual risk (MIR) parameter will be used in this assessment. For this parameter frequency of fatality is calculated for an individual who is presumed to be present at a specified location. This parameter (defined as the consequence of an event multiplied by the likelihood of the event) is not dependent on knowledge of populations at risk. So, it is an easier parameter to use in the predictive mode than average individual risk or weighted individual risk. The unit of measure is the risk of fatality per person per year.

4.3.3.2 Acceptable Risks

The next step, after having characterised a risk and obtained a risk level, is to recommend whether the outcome is acceptable.

In contrast to the employees at a facility, who may be assumed to be 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 acceptable risk. In an attempt to account for risks in a manner similar to those used in everyday life, the UK Health and Safety Executive (HSE) developed the risk ALARP triangle. Applying the triangle 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 pre-cautions are necessary;
- If a risk falls between these two states so that it has been reduced to levels as low as reasonably practicable (ALARP).

This is illustrated in Figure 4.3.

ALARP stands for 'as low as reasonably practicable'. As used in the UK, it is the region between that which is intolerable, at $1x10^{-4}$ per year, and that which is broadly acceptable, at $1x10^{-6}$ per year. A further lower level of risk, at $3x10^{-7}$ per year, is applied to either vulnerable or very large populations for land-use planning.

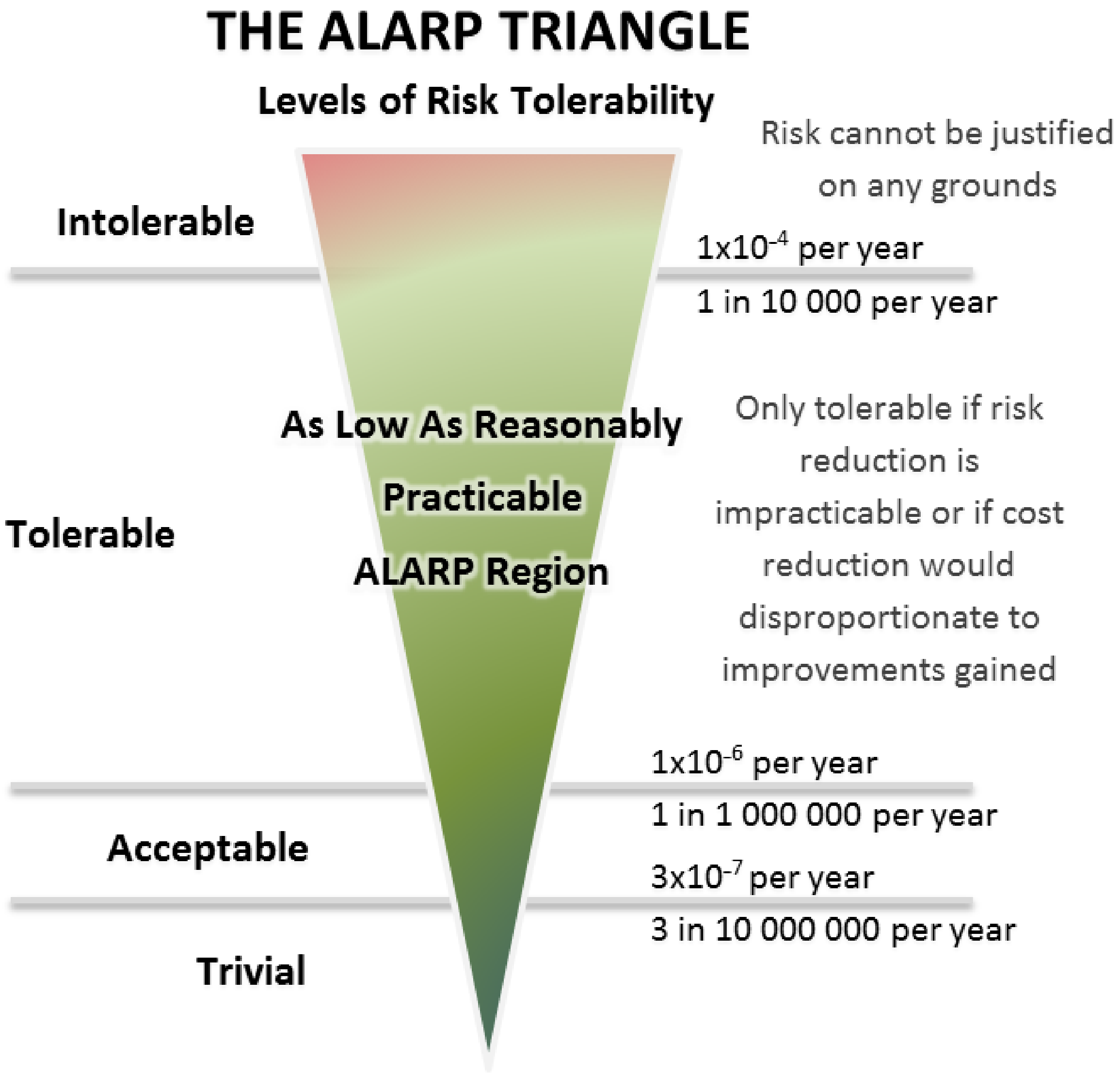


Figure 4.3: UK HSE decision-making framework

It should be emphasised that the risks considered acceptable to employees are different to those considered acceptable to the public. This is due to the fact that employees have personal protection equipment (PPE), are aware of the hazards, are sufficiently mobile to evade or escape the hazards and receive training in preventing injuries.

The HSE (UK) gives more detail on the word practicable in the following statement:

" *In essence, making sure a risk has been reduced to ALARP is about weighing the risk against the sacrifice needed to further reduce it. The decision is weighted in favour of health and safety because the presumption is that the duty-holder should implement the risk reduction measure. To avoid having to make this sacrifice, the duty-holder must be able to show that it would be grossly disproportionate to the benefits of risk reduction that would be achieved. Thus, the process is not one of balancing the costs and benefits of measures but, rather, of adopting measures except where they are ruled out because they involve grossly disproportionate sacrifices. Extreme examples might be:*

- *To spend £1m to prevent five staff members suffering bruised knees is obviously grossly disproportionate; but,*
- *To spend £1m to prevent a major explosion capable of killing 150 people is obviously proportionate.*

Proving ALARP means that if the risks are lower than 1x10^{-4} fatalities per person per year, it can be demonstrated that there would be no more benefit from further mitigation, sometimes using cost benefit analysis. "

4.3.3.3 Land Planning

There are no legislative land-planning guidelines in South Africa and in many parts of the world. Further to this, land-planning guidelines vary from one country to another, and thus it is not easy to benchmark the results of this study to international criteria. In this instance, RISCOM would only advise on applicable land planning and would require governmental authorities to make final decisions.

Land zoning applied in this study follows the HSE (UK) approach of defining the area affected into three zones, consistent to the ALARP approach (HSE 2011).

The three zones are defined as follows:

- The inner zone is enclosed by the risk of 1×10^{-5} fatalities per person per year isopleth;
- The middle zone is enclosed by the risk of 1×10^{-5} fatalities per person per year and the risk of 1×10^{-6} fatalities per person per year isopleths;
- The outer zone is enclosed by the risk 1×10^{-6} fatalities per person per year and the risk of 3×10^{-7} fatalities per person per year isopleths.

The risks decrease from the inner zone to the outer zone as shown in Figure 4.4 and Figure 4.5.

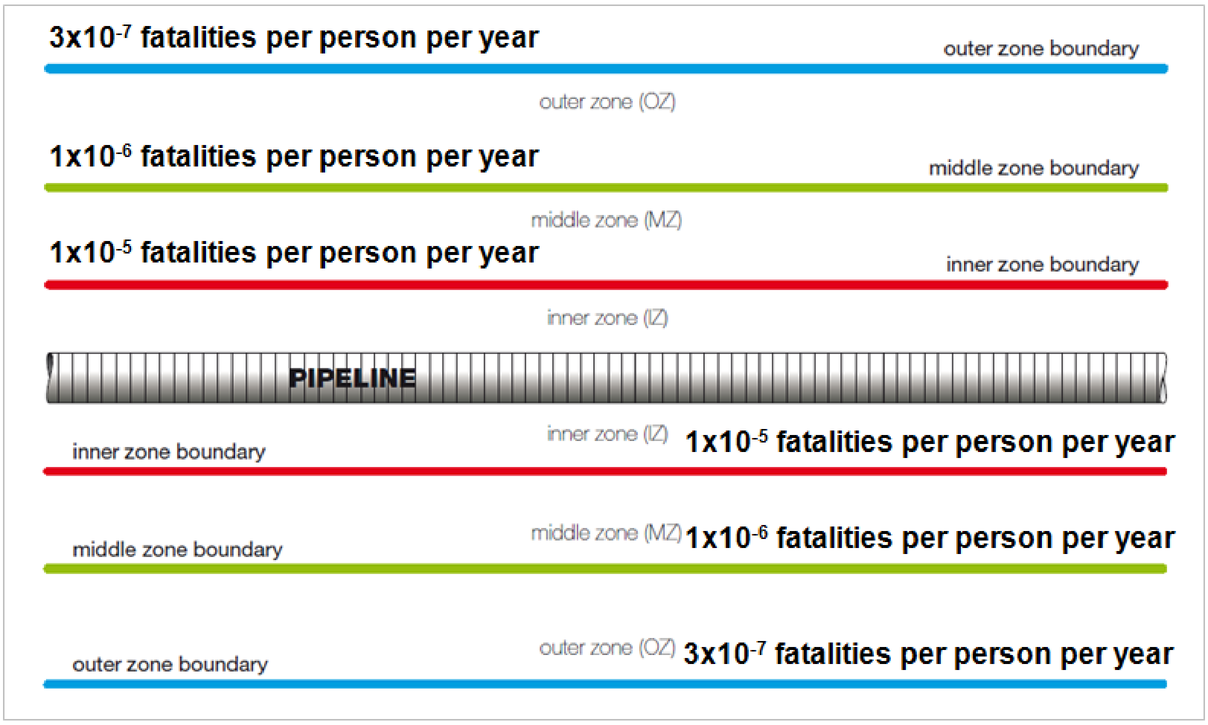


Figure 4.4: Town-planning zones for pipelines

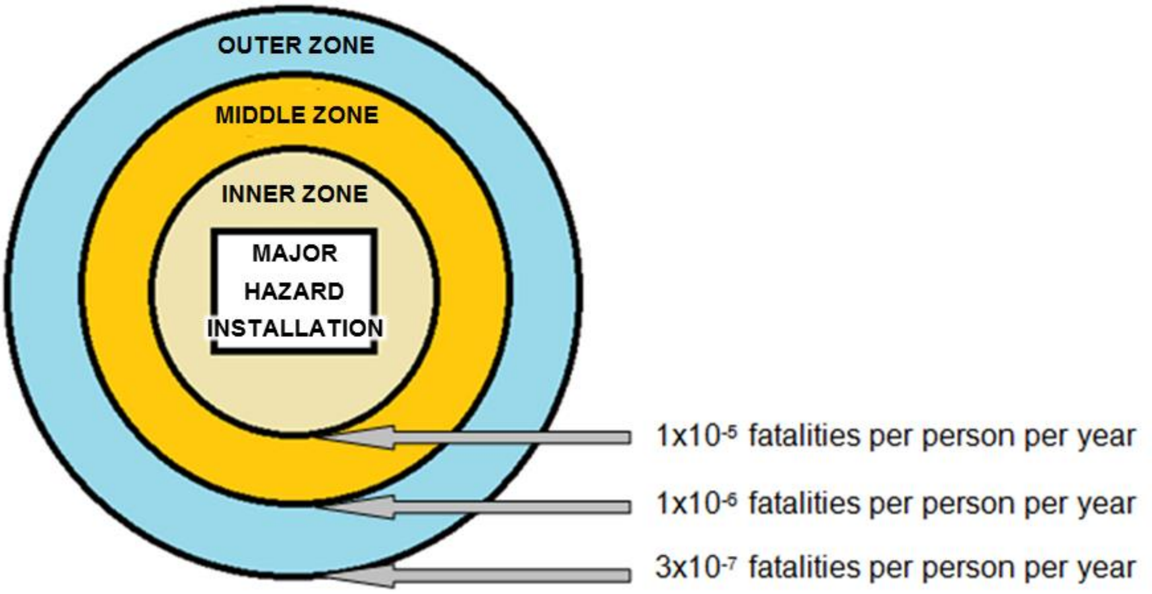


Figure 4.5: Town-planning zones

Once the zones are calculated, the HSE (UK) methodology then determines whether a development in a zone should be categorised as ‘advised against’ (AA) or as ‘don’t advise against’ (DAA), depending on the sensitivity of the development, as indicated in Table 4.15. There are no land-planning restrictions beyond the outer zone.

Table 4.15: Land-use decision matrix

Level of Sensitivity	Development in Inner Zone	Development in Middle Zone	Development in Outer Zone
1	DAA	DAA	DAA
2	AA	DAA	DAA
3	AA	AA	DAA
4	AA	AA	AA

The sensitivity levels are based on a clear rationale: progressively more severe restrictions are to be imposed as the sensitivity of the proposed development increases.

There are four sensitivity levels, with the sensitivity for housing defined as follows:

- Level 1 is based on workers who have been advised of the hazards and are trained accordingly;
- Level 2 is based on the general public at home and involved in normal activities;
- Level 3 is based on the vulnerability of certain members of the public (e.g. children, those with mobility difficulties or those unable to recognise physical danger);
- Level 4 is based on large examples of Level 2 and of Level 3.

Refer to Appendix D for detailed planning advice for developments near hazardous installations (PADHI) tables. These tables illustrate how the HSE land-use decision matrix, generated using the three zones and the four sensitivity levels, is applied to a variety of development types.

4.4 Quantitative Risk Assessment (QRA) Scenarios

4.4.1 Methodology

Due to the absence of South African legislation regarding determination methodology for quantitative risk assessment (QRA), the methodology of this assessment is based on the legal requirements of the Netherlands, outlined in CPR 18E (Purple Book; 1999) and RIVM (2009).

The evaluation of the acceptability of the risks is done in accordance with the Health and Safety Executive (HSE; UK) ALARP criteria, which clearly covers land use, based on the determined risks.

The QRA process is summarised with the following steps:

1. Identification of components that are flammable, toxic, reactive or corrosive and that have potential to result in a major incident from fires, explosions or toxic releases;
2. Development of accidental loss of containment (LOC) scenarios for equipment containing hazardous components (including release rate, location and orientation of release);
3. For each incident developed in Step 2, determination of consequences (such as thermal radiation, domino effects, toxic-cloud formation and so forth);
4. For scenarios with off-site consequences (greater than 1% fatality off-site), calculation of maximum individual risk (MIR), taking into account all generic failure rates, initiating events (such as ignition), meteorological conditions and lethality.

Scenarios included in this QRA have impacts external to the establishment. The 1% fatality from acute affects (thermal radiation, blast overpressure and toxic exposure) is determined as the endpoint (RIVM 2009). Thus, a scenario producing a fatality of less than 1% at the establishment boundary under worst-case meteorological conditions would be excluded from the QRA.

4.4.2 Scenario Selection

Guidelines for selection of scenarios is given in RIVM (2009) and CPR 18E (Purple Book; 1999). A particular scenario may produce more than one major consequence. In such cases, consequences are evaluated separately and assigned failure frequencies in the risk analysis. Some of these phenomena are described in the subsections that follow.

4.4.2.1 Scenarios for Release of a Pressurised Liquefied Gas

The nature of the release of a liquefied gas from a pressurised vessel is dependent on the position of the hole.

A hole above the liquid level will result in a vapour release only, and the release rate would be related to the size of the hole and internal pressure of the tank. Over a period of time, bulk temperature reduces, with an associated decrease in the vapour release rate.

A hole below the liquid level will result in a release of a liquid stream. In the reduced pressure of the atmosphere, a portion of the liquid will vaporise at the normal boiling point. This phenomenon is called flashing and is shown in Figure 4.6. The pool, formed after flashing, then evaporates at a rate proportional to the pool area, surrounding temperature and wind velocity.

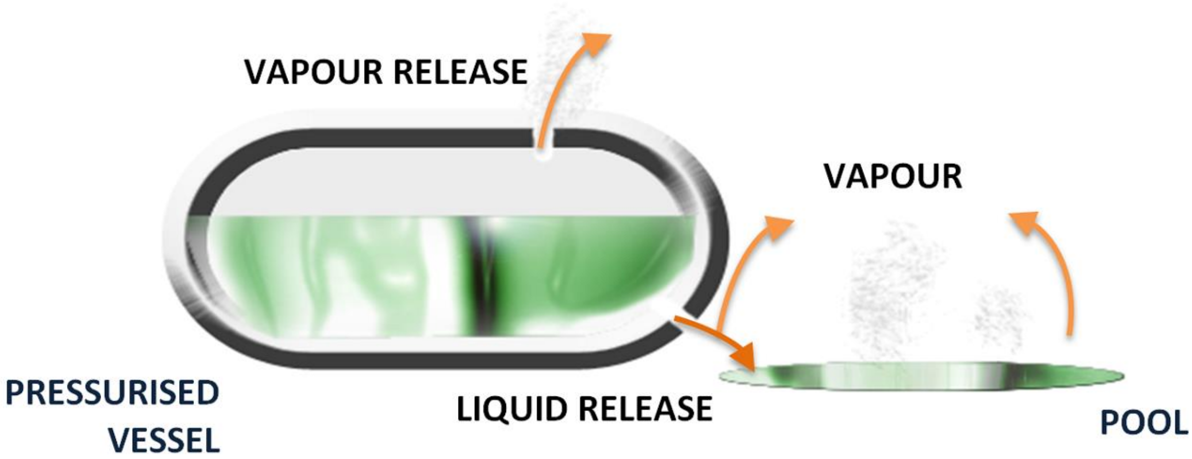


Figure 4.6: Airborne vapours from a loss of containment of liquefied gas stored in a pressurised vessel

- **Instantaneous Release of a Pressured Liquefied Flammable Gas**

An instantaneous loss of containment of a liquefied flammable gas could result in the consequences given in the event tree of Figure 4.7. Probability of the events occurring is dependent on a number of factors and is determined accordingly. All the scenarios shown in the figure are determined separately and reported in relevant subsections of the report.

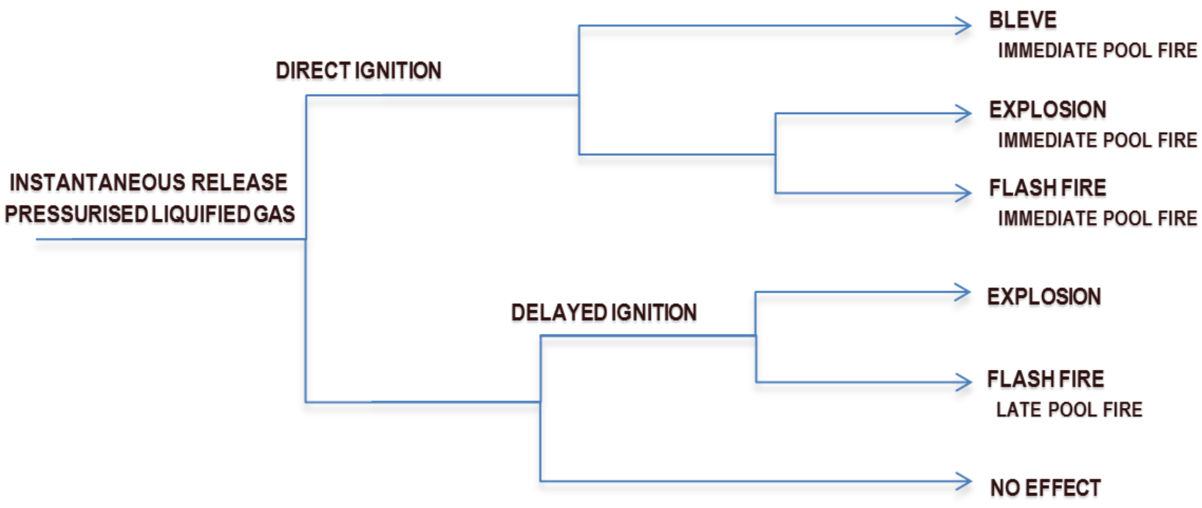


Figure 4.7: Event tree for an instantaneous release of a liquefied flammable gas

- **Continuous Release of a Pressurised Liquefied Flammable Gas**

The continuous loss of containment of a liquefied flammable gas could result in the consequences given in the event tree of Figure 4.8. Probability of the events occurring is dependent on a number of factors and is determined accordingly. All the scenarios shown in the figure are determined separately and reported in relevant subsections of the report.

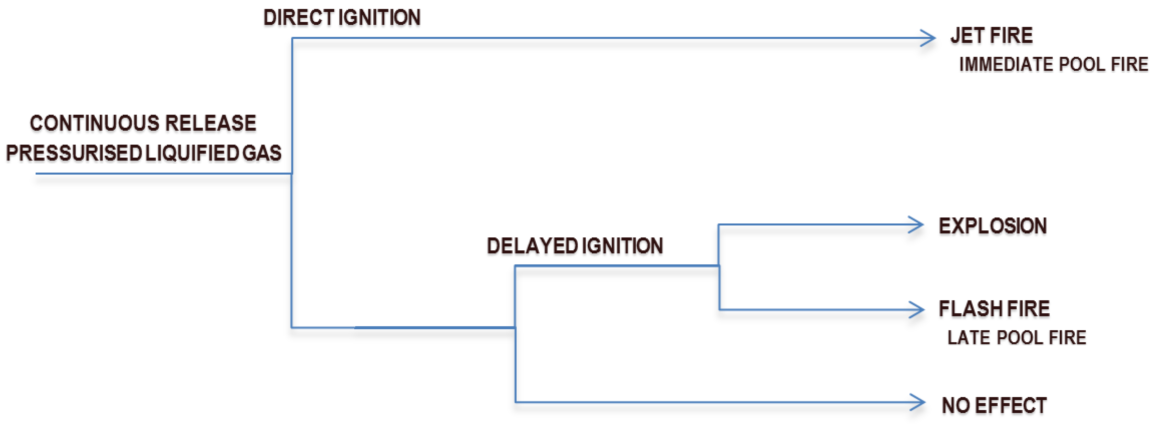


Figure 4.8: Event tree for a continuous release of a liquefied flammable gas

4.4.2.2 *Continuous Release of a Flammable Gas*

The continuous loss of containment of a flammable gas could result in the consequences given in the event tree of Figure 4.9. Probability of the events occurring is dependent on a number of factors and is determined accordingly. All the scenarios shown in the figure are determined separately and reported in relevant sub-sections of the report.

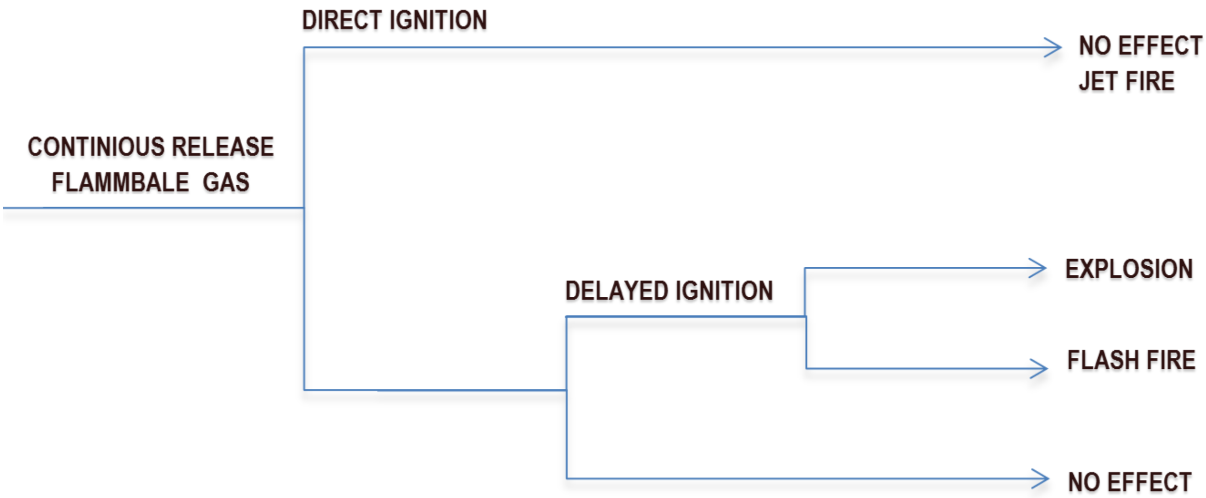


Figure 4.9: Event tree for a continuous release of a flammable gas

4.4.2.3 *Continuous Release of a Flammable Liquid*

The continuous loss of containment of a flammable liquid could result in the consequences given in the event tree of Figure 4.10. Probability of the events occurring is dependent on a number of factors and is determined accordingly. All the scenarios shown in the figure are determined separately and reported in relevant subsections of the report.

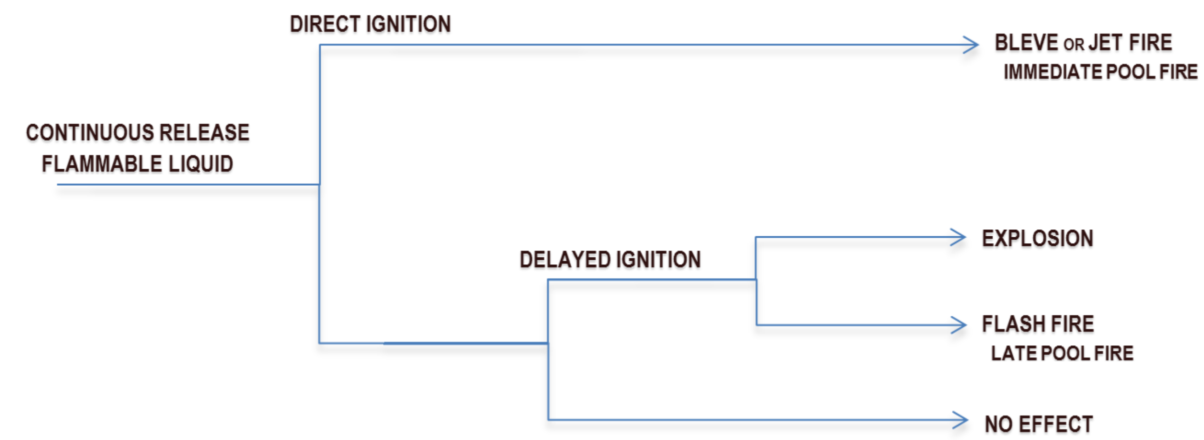


Figure 4.10: Event tree for a continuous release of a flammable liquid

5 RISK ASSESSMENT

A risk assessment was done of each processing unit by firstly selecting a scenario and then completing consequence and outflow modelling. Consequences with possible impacts beyond the site boundary were retained for risk analysis of the unit.

Finally, the risk of the entire facility is determined as a combination of the risk calculated for each unit.

5.1 Chlorine Installation

5.1.1 The Purpose of Chlorine Installation

Chlorine would be used for the treatment of process water as well as sewage and wastewater. The likely method of use would be direct injection of chlorine. This study assumes three 925 kg chlorine drums would be kept on site with one drum connected to the seawater, one to the wastewater system and one spare. Gaseous chlorine would be drawn through an eductor into the water at the required rate for treatment.

Chlorine is toxic in nature and as such was assessed for the potential effects of its loss of containment on the surrounding populations.

5.1.2 Chlorine Consequence Modelling

5.1.2.1 Toxic Vapour Clouds

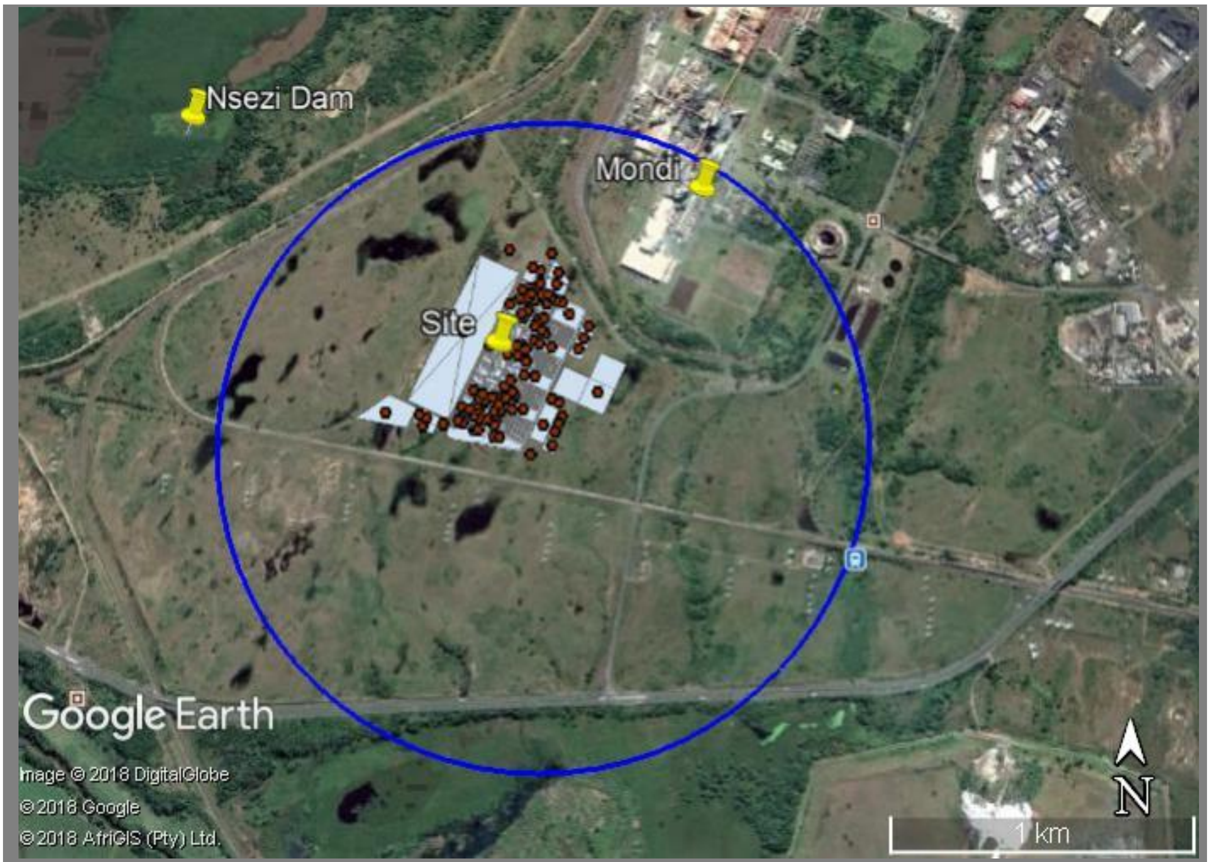
Chlorine is a greenish-yellow gas, with an irritating and suffocating odour. This gas is extremely toxic and a powerful oxidising agent. It has to be handled, stored and processed with caution.

The toxic effects of chlorine are described in great detail in Section 4.1.1.1.

Figure 5.11 shows the scenario with the largest distance to the 1% fatality. The scenario is the catastrophic failure of a chlorine drum and the furthest contour could extend 1,156 m downwind of the release. The contour illustrated in the figure represents the extent of the plume from all wind directions.

The contour extends in the northerly direction over the Mondi site, and in all other directions extends over predominantly agricultural land. To the south it extends over the R34 John Ross Highway. Fatalities are possible in the northerly direction over the Mondi facility.

1 An updated layout is available which does not differ significantly from that shown in the Figure provided. The overall findings of the report will remain the same.



LEGEND **SCENARIO**

Chlorine 1% fatality contour

Figure 5.1: Maximum extent of the 1% fatality for major releases

5.2 Natural Gas Installation

5.2.1 The Purpose of Natural Gas

Natural gas is proposed as a fuel for the gas turbines to be located onsite. Natural gas will be received by the site via pipeline at a pressure of between 25 and 30 bar at the facility fence. The gas would then be metered and its pressure reduced prior to entry into the gas engines. A line diameter of 200 mm has been assumed based on previous project experienced for similar facilities. Releases related to natural gas were centred around Areas 23 and 24.

5.2.2 Consequence Modelling

5.2.2.1 Fires

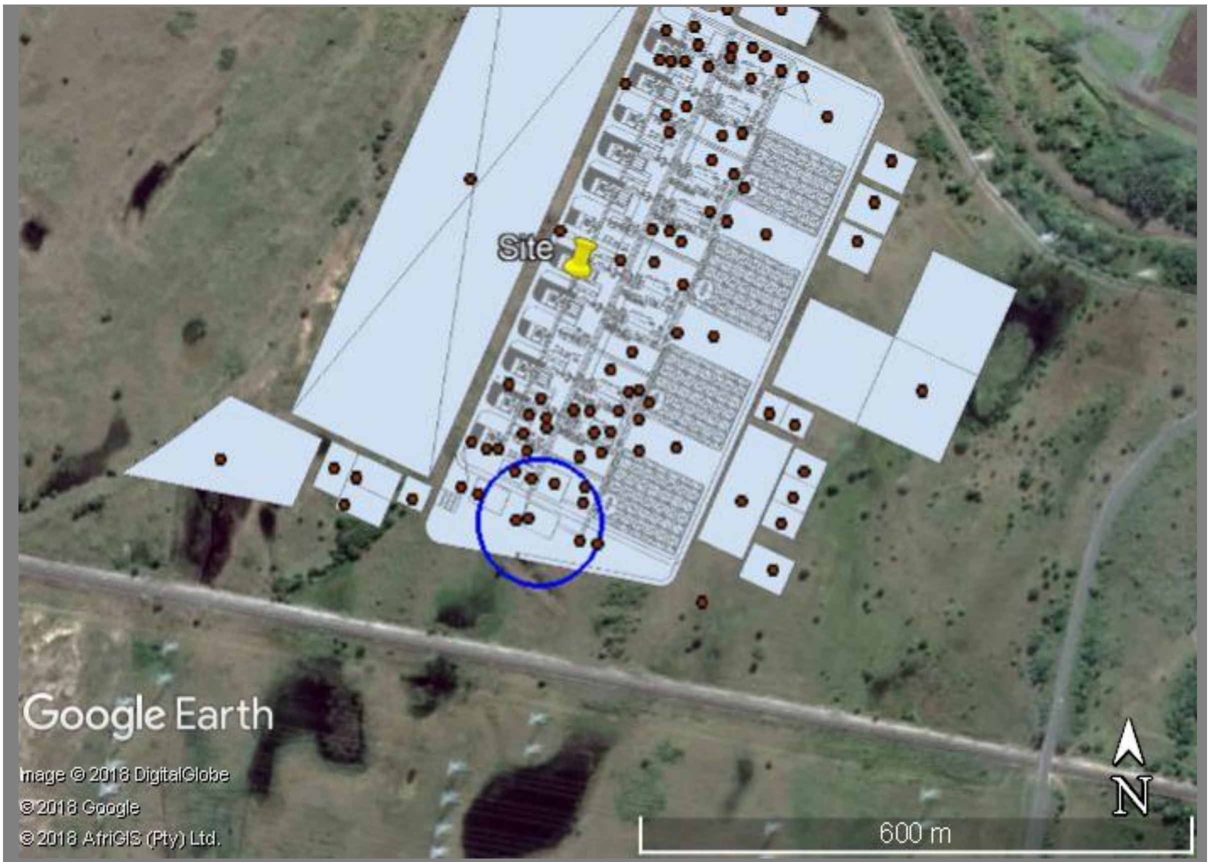
- **Jet Fires**

Full bore rupture scenario

A natural gas line full bore rupture was modelled and the worst case thermal radiation contours were found to occur at a weather of F1.5. The high pressure which characterises the release means that there is rapid mixing of vapour and rapid air entrainment upon release. An assumption was made that vapour moved in the line at a speed of approximately 2 m/s. Applying a maximum release duration of 30 minutes, the inventory in the line available for release was approximately 113 m^3. The thermal radiation contour equal to 10 kW/m^2, whose effect could be 1% fatality to the exposed population, is shown in Figure 5.21.

The 1% fatality contour extends a short distance over the southern site boundary over agricultural land and this scenario was analysed further.

1 An updated layout is available which does not differ significantly from that shown in the Figure provided. The overall findings of the report will remain the same.



LEGEND	THERMAL RADIATION (kW/m^2)
(blue line)	10

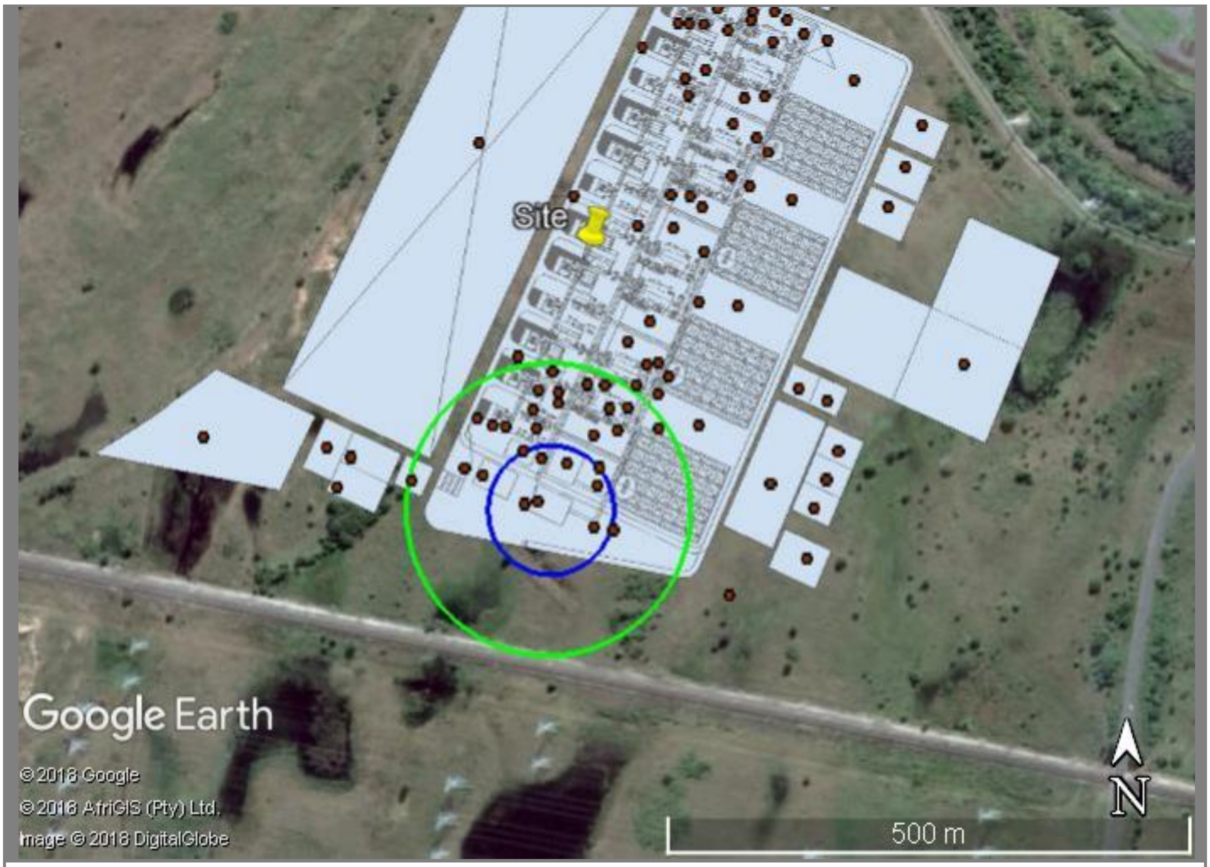
Figure 5.2: Isopleths representing thermal radiation from a jet fire due to a 10 mm hole

- **Flash Fires**

The extent of flash fires from the point of release in worst-case meteorological conditions due to a 10-minute release is shown in Figure 5.3[1].

The LFL contour extends a short distance over the southern site boundary while the ½ LFL contour extends further over the southern site boundary over agricultural land. The LFL contour indicates areas offsite where there is a high probability that fatalities could occur for individuals located outdoors, located within it. The ½ LFL contour indicates areas beyond the LFL contour where pockets of flammable gas could be present and so are useful for the purposes of emergency response and the determination of exclusion distances.

While fatalities could occur beyond the site boundaries, the surrounding area is agricultural and undeveloped reducing the probability of fatalities.



LEGEND	SCENARIO
Blue line	Flash Fire – LFL contour
Green line	Flash Fire – ½ LFL contour

Figure 5.3: Flash fire limits due to a release of Natural Gas flammable vapour

1 An updated layout is available which does not differ significantly from that shown in the Figure provided. The overall findings of the report will remain the same.

5.2.2.2 Explosions

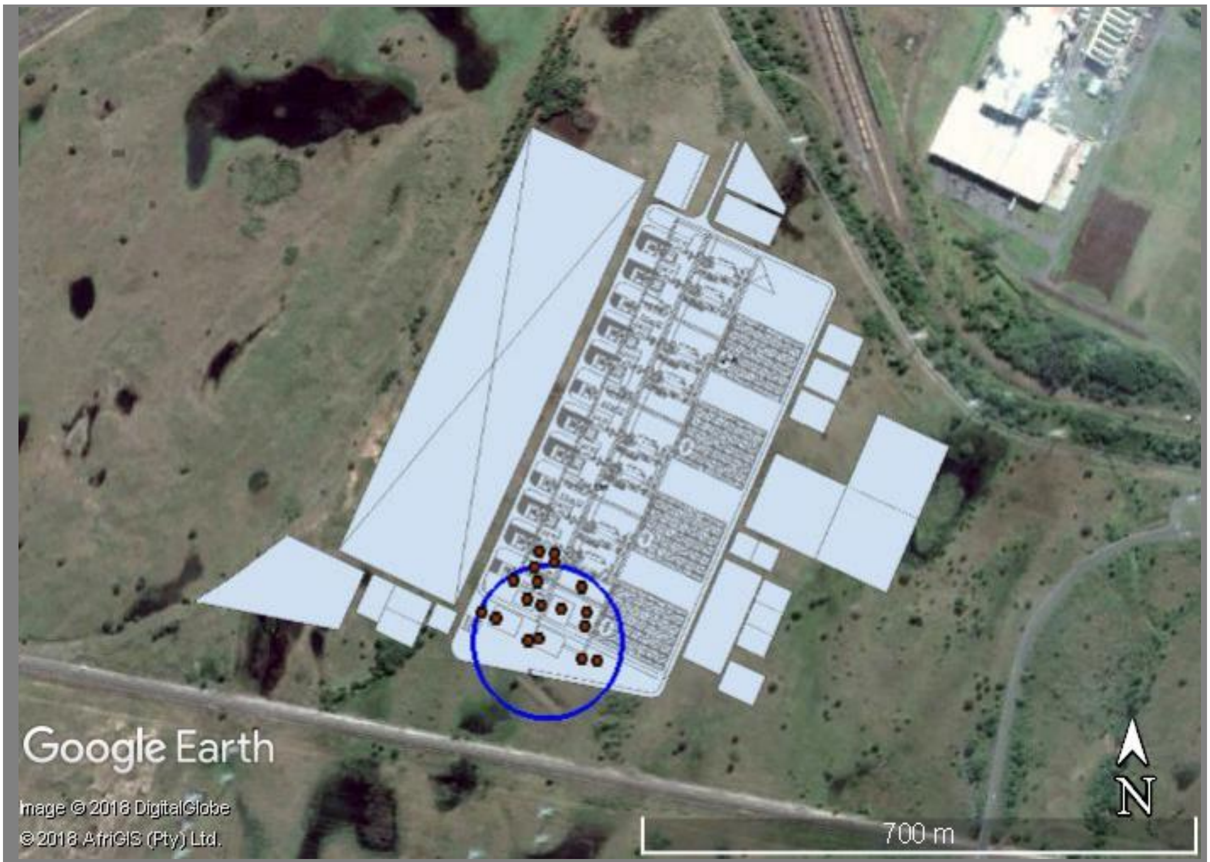
- **Vapour Cloud Explosions (VCEs)**

  - ***Full bore rupture incoming natural gas line***

Figure 5.4[1] shows the worst case 0.1 bar blast overpressure isopleth, representing the 1% fatality, due to full bore rupture in worst-case meteorological condition F1.5. No lethal effects are expected below 0.1 bar overpressure for people in the open.

In this scenario, vapours drifted to an ignition point before detonating. This is referred to as a 'late explosion'. The contour shows the total extent of the effects, including drift distance and overpressure effects.

The 1% fatality contour extends a short distance over the southern site boundary onto agricultural land, the risk due to this scenario were analysed further.



LEGEND	SCENARIO
(blue line)	0.1 bar overpressure contour

Figure 5.4: 0.1 bar overpressures from VCEs from natural gas releases

1 An updated layout is available which does not differ significantly from that shown in the Figure provided. The overall findings of the report will remain the same.

5.3 Diesel Installations

5.3.1 The Purpose of the Diesel Installations

Diesel would be used as a back-up fuel for the gas turbines. As such bulk storage would be required and achieved through storage in 2 x 5,400 m^3 bunded tanks located in Area 45 on-site.

5.3.2 Diesel Consequence Modelling

5.3.2.1 Fires

- **Bund and Pool Fires**

Diesel would be used as a back-up fuel for the turbines on site. It would be delivered to site in road tankers and offloaded in Area 46. There are two storage vessels each 5,400 m^3 in size. Due to the size of the tanks compared with that of typical road tankers (approximately 40 m^3, the thermal radiation effects from losses of containment from the tanks would exceed those from road tankers and therefore only the tanks were considered.

Instantaneous failure of a storage tank can result if a proportion of the component overflows the top of the bund, referred to as 'overtopping'. For the scenario of an instantaneous release, the amount of overtopping is taken to be an average of 33%. This is translated to the risk assessment by increasing the surface area of the bund by 50% (RIVM 2009)

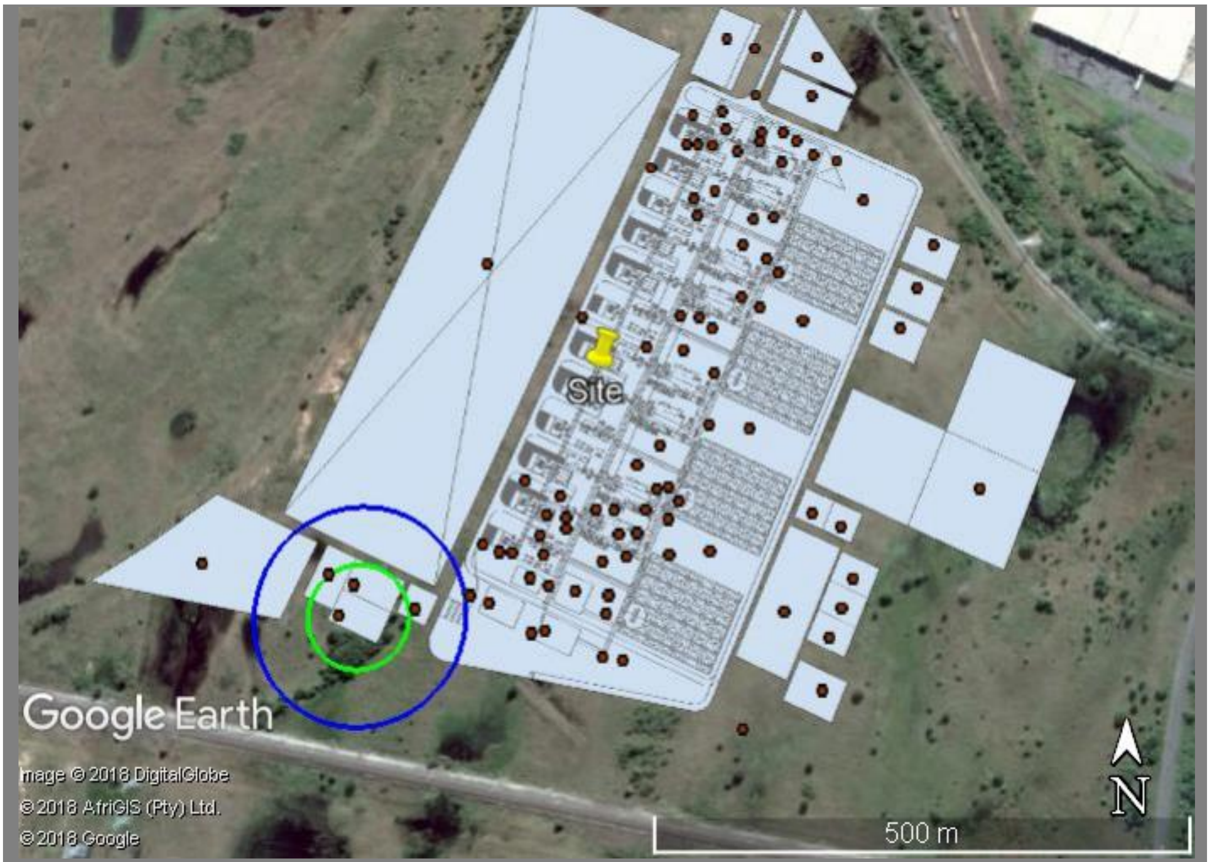
A tank release such as an overfilling or piping failure would not result in overtopping, and even in the worst case would be contained within the bunded area.

The maximum effect of a pool fire from a loss of containment in the storage area is shown Figure 5.5[1].

Due to the smokiness of the flame modelled by the consequence software, the emissive power at the flame surface did not exceed 20 kW/m^2, which is the emissive power of soot; the software assumed the entire flame surface to be covered in soot and smoke. Therefore, the 35 kW/m2 radiation level was not reached.

The 10 kW/m^2 thermal radiation, representing the 1% fatality, extends a short distance over the southern site boundary while the 4 kW/m^2 contour, representing the radiation level of interest for emergency response arrangements, also extends some distance to the south of the site boundary.

1 An updated layout is available which does not differ significantly from that shown in the Figure provided. The overall findings of the report will remain the same.



LEGEND	THERMAL RADIATION (kW/m^2)
Blue line	4
Green line	10
Red line	35 (not reached)

Figure 5.5: Thermal radiation from large diesel pool fires in the storage area

5.4 Hydrogen Installation

5.4.1 The Purpose of the Processing Unit

Hydrogen is expected to be used as a coolant for the mechanical bearings and to be produced on site on by splitting water into hydrogen and oxygen in an electrolyser. Oxygen would be vented to the atmosphere, while the hydrogen from the electrolysers would be compressed and stored in three 20 m^3 vessels at a maximum pressure of 25 bar. The study assumes that the hydrogen installations would be located in the vicinity of Area 22.

5.4.2 Hydrogen Consequence Modelling

5.4.2.1 Fires

- **Jet Fires**

o ***10 mm Hole release***

A 10 mm hole, representing a failed valve, would release vapour at approximately 0.11 kg/s. The worst-case release orientation would be in the horizontal. The surface of the flame would have an emissive power of approximately 49 kW/m^2, thermal radiation that could cause severe damage to nearby equipment within a short time and could result in fatalities within a short distance from the flame.

The thermal radiation contours from a 10 mm hole is at the worst case weather condition D9 extend approximately 10 metres from the centre of Area 22. Due to the nature of the material, the profile of thermal radiation vs distance downwind the source of the release (Figure 5.6) meant that the distances to the 4, 10 and 35 kW/m^2 were identical.

None of the thermal radiation contours of interest extended off-site.

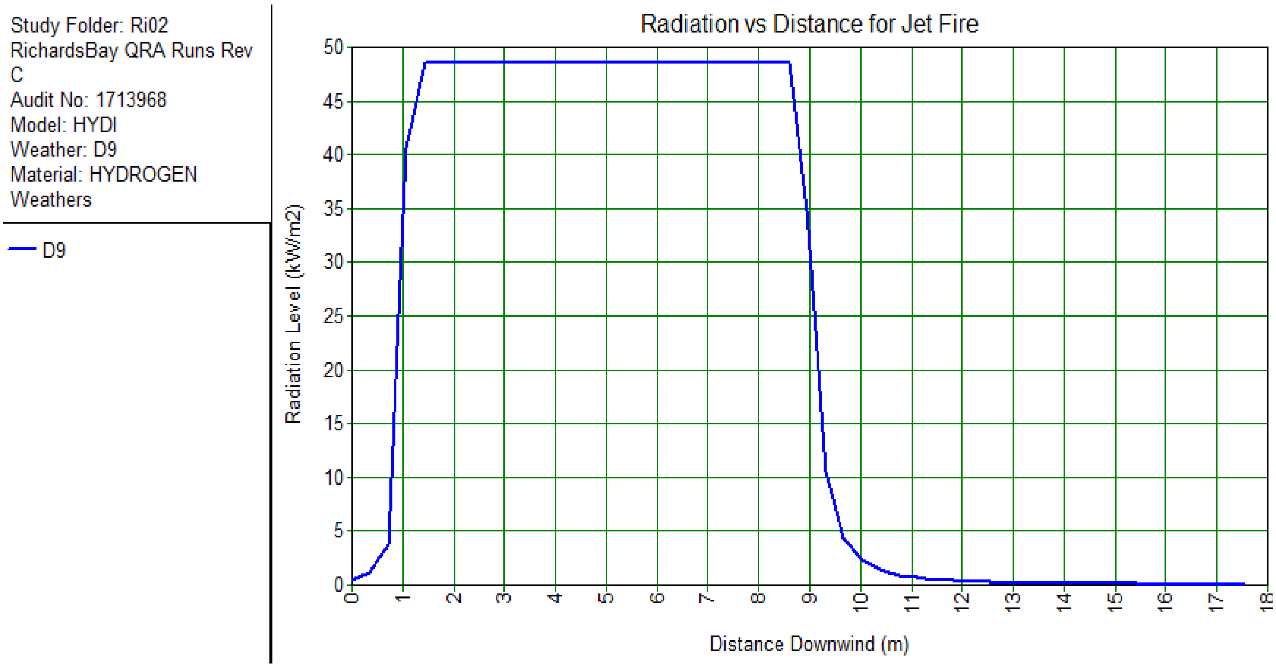


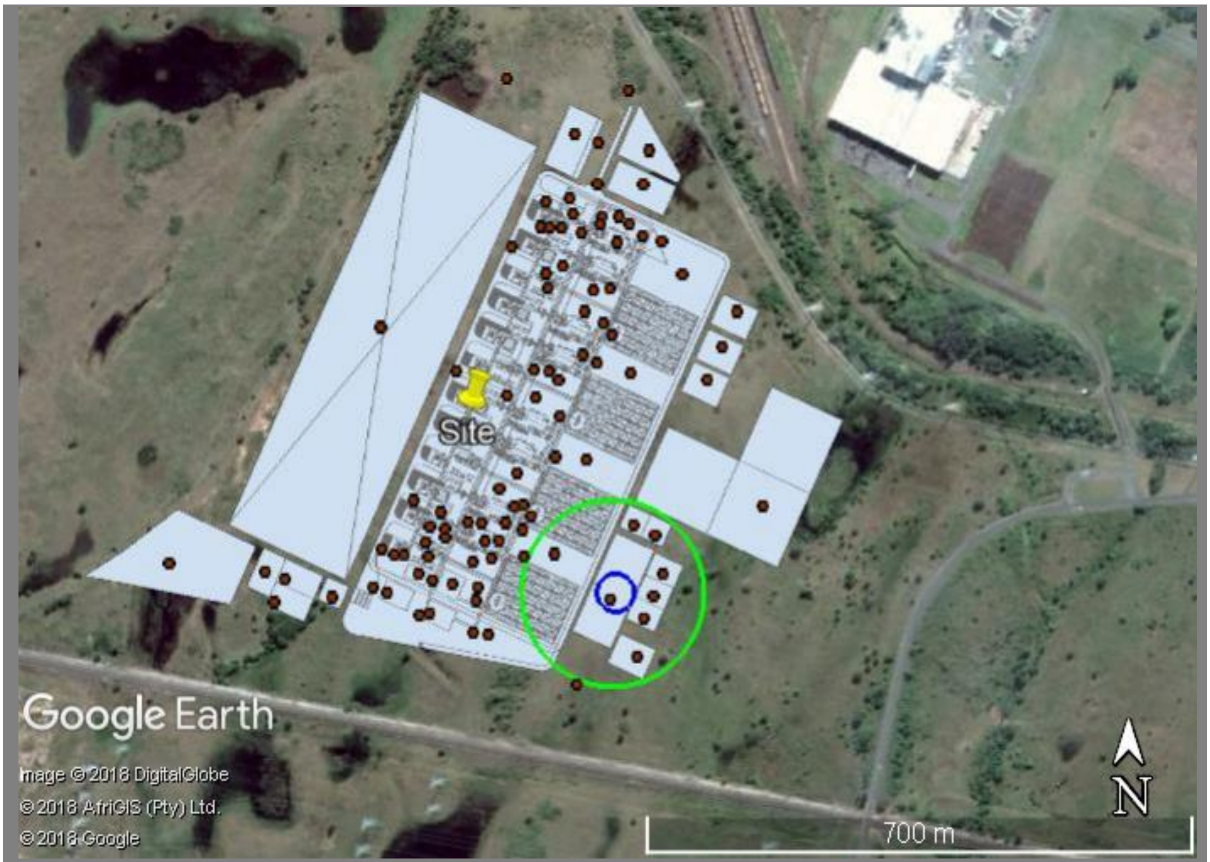
Figure 5.6: Thermal radiation profile vs distance downwind for Hydrogen 10 mm hole leak jet fire scenario

- **Flash Fires**

o ***Catastrophic Rupture of Vessel***

The extent of flash fires[1] from the point of release in worst-case meteorological conditions due to a catastrophic rupture of a hydrogen vessel results in a distance to the LFL contour of approximately 23 metres, and 116 metres the ½ LFL contour.

The LFL contour is limited to the process area, while the ½ LFL contour extends off-site very slightly in a south-easterly direction. The area covered by the ½ LFL contour would likely contain pockets of flammable vapour and this contour is of interest from an emergency response perspective – for the determination of exclusion distances.



LEGEND	SCENARIO
(blue line)	Flash Fire – LFL contour
(green line)	Flash – ½ LFL contour

Figure 5.7: Flash Fire contours from hydrogen vessel catastrophic failure

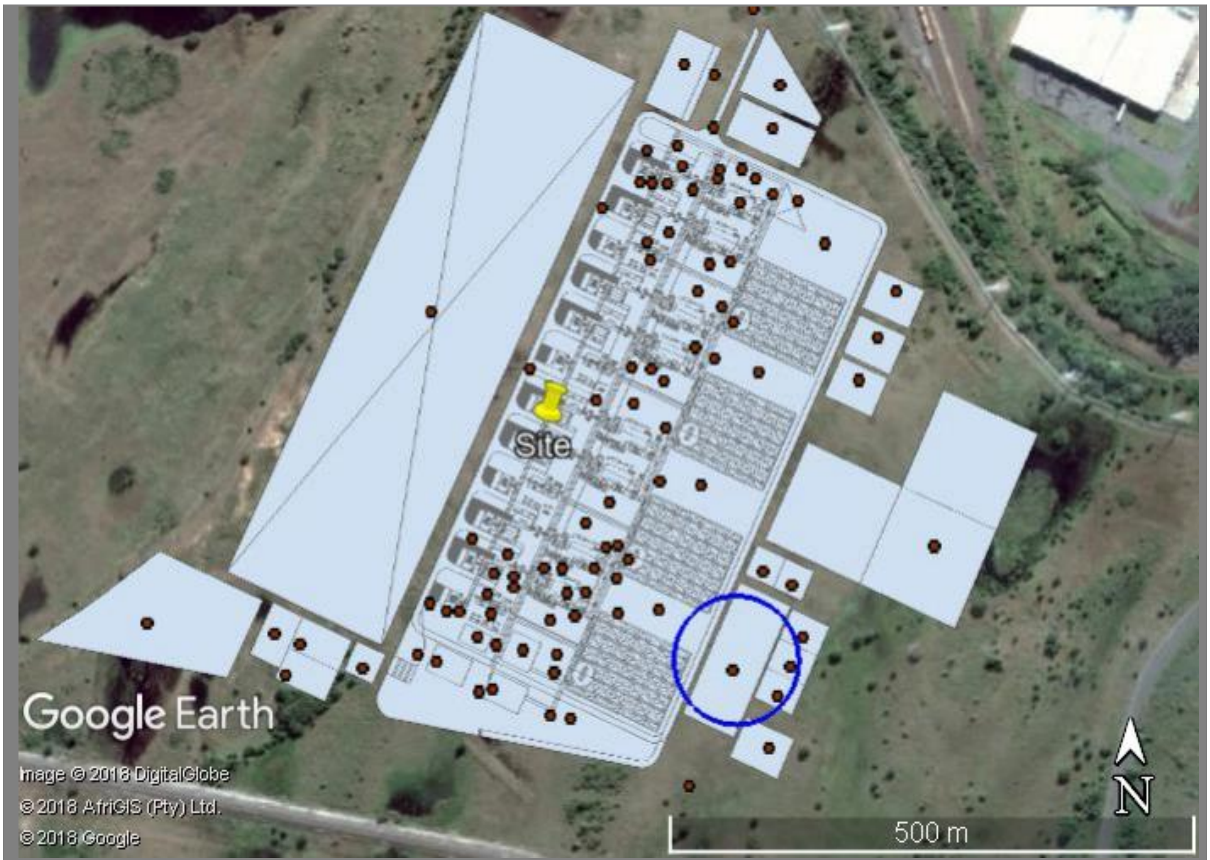
1 An updated layout is available which does not differ significantly from that shown in the Figure provided. The overall findings of the report will remain the same.

5.4.2.3 Explosions

- **Vapour Cloud Explosions (VCEs)**

Vapour cloud explosions related to the hydrogen installations are possible if leaks were to occur and congestion or confinement encountered. The worst case explosion event was due to the catastrophic failure of a hydrogen storage vessel leading to formation of flammable vapour which would drift some distance before encountering an ignition source and exploding, leading to overpressure effects.

The 0.1 bar blast overpressure isopleth[1,] representing the 1% fatality does not extend beyond the site boundary. No lethal effects are expected below 0.1 bar overpressure for people in the open and some equipment damage is to be expected within the contour.



LEGEND	SCENARIO
(blue line)	0.1 bar overpressure contour

Figure 5.8: Hydrogen explosion 0.1 bar overpressure contour – catastrophic vessel failure

1 An updated layout is available which does not differ significantly from that shown in the Figure provided. The overall findings of the report will remain the same.

5.5 LPG Installations

5.5.1 The Purpose of the LPG

LPG is proposed to be used as a pilot fuel for the gas turbines. It is proposed to be stored in 3 x 11 m^3 bullets, each vessel containing LPG stored as a saturated liquid (i.e. liquid and vapour LPG in equilibrium). The LPG vessels are proposed to be located in close proximity to the gas turbines themselves.

5.5.2 LPG Consequence Modelling

5.5.2.1 Fires

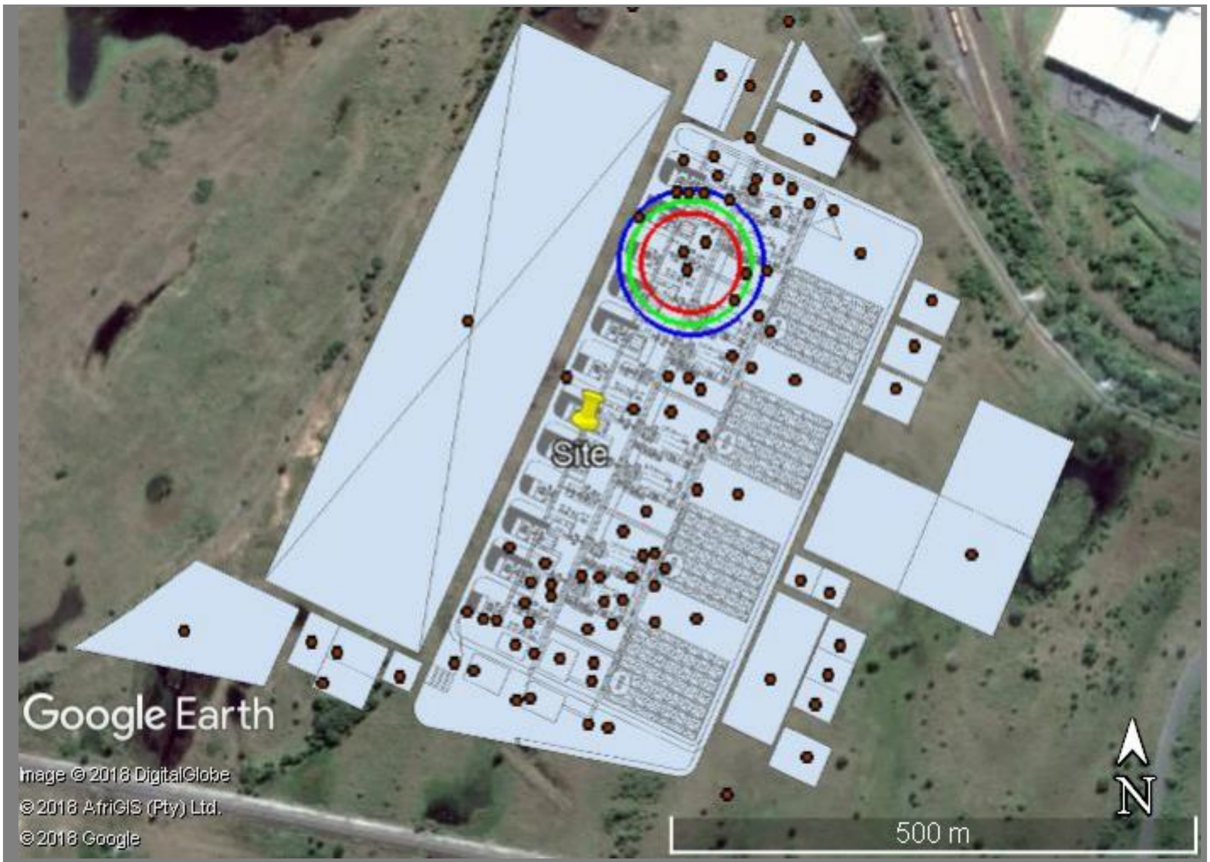
- **Jet Fires**

10 minute fixed duration release

DNVGL Phast v6.7 was used to model a fixed duration 10 minute release from an LPG vessel, i.e. the entire contents were modelled to be released in 10 minutes. The software adjusted the hole diameter and therefore release rate based on the initial inventory in the vessel. Jet fires could form as a result of ignition of the released jet of flammable vapour. The worst case thermal radiation contours from those jet fires are illustrated Figure 5.9[1].

None of the thermal radiation contours of interest extend offsite for the LPG vessel illustrated, which is the closest one to the site boundary.

1 An updated layout is available which does not differ significantly from that shown in the Figure provided. The overall findings of the report will remain the same.



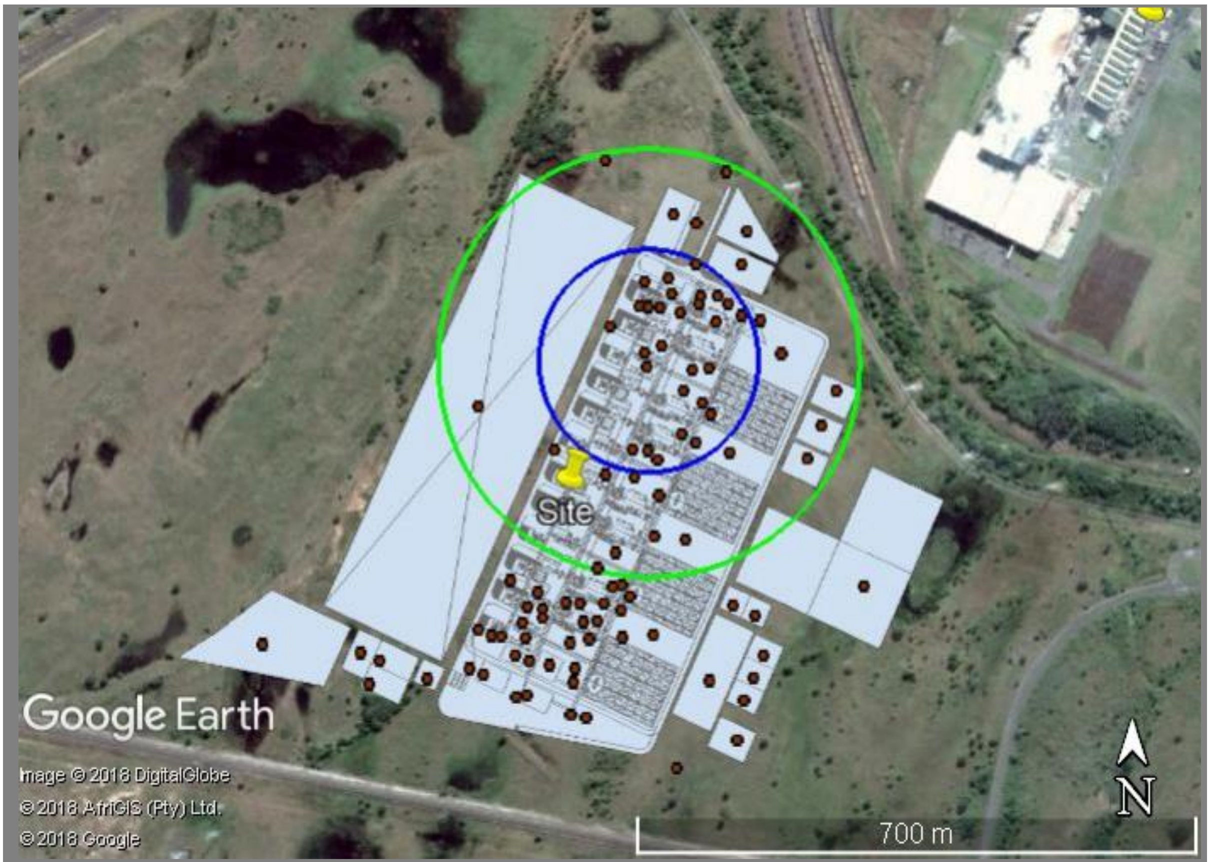
LEGEND	THERMAL RADIATION (kW/m²)
Blue line	4
Green line	10
Red line	35

Figure 5.9: Isopleths representing thermal radiation from a jet fire due to a 10 minute fixed duration release

- **LPG Flash Fires**

The extent of flash fires from the point of release in worst-case meteorological conditions due to a catastrophic failure of an LPG vessel is shown in Figure 5.10[1].

Based on the location of the LPG vessel closest to the site boundary, only the ½ LFL contour extends slightly offsite to the north, while the LFL contour does not. The ½ LFL contour is useful for emergency planning purposes. Where a release occurs, the contour can be useful in predicting how far pockets of flammable gas may extend, giving an indication of evacuation distances.



LEGEND	SCENARIO
Blue line	LFL contour
Green line	½ LFL contour

Figure 5.10: Flash fire limits due to a catastrophic failure and release of LPG

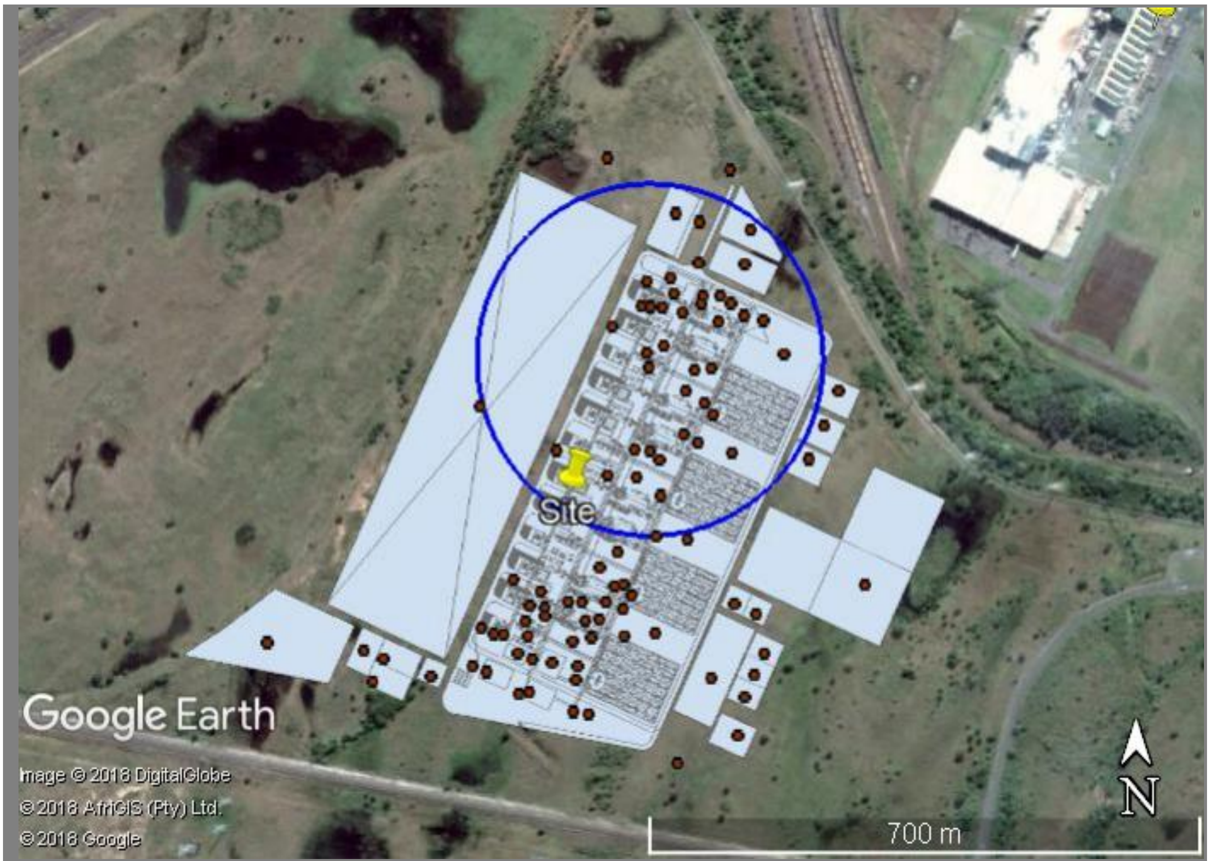
1 An updated layout is available which does not differ significantly from that shown in the Figure provided. The overall findings of the report will remain the same.

5.5.2.2 LPG Explosions

- **Vapour Cloud Explosions (VCEs)**

Figure 5.11[1] shows the 0.1 bar blast overpressure isopleth, representing the 1% fatality, due to a flammable vapour release from a catastrophic release of LPG. In this scenario, vapours drifted to an ignition point before detonating (late explosion).

The 1% fatality contour extends a short distance over the northern site boundary. This scenario and others for LPG were analysed further for their contribution to site risk.



LEGEND	SCENARIO
(blue line)	0.1 bar overpressure contour

Figure 5.11: 0.1 bar overpressure contour - VCE from LPG catastrophic release

1 An updated layout is available which does not differ significantly from that shown in the Figure provided. The overall findings of the report will remain the same.

5.6 Ammonia Installation

5.6.1 The Purpose of the Ammonia Installation

Anhydrous ammonia may be used to condition water for use in the boiler. It is assumed that it would be delivered to site in 8–10 t trucks and offloaded into 2 x 20 m^3 storage vessels. Ammonia is considered toxic and its toxic properties are discussed in detail in Section 4.1.1.3

5.6.2 Ammonia Consequence Modelling

5.6.2.1 Toxic Vapour Clouds

Ammonia is a colourless gas with a pungent and suffocating odour. It liquefies easily under pressure, with a normal boiling point of -33°C. Although classified as a non-flammable gas, it will burn in 16–25% vapour concentrations in air when exposed to open flames.

A full treatment of its toxic characteristics is given in Section 4.1.1.1.

Based on probit analysis, the 1% fatality contour for ammonia released from a 10 minute fixed duration release is illustrated in Figure 5.12[1.] The contour can be seen to extend slightly offsite in a south-easterly direction. The area onto which the contour extends is agricultural and a small population density is expected. The scenario was taken for further analysis.

LEGEND	SCENARIO
(blue line)	1% lethality contour

Figure 5.12: The extent of the 1% lethality contour – Ammonia fixed duration release

1 An updated layout is available which does not differ significantly from that shown in the Figure provided. The overall findings of the report will remain the same.

5.7 Combined Site Individual Risk

Considering the extent of the consequences of the releases contemplated in the preceding subsections of Section 5 and others, as well as the frequency of occurrence of each release as contemplated in Section 4.3.2.1, the combined site risk is the summation of all the individual risks and is shown in Figure 5.13[1].

Individual Risk, as introduced in Section 4.3.3, describes the chance of fatality of an individual situated at a particular location, due to operations onsite. Maximum individual risk assumes that individual is situated at a particular location 24 hours per day for 365 days per year. This tends to be an overstatement of risk, but one which is generally accepted as sufficiently conservative.

The individual risk contours illustrated in Figure 5.13 extend as follows:

- The $1x10^{-9}$ and $1x10^{-8}$ /year contours extend off-site, but only slightly to the south and the north of the site. These contours extend over mainly agricultural, generally sparsely populated land.
- The $3x10^{-7}$ contour extends only slightly off-site to the south of the site. This contour represents the threshold for 'trivial' risk. Risk below this threshold is considered trivial, but risk between this level and the level of $1x10^{-6}$ is considered 'broadly acceptable' to the general public but 'tolerable if proven to be ALARP' for vulnerable populations such as hospitals, retirement homes, nursery schools, prisons, large gatherings in the open, and so forth.
- Neither the $1x10^{-6}$, the $1x10^{-5}$ nor the $1x10^{-4}$ /year contours extend offsite.

Acceptability criteria for individual risk are detailed in Section 4.3.3.2. No new land planning should be approved without consultation of the PADHI land-planning tables described in Appendix D.

1 An updated layout is available which does not differ significantly from that shown in the Figure provided. The overall findings of the report will remain the same.

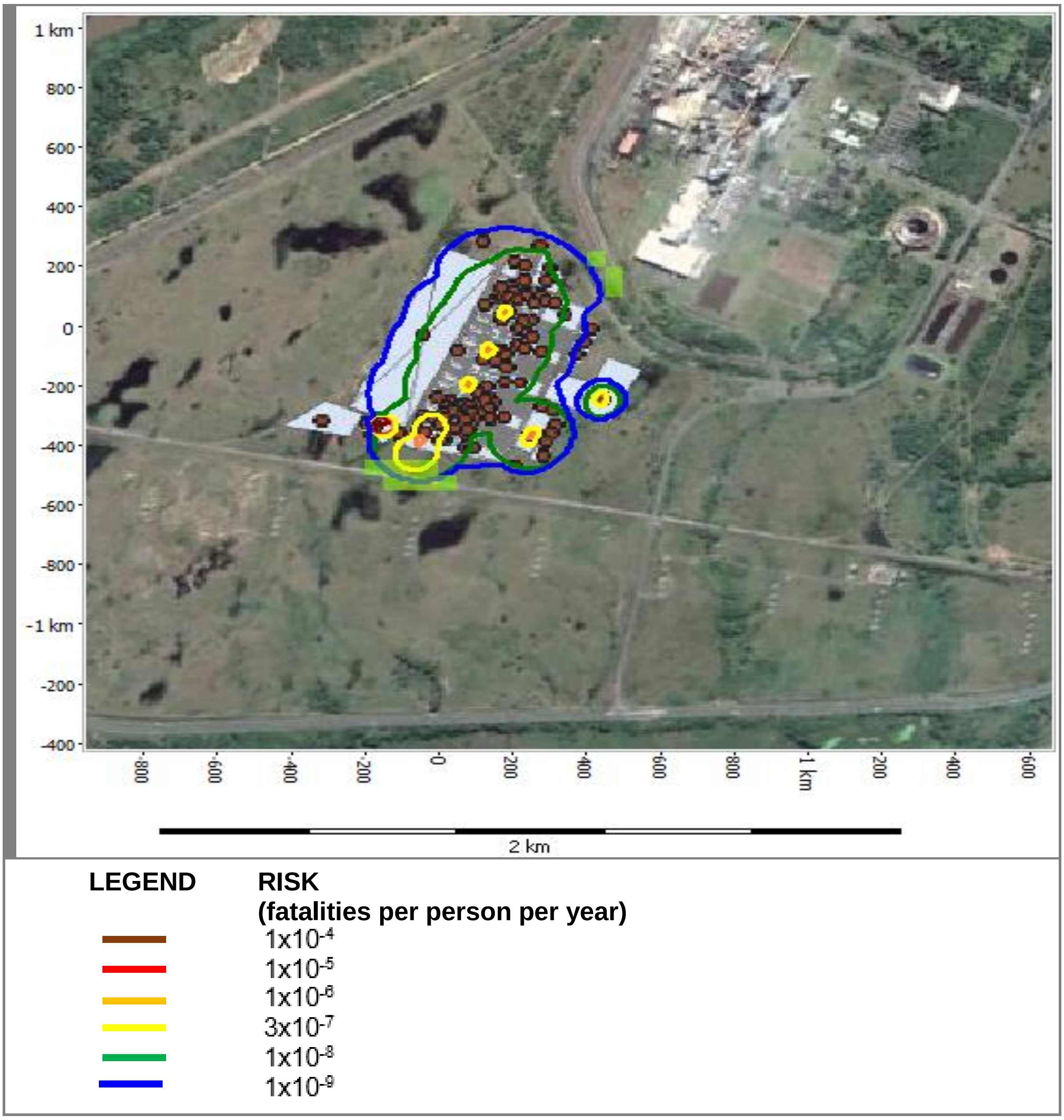


Figure 5.13: Individual Risk contours – combined risk

5.9 Combined Site Societal Risk

Societal risk is a measure of risk to groups of individuals and its calculation is based on estimates of populations surrounding the facility. Populations were estimated based on the types of land uses surrounding the site.

In this assessment societal risk was found to be negligible, driven mainly by the low population density of the areas around the site and the nature of the materials used and stored on-site.

Therefore, societal risk is broadly acceptable.

6 IMPACT ASSESSMENT

6.1 Impact Assessment Methodology

As described in the terms of reference of the project, assessment of the Impacts of the loss of containment scenarios considered in this study took cognisance of the following aspects as they related to local population:

- An assessment of the magnitude of the impacts (the consequences of the project on members of the surrounding public);
- An assessment of the significance of the impacts, taking into account the sensitivity of the receptors;
- Development of mitigation measures to avoid, reduce or manage the impacts; and
- Assessment of the residual significant impacts after applying the mitigation measures.

The criteria that were used in impact assessment are summarised below (verbatim from the terms of reference document):

- The nature, which shall include a description of what causes the effect, what will be affected and how it will be affected.
- The extent, wherein it will be indicated whether the impact will be local (limited to the immediate area or site of development) or regional, and a value between 1 and 5 will be assigned as appropriate (with 1 being low and 5 being high).
- The duration, wherein it will be indicated whether:
    - the lifetime of the impact will be of a very short duration (0–1 years) – assigned a score of 1;
    - the lifetime of the impact will be of a short duration (2-5 years) - assigned a score of 2;
    - medium-term(5–15 years) – assigned a score of 3;
    - long term(> 15 years) - assigned a score of 4; or
    - permanent - assigned a score of 5.
- The magnitude, quantified on a scale from0-10, where a score is assigned:
    - 0 is small and will have no effect on the environment
    - 2 is minor and will not result in an impact on processes
    - 4 is low and will cause a slight impact on processes
    - 6 is moderate and will result in processes continuing but in a modified way
    - 8 is high (processes are altered to the extent that they temporarily cease)
    - 10 is very high and results in complete destruction of patterns and permanent cessation of processes.
- The probability of occurrence, which shall describe the likelihood of the impact actually occurring. Probability will be estimated on a scale of 1–5,where:
    - 1 is very improbable (probably will not happen),
    - 2 is improbable (some possibility, but low likelihood), 3 is probable (distinct possibility), 4 is highly probable (most likely) and
    - 5 is definite (impact will occur regardless of any prevention measures).
- the significance, which shall be determined through a synthesis of the characteristics described above and can be assessed as low, medium or high; and
- the status, which will be described as either positive, negative or neutral.

- the degree to which the impact can be reversed.
- the degree to which the impact may cause irreplaceable loss of resources.
- the degree to which the impact can be mitigated.

The significance is calculated by combining the criteria in the following formula:

S = (E+D+M)P

S = Significance weighting
E = Extent
D = Duration
M =Magnitude
P = Probability

The significance weightings for each potential impact are as follows:

- < 30 points: Low (i.e. where this impact would not have a direct influence on the decision to develop in the area),
- 30-60 points: Medium (i.e. where the impact could influence the decision to develop in the area unless it is effectively mitigated),
- > 60 points: High (i.e. where the impact must have an influence on the decision process to develop in the area).

6.2 Methodology - cumulative impacts

“Cumulative Impact”, in relation to an activity, means the past, current and reasonably foreseeable future impact of an activity, considered together with the impact of activities associated with that activity, that in itself may not be significant, but may become significant when added to existing and reasonably foreseeable impacts eventuating from similar or diverse activities.

The role of the cumulative assessment is to test if such impacts are relevant to the proposed project in the proposed location (i.e. whether the addition of the proposed project in the area will increase the impact).

This section addresses whether the construction of the proposed development will result in:

- Unacceptable risk
- Unacceptable loss
- Complete or whole-scale changes to the environment or sense of place
- Unacceptable increase in impact.

6.3 Impact Assessment of Eskom Richards Bay site

6.3.1 Chlorine Installation

The impact of the chlorine installation is assessed as follows:

Table 6.1: Impact Assessment of Chlorine Installation

Nature:

Worst case loss of containment scenario – catastrophic rupture of chlorine storage vessel with subsequent dispersion of toxic vapours over surrounding area.

	Without Mitigation	**With Mitigation**
Extent	3	2
Duration	1	1
Magnitude	8	6
Probability	1	1
Significance	12 (LOW)	9 (LOW)
Status (positive or negative)	Negative	Negative
Reversibility	Irreversible	Irreversible
Irreplaceable loss of resources?	Yes (human)	Yes (human)
Can impacts be mitigated?	Yes	Yes

Mitigation:
Mitigation includes a regional (industrial area-wide) emergency response plan with involvement by the local authorities as well as alarms and communication systems which allow for fast and effective communication to neighbouring facilities such as the Mondi facility to the north. The area around the site is sparsely populated, so any impact would not be experienced by a large number of people.

Residual Risks:
Even with mitigation, there is still possibility of human death as a result of prolonged exposure to chlorine vapour and as such, any impact could be irreversible (human death). However, the area over which impact would occur could experience up to a 1% fatality probability.

6.3.2 Natural Gas Installation

The following is an impact assessment of the natural gas installation:

Table 6.2: Impact Assessment of Natural Gas Installation

Nature:

Worst case loss of containment scenario – full bore rupture of incoming natural gas line with flammable vapour dispersion, ignition and flash fire or explosive effects

	Without Mitigation	**With Mitigation**
Extent	2	1
Duration	1	1
Magnitude	8	6
Probability	1	1
Significance	11 (LOW)	8 (LOW)
Status (positive or negative)	Negative	Negative
Reversibility	Irreversible	Irreversible
Irreplaceable loss of resources?	Yes (human)	Yes (human)
Can impacts be mitigated?	Yes	Yes

Mitigation:
Mitigation would include sufficient emergency shut-down valving systems, gas detection, alarm and executive function systems to limit the amount of vapour that's released.

Residual Risks:
Even with mitigation, there is still possibility of human death as a result of flash fire thermal radiation exposure, or vapour cloud explosion overpressure exposure. The area over which impacts occur could be limited, however, those caught up in an event could suffer death.

6.3.3 Diesel Installations

The following is the impact assessment of the diesel installations:

Table 6.3: Impact Assessment of Diesel Installations

Nature:

Worst case loss of containment scenario – catastrophic tank rupture with full bund fire and possible bund overtopping.

	Without Mitigation	**With Mitigation**
Extent	2	1
Duration	1	1
Magnitude	8	6
Probability	1	1
Significance	11 (LOW)	8 (LOW)
Status (positive or negative)	Negative	Negative
Reversibility	Irreversible	Irreversible
Irreplaceable loss of resources?	Yes (human)	Yes (human)
Can impacts be mitigated?	Yes	Yes

Mitigation:
Mitigation would include emergency response arrangements and systems such as foam pourers, fire-fighting systems and cooperation with emergency responders. Preventive measures could include maintenance procedures to prevent the occurrence of a catastrophic loss of containment, as well as strict control of ignition sources and other measures which may be required according to standards such as those prescribed by the South African National Standards system.

Residual Risks:
Even with mitigation, there is still possibility of human death as a result of pool fire thermal radiation and smoke exposure. There is also possibility of contamination of ground and water systems from diesel spills and exposure to fire-fighting foam.

6.3.4 Hydrogen Installation

The following is an impact assessment of the hydrogen installation:

Table 6.4: Impact Assessment of Hydrogen Installation

Nature:

Worst case loss of containment scenario – catastrophic rupture of hydrogen storage vessel leading to flammable vapour dispersion and ignition leading to flash fire thermal radiation effects and/or vapour cloud explosion overpressure effects.

	Without Mitigation	**With Mitigation**
Extent	1	1
Duration	1	1
Magnitude	8	6
Probability	1	1
Significance	10 (LOW)	8 (LOW)
Status (positive or negative)	Negative	Negative
Reversibility	Irreversible	Irreversible
Irreplaceable loss of resources?	Yes (human)	Yes (human)
Can impacts be mitigated?	Yes	Yes

Mitigation:
Mitigation would include emergency response arrangements and systems such as alarms to allow for personnel to muster in case of emergency, as well as fire-fighting systems and cooperation with emergency responders. Preventive measures could include maintenance procedures to prevent the occurrence of a catastrophic loss of containment, as well as strict control of ignition sources and other measures which may be required according to standards such as those prescribed by the South African National Standards system.

Residual Risks:
With mitigation, correct muster and fire-fighting arrangements and execution, there should be limited residual risk.

6.3.5 LPG Installations

The following is the impact assessment of the LPG installations:

Table 6.5: Impact Assessment of LPG Installations

Nature:

Worst case loss of containment scenario – catastrophic rupture of LPG storage vessel leading to a fireball event, flammable vapour dispersion and ignition leading to flash fire thermal radiation effects and/or vapour cloud explosion overpressure effects.

	Without Mitigation	**With Mitigation**
Extent	2	1
Duration	1	1
Magnitude	8	6
Probability	1	1
Significance	11 (LOW)	8 (LOW)
Status (positive or negative)	Negative	Negative
Reversibility	Irreversible	Irreversible
Irreplaceable loss of resources?	Yes (human)	Yes (human)
Can impacts be mitigated?	Yes	Yes

Mitigation:
Mitigation would include emergency response arrangements and systems such as alarms to allow for personnel to muster in case of emergency, as well as fire-fighting systems and cooperation with emergency responders. Preventive measures could include maintenance procedures to prevent the occurrence of a catastrophic loss of containment from corrosion, fire and gas detection and firewater systems to prevent escalation as well as strict control of ignition sources and other measures which may be required according to standards such as those prescribed by the South African National Standards system.

Residual Risks:
Even with mitigation, there may be residual risk of occurrence due to failures in protection systems and break-down in procedures and documented systems.

6.3.6 Ammonia Installation

The following is the impact assessment of the Ammonia installation

Table 6.6: Impact Assessment of Ammonia Installation

Nature:

Worst case loss of containment scenario – catastrophic rupture of ammonia storage vessel with subsequent dispersion of toxic vapours over surrounding area.

	Without Mitigation	**With Mitigation**
Extent	2	1
Duration	1	1
Magnitude	8	6
Probability	1	1
Significance	11 (LOW)	8 (LOW)
Status (positive or negative)	Negative	Negative
Reversibility	Irreversible	Irreversible
Irreplaceable loss of resources?	Yes (human)	Yes (human)
Can impacts be mitigated?	Yes	Yes

Mitigation:
Mitigation includes an effective emergency response plan with involvement by the local authorities as well as alarms and communication systems which allow for fast and effective communication for muster of employees. The area around the site is sparsely populated, so any impact would not be experienced by a large number of people.

Residual Risks:
Even with mitigation, there is still possibility of human death as a result of prolonged exposure to ammonia vapour and as such, any impact could be irreversible (human death). However, the area over which impact would occur could experience up to a 1% fatality probability.

6.5 Cumulative Impact Assessment

This section considers all impacts in the preceding Section 6.3 and the cumulative impact of all installations.

Table 6.7: Cumulative impact of project as a whole

Nature: Potential impact on surrounding human populations including possibility of serious injury or death as a result of major industrial accidents from hazardous materials used on-site.		
	Overall impact of the proposed project in isolation	**Cumulative impact of the project and other projects in the area**
Extent	Low (1)	Low (1)
Duration	Very short (1)	Very short (1)
Magnitude	High (8)	High (8)
Probability	Very improbable (1)	Very improbable (1)
Significance	**10 (LOW)**	**10 (LOW)**
Status (positive or negative)	Negative	Negative
Reversibility	Irreversible (worst case: death)	Irreversible (worst case: death)
Irreplaceable loss of resources?	Yes (human)	Yes (human)
Can impacts be mitigated?	Yes	Yes
Confidence in findings: Medium to High (more process detail required to increase confidence)		
Mitigation: Mitigation includes an effective emergency response plan with involvement by the local authorities as well as neighbouring facilities, especially Mondi in the north and others in the general area. Emergency drills must be undertaken together with neighbours and authorities to increase the effectiveness and speed of response to emergency situations – this may reduce the number of casualties in an emergency. The implementation of effective [process] safety management systems would act as a mitigation measure.		
Residual Risks: Even with mitigation, there is still possibility of human death as a result of major incidents on-site due to the nature of operations.		

7 CONCLUSIONS

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

This risk assessment included the consequences of fires and explosions as well as toxic releases at the Eskom facility in Richards Bay. A number of well-known sources of incident data were consulted and applied to determine the likelihood of an incident to occur.

This risk assessment was performed with the assumption that the site would be maintained to an acceptable level and that all statutory regulations would be applied. It was also assumed that the detailed engineering designs would be done by competent people and would be correctly specified for the intended duty. For example, it was assumed that tank wall thicknesses have been correctly calculated, that vents have been sized for emergency conditions, that instrumentation and electrical components comply with the specified electrical area classification, that material of construction is compatible with the products, etc.

It is the responsibility of the owners and their contractors to ensure that all engineering designs would have been completed by competent persons and that all pieces of equipment would have been installed correctly. All designs should be in full compliance with (but not limited to) the Occupational Health and Safety Act 85 of 1993 and its regulations, the National Buildings Regulations and the Buildings Standards Act 107 of 1977 as well as local by-laws.

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

Furthermore, the following conclusions are made:

- The following installations were considered for analysis in the QRA:
    - Chlorine;
    - Natural gas;
    - Diesel;
    - Hydrogen;
    - LPG; and
    - Ammonia.
- Consequences for the installations were analysed and assessed, with several worst case scenarios having the potential to affect individuals located offsite. The largest of these was toxic vapour dispersion from the catastrophic rupture of a chlorine drum stored on-site.
- The likelihood of failure of these installations were assessed and the combination of consequence and likelihood being used to calculate the overall individual and societal risk.
- Overall individual and societal risk were found to be broadly acceptable according to the acceptability criteria for individual risk are detailed in Section 4.3.3.2. Societal risk was found to be negligible and therefore also broadly acceptable.
- No new land planning should be approved without consultation of the PADHI land-planning tables described in Appendix D.
- Impact Assessments of each installation assessed was performed and each was found to LOW SIGNIFICANCE, with and without mitigation. Cumulative Impact of all installations was assessed and the significance thereof was found to be LOW.

8 RECOMMENDATIONS

RISCOM did not find any fatal flaws that would prevent the project proceeding to the detailed engineering phase of the project.

RISCOM would support the project with the following conditions:

- Compliance with all statutory requirements, i.e. pressure vessel designs;
- Compliance with applicable SANS codes, i.e. SANS 10087, SANS 10089, SANS 10108, etc.;
- Incorporation of applicable guidelines or equivalent international recognised codes of good design and practice into the designs;
- Completion of a recognised process hazard analysis (such as a HAZOP study, FMEA, etc.) on the proposed facility prior to construction to ensure design and operational hazards have been identified and adequate mitigation put in place;
- Compliance with IEC 61508 and IEC 61511 (Safety Instrument Systems) standards or equivalent to ensure that adequate protective instrumentation is included in the design and would remain valid for the full life cycle of the tank farm:
    - Including demonstration from the designer that sufficient and reliable instrumentation would be specified and installed at the facility;
- Preparation and issue of a safety document detailing safety and design features reducing the impacts from fires, explosions and flammable atmospheres to the MHI assessment body at the time of the MHI assessment:
    - Including compliance to statutory laws, applicable codes and standards and world's best practice;
    - Including the listing of statutory and non-statutory inspections, giving frequency of inspections;
    - Including the auditing of the built facility against the safety document;
    - Noting that codes such as IEC 61511 can be used to achieve these requirements;
- Demonstration by Eskom or their contractor that the final designs would reduce the risks posed by the installation to internationally acceptable guidelines;
- Signature of all terminal designs by a professional engineer registered in South Africa in accordance with the Professional Engineers Act, who takes responsibility for suitable designs;
- Completion of an emergency preparedness and response document for on-site and off-site scenarios prior to initiating the MHI risk assessment (with input from local authorities);
- Permission not being granted for increases to the product list or product inventories without redoing part of or the full EIA;
- Final acceptance of the facility risks with an MHI risk assessment that must be completed in accordance to the MHI regulations:
    - Basing such a risk assessment on the final design and including engineering mitigation.

9 REFERENCES

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10 ABBREVIATIONS AND ACRONYMS

AEGL	**Acute exposure guideline levels** are values published by the US Environmental Protection Agency (EPA). AEGL values represent threshold exposure limits for the general public applicable to five emergency exposure periods (10 minutes, 30 minutes, 1 hour, 4 hours and 8 hours) and are distinguished by varying degrees of severity of toxic effects. **AEGL-1** is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure. **AEGL-2** is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long lasting adverse health effects or an impaired ability to escape. **AEGL-3** is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death. Although the AEGL values represent threshold levels for the general public, including susceptible subpopulations, such as infants, children, the elderly, persons with asthma and those with other illnesses, it is recognized that individuals, subject to unique or idiosyncratic responses, could experience the effects described at concentrations below the corresponding AEGL value.
AIA	See **Approved Inspection Authority**
ALARP	The UK Health and Safety Executive (HSE) developed the risk **ALARP** triangle, in an attempt to account for risks in a manner similar to those used in everyday life. This involved 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; • Whether a risk falls between these two states and has been reduced to levels '**as low as reasonably practicable'** (ALARP). Reasonable practicability involves weighing a risk against the trouble, time and money needed to control it.
Approved Inspection Authority	An **approved inspection authority** (AIA) is defined in the Major Hazard Installation regulations (July 2001)
Asphyxiant	An **asphyxiant** is a gas that is nontoxic but may be fatal if it accumulates in a confined space and is breathed at high concentrations since it replaces oxygen containing air.
Blast Overpressure	**Blast overpressure** is a measure used in the multi-energy method to indicate the strength of the blast, indicated by a number ranging from 1 (for very low strengths) up to 10 (for detonative strength).
BLEVE	**Boiling liquid expanding vapour explosions** result from the sudden failure of a vessel containing liquid at a temperature above its boiling point. A **BLEVE** of flammables results in a large fireball.
Deflagration	**Deflagration** is a chemical reaction of a substance, in which the reaction front advances into the unreacted substance at less than sonic velocity.

Detonation	**Detonation** is a release of energy caused by extremely rapid chemical reaction of a substance, in which the reaction front of a substance is determined by compression beyond the auto-ignition temperature.
Emergency Plan	An **emergency plan** is a plan in writing that describes how potential incidents identified at the installation together with their consequences should be dealt with, both on site and off site.
ERPG	**Emergency response planning guidelines** were 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 anything 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.
Explosion	An **explosion** is a release of energy that causes a pressure discontinuity or blast wave.
Flammable Limits	**Flammable limits** are a range of gas or vapour concentrations in the air that will burn or explode if a flame or other ignition source is present. The lower point of the range is called the lower flammable limit (LFL). Likewise, the upper point of the range is called the upper flammable limit (UFL).
Flammable Liquid	The Occupational Health and Safety Act 85 of 1993 defines a **flammable liquid** as any liquid which produces a vapour that forms an explosive mixture with air and includes any liquid with a closed cup flashpoint of less than 55°C. Flammable products have been classified according to their flashpoints and boiling points, which ultimately determine the propensity to ignite. Separation distances described in the various codes are dependent on the flammability classification. **Class Description** 0 Liquefied petroleum gas (LPG) IA Liquids that have a closed cup flashpoint of below 23°C and a boiling point below 35°C IB Liquids that have a closed cup flashpoint of below 23°C and a boiling point of 35°C or above IC Liquids that have a closed cup flashpoint of 23°C and above but below 38°C II Liquids that have a closed cup flashpoint of 38°C and above but below 60.5°C IIA Liquids that have a closed cup flashpoint of 60.5°C and above but below 93°C
Flash Fire	A **flash fire** is defined as combustion of a flammable vapour and air mixture in which the flame passes through the mixture at a rate less than sonic velocity so that negligible damaging overpressure is generated.
Frequency	**Frequency** is the number of times an outcome is expected to occur in a given period of time.

IDLH	**Immediately dangerous to life or health** values were developed by the National Institute of Occupational Safety and Health (NIOSH). **IDLH** value refers to a maximum concentration to which a healthy person may be exposed for 30 minutes and escape without suffering irreversible health effects or symptoms that impair escape (ranging from runny eyes that temporarily impair eyesight to a coma). IDLH values are intended to ensure that workers can escape from a given contaminated environment in the event of failure of the respiratory protection equipment.
Ignition Source	An **ignition source** is a source of temperature and energy sufficient to initiate combustion.
Individual Risk	**Individual risk** is the probability that in one year a person will become a victim of an accident if the person remains permanently and unprotected in a certain location. Often the probability of occurrence in one year is replaced by the frequency of occurrence per year.
Isopleth	See **Risk Isopleth**
Jet	A **jet** is the outflow of material emerging from an orifice with significant momentum.
Jet Fire or Flame	A **jet fire or flame** is combusting material emerging from an orifice with a significant momentum.
LC	**Lethal concentration** is the concentration by which a given percentage of the exposed population will be fatally injured. The LC_{50} 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).
LFL	**Lower Flammable Limit** see Flammable Limits
LOC	See **Loss of Containment**
Local Government	**Local government** is defined in Section 1 of the Local Government Transition Act, 1993 (Act No. 209 of 1993).
Loss of Containment	**Loss of containment** (LOC) is the event resulting in a release of material into the atmosphere.
Major Hazard Installation	**Major Hazard Installation** (MHI) means an installation: • Where more than the prescribed quantity of any substance is or may be kept, whether permanently or temporarily; • Where any substance is produced, used, handled or stored in such a form and quantity that it has the potential to cause a major incident (the potential of which will be determined by the risk assessment).
Major Incident	A **major incident** is an occurrence of catastrophic proportions, resulting from the use of plant or machinery or from activities at a workplace. When the outcome of a risk assessment indicates that there is a possibility that the public will be involved in an incident, then the incident is catastrophic.
Material Safety Data Sheet	According to ISO-11014, a **material safety data sheet** (MSDS) is a document that contains information on the potential health effects of exposure to chemicals or other potentially dangerous substances and on safe working procedures when handling chemical products. It is an essential starting point for the development of a complete health and safety program. It contains hazard evaluations on the use, storage, handling and emergency procedures related to that material. An MSDS contains much more information about the material than the label and it is prepared by the supplier. It is intended to tell what the hazards of the

	product are, how to use the product safely, what to expect if the recommendations are not followed, what to do if accidents occur, how to recognize symptoms of overexposure and what to do if such incidents occur.
MHI	See **Major Hazard Installation**
MIR	**Maximum Individual Risk** (see Individual Risk)
MSDS	See **Material Safety Data Sheet**
OHS Act	**Occupational Health and Safety Act**, 1993 (Act No. 85 of 1993)
PAC	See **Protective Action Criteria**
PADHI	**PADHI** (**planning advice for developments near hazardous installations**) is the name given to a methodology and software decision support tool developed and used in the HSE. It is used to give land-use planning (LUP) advice on proposed developments near hazardous installations. PADHI uses two inputs into a decision matrix to generate either an 'advise against' or 'don't advise against' response: • The zone in which the development is located of the three zones that HSE sets around the major hazard: o The inner zone (> $1x10^{-5}$ fatalities per person per year); o The middle zone ($1x10^{-5}$ fatalities per person per year to $1x10^{-6}$ fatalities per person per year); o The outer zone ($1x10^{-6}$ fatalities per person per year to $3x10^{-7}$ fatalities per person per year); • The 'sensitivity level' of the proposed development which is derived from an HSE categorisation system of 'development types' (see the 'development type tables' in Appendix D).
Protective Action Criteria	**Protective action criteria** (PAC) for emergency planning of chemical release events are based on the following chemical exposure limit values: • Acute exposure guideline level (AEGL) values published by the US Environmental Protection Agency (EPA); • Emergency response planning guideline (ERPG) values produced by the American Industrial Hygiene Association (AIHA); • Temporary emergency exposure limit (TEEL) values developed by the Subcommittee on Consequence Assessment and Protective Actions (SCAPA).
QRA	See **Quantitative Risk Assessment**
Quantitative Risk Assessment	A **quantitative risk assessment** is the process of hazard identification, followed by a numerical evaluation of effects of incidents, both consequences and probabilities and their combination into the overall measure of risk.
Risk	**Risk** is the measure of the consequence of a hazard and the frequency at which it is likely to occur. Risk is expressed mathematically as: **Risk = Consequence x Frequency of Occurrence**
Risk Assessment	**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 potential causes of such an incident.
Risk Contour	See **Risk Isopleth**
Societal Risk	**Societal risk** is risk posed on a societal group who are exposed to a hazardous activity.
Temporary Installation	A **temporary installation** is an installation that can travel independently between planned points of departure and arrival for the purpose of transporting any substance and which is only deemed to be an installation at the points of departure and arrival, respectively.
TLV-STEL	**Short-term exposure threshold limit values** are the concentrations to which workers can be exposed continuously for a short period (15 minutes) of time without suffering from: irritation; chronic or irreversible tissue damage; or, narcosis to a sufficient degree to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency, provided that the daily TLV-TWA is not exceeded.
TLV-TWA	**Time weighted average threshold limit values** are the concentrations for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed day after day, without adverse effects.
UFL	**Upper Flammable Limit** (see Flammable Limits)
Vapour Cloud Explosion	A **vapour cloud explosion** (VCE) results from ignition of a premixed cloud of a flammable vapour, gas or spray with air, in which flames accelerate to sufficiently high velocities to produce significant overpressure.
VCE	See **Vapour Cloud Explosion**

11 APPENDIX A: DECLARATION OF THIRD PARTY INDEPENDENCE

4.2 The specialist appointed in terms of the Regulations_

I, MOTLATSI GOVERNADOR MABASO , declare that --

General declaration:

I act as the independent specialist in this application;
I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
I declare that there are no circumstances that may compromise my objectivity in performing such work;
I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity;
I will comply with the Act, Regulations and all other applicable legislation;
I have no, and will not engage in, conflicting interests in the undertaking of the activity;
I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
all the particulars furnished by me in this form are true and correct; and
I realise that a false declaration is an offence in terms of regulation 48 and is punishable in terms of section 24F of the Act.

Signature of the specialist:

Riscom (Pty) Ltd

Name of company (if applicable):

10 April 2018

Date:

11 APPENDIX A: DECLARATION OF THIRD PARTY INDEPENDENCE

4.2 The specialist appointed in terms of the Regulations_

I, MOTLATSI GOVERNADOR MABASO, declare that --

General declaration:

I act as the independent specialist in this application;
I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
I declare that there are no circumstances that may compromise my objectivity in performing such work;
I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity;
I will comply with the Act, Regulations and all other applicable legislation;
I have no, and will not engage in, conflicting interests in the undertaking of the activity;
I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
all the particulars furnished by me in this form are true and correct; and
I realise that a false declaration is an offence in terms of regulation 48 and is punishable in terms of section 24F of the Act.

____
Signature of the specialist:

Riscom (Pty) Ltd
Name of company (if applicable):

10 April 2018
Date:

12 APPENDIX B: SPECIALIST DOCUMENTATION

12.1 Professional Body Registration (overleaf)

Engineering Council

Established for the promotion and development
of the knowledge and best practice of engineering

This is to certify that

Motlatsi Governador Mabaso

in membership of the

Institution of Chemical Engineers

has been registered by the Engineering Council and is hereby authorised
to use the style or title of

Chartered Engineer

Chairman

Chief Executive Officer

Date of Registration 27 May 2014

Date of Issue 28 May 2014

Registration No. 614475
This certificate is the property of the Engineering Council
Returnable on request or de-registration

Institution of Chemical Engineers

This is to Certify that

Motlatsi G Mabaso

was elected a

Chartered Chemical Engineer

in the class of

Members

on this *29th* day of *April 2014*

President

Hon. Registrar

Issued at One Portland Place, London, UK

IChemE ADVANCING CHEMICAL ENGINEERING WORLDWIDE

12.2 Curriculum Vitae (Motlatsi Mabaso) (overleaf)

Motlatsi Mabaso CEng MIChemE

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Profile

Motlatsi Mabaso CEng MIChemE is a Chartered Chemical Engineer and Member of the Institute of Chemical Engineers (IChemE) who is currently self-employed as Director and Consultant at The Koprocon Group (Pty) Ltd, South Africa. He has **10½ years'** experience in **safety & risk consulting, risk management, technical safety engineering,** and **process engineering**. He has worked in South Africa and the United Kingdom and has experience in the **oil and gas (onshore and offshore), mining/ metal extraction, fast moving consumer goods, manufacturing,** and **chemicals** sectors. As Lead Process Safety Engineer and a senior member of project process safety teams he has experience focusing on areas of risk management and process safety management during design (Pre-FEED FEED and Detailed Design), and including **risk register compilation, consequence modeling, HAZOP, HAZID, SIMOPS, Fault-Tree analysis, Event-Tree analysis, risk summation: individual and societal risk calculation, assessment of Risk, ALARP Demonstration, firewater demand calculation, metallurgical engineering design** using analysis tools such as **DNV PHAST**, **RiskPlot** and **ViewRisk** for risk analysis and **MetSim** for metallurgical design. The projects he has been involved in have been in Cameroon, Oman, Iraq, Abu-Dhabi, Canada, Norwegian North Sea, Scotland, Russia, Nigeria, Ghana, South Africa, Zambia, Russia, Scotland and the United States.

Professional Affiliations

- Chartered Chemical Engineer and member of the Institution of Chemical Engineers (IChemE) – **CEng MIChemE**
- Member – **Department of Labour Technical Committee for the drafting of the MHI Regulations (from 2017)**
- University of Cape Town Chemical Engineering Department – **Visiting Engineer Designate 2017**
- Council Member of the South African Institute of Chemical Engineers - **SAIChE**
- Technical Committee Member of the Institute of Risk Management, South Africa - **IRMSA**

Work Experience

Director at The Koprocon Group (Pty) Ltd

September 2017 – Present (Johannesburg, South Africa)

- The Koprocon Group is an umbrella entity which comprises the following trade names:
  - **MMRisk | Process Safety and Risk Consulting services**

    We provide process safety and risk consulting services to assist clients in complying with process safety and risk legislation and best practice. Consulting services include Hazard Identification services (HAZID, HAZOP, SIMOPS), Consequence Analysis (Fire, Explosion, Toxic dispersion as required), Frequency (Likelihood) analysis (Fault Tree Analysis, Event Tree Analysis, application of Frequency data from international databases), Risk summation and assessment (Individual and Societal Risk), full Quantified Risk Assessment (QRA). We are under application with the South African National Accreditation System (SANAS) as an Approved Inspection Body to perform Major Hazard Installation (MHI) Risk Assessments.

    Notable Projects:

    - ***Quantified Risk Assessment studies** in support of **Environmental Impact Assessments** for proposed **combined cycle gas fired power stations** in Mozambique and South Africa using natural gas as a fuel.*
    - ***Emergency Response Plan** compilation for a major JSE-listed **consumer products manufacturing** company, site based in Johannesburg, South Africa.*

- **whybuyyourgas | Waste to Energy Projects**

  We advise clients on organic waste to hydrocarbon energy solutions and perform engineering design of waste to energy capital projects. This includes the sourcing of project funding and applying incentive programmes to accelerate pay-back periods, etc.

Principal Safety & Risk Consultant *at Environmental Resources Management (ERM)*

March 2016 – September 2017 (Johannesburg, South Africa)

- Project Manager on quantified risk assessments (QRAs) to assist clients with fulfilling the requirements of the Major Hazard Installation (MHI) Regulations of South Africa, for clients in the manufacturing, oil and gas industries. Project Management role includes taking charge of: i) facilitating client engagement; ii) delivery and control of technical process safety aspects; iii) supervising personnel performing technical work; and iv) financial and budgetary control. Facilities assessed have included crude oil refineries, paper mills, food production facilities, bulk fuel storage terminals.

- Major clients have included: Total South Africa (Pty) Ltd – several petroleum product storage and distribution terminals and depots, including a lube oil manufacturing plant; South African Petroleum Refineries (SAPREF); Cape Town Refinery; Tiger Brands Ltd; Mondi Ltd; Engen South Africa (Pty) Ltd – petroleum storage and distribution depots in the Western Cape, South Africa; Chevron South Africa (Pty) Ltd.

Director & Consulting Process Safety Engineer *at Kopano Safety & Risk Engineers UK Ltd*

April 2014 – November 2016 (Oxford, United Kingdom)

- Senior member of technical health, safety and environment (THSE) FEED project team responsible for the design of a Liquefied Natural Gas (LNG) production facility in central Africa. I took charge of: (i) Conducting a plant spacing study using consequence and frequency analysis software tool and advising piping and layout engineers on plant spacing requirements from a safety & risk point of view; (ii) Managing subcontractors providing Fire and Explosion Risk Analysis (FERA) services in favour of the design of the plant. **Client: Engie, Amec Foster Wheeler Energy Ltd (Reading, UK).**

- **Lead Process Safety Engineer** for FEED design of a 200-million barrel capacity crude oil storage terminal in Oman. I took charge of: (i) management aspects related to the project, such as of deliverable and manpower planning and management; (ii) delivery and control of all technical process safety aspects as lead process safety engineer; (iii) supervision of deliverables from colleagues in the UK and India, such as Safety Philosophy, Safety Plan, Hazards & Effects and Risk Register, HAZID/ENVID Procedure and report, Fire Risk Assessment, Fire & Explosion Hazard Analysis, QRA, Facilities Siting Study, Design Safety Case; (iv) coordination with other disciplines on design aspects; (v) managing the bidding process of third party consultants who performed safety and risk studies in support of the project. **Client: Oman Tank Terminal Company (OTTCO), Amec Foster Wheeler Energy Ltd (Reading, UK).**

- Senior member of technical health safety and environment (THSE) EPC project team responsible for the design of a gas processing, compression and gas/condensate export project in Iraq. I took charge of: (i) the development of **ALARP Demonstration** Sheets in support of an ALARP Demonstration Workshop, (ii) performing **gas dispersion** and **thermal radiation flux analysis** in support of the design of closed drain and slugcatcher depressurization vent systems, (iii) Developing a **hazardous area classification schedule** for the 2-train gas compression system, (iv) Safety Critical Elements Performance Standards Technical Integrity Verification Plan. I assisted the lead safety engineers and project team in THSE deliverables (HAZOP, Escape/Evacuation Layouts, Fire Protection Philosophy, Fire & Gas Detection Basis of Design) and maintaining the project schedule. **Client: SHELL, Foster Wheeler Energy Ltd (Reading, UK).**

- Study Manager for a Tank Hazards Study performed on **Intermediate Storage and Import-Export Storage** tank farms of an aromatics complex near **Abu-Dhabi**. I conducted a coarse quantitative and qualitative assessment of consequences, frequencies and individual risks associated with both storage facilities. As part of the study, a review of the existing layout for both storage facilities was performed and changes recommended in order to reduce the resulting individual risks to as low as reasonably practicable. **Client: Abu-Dhabi Chemicals Company (CHEMAWYATT), Foster Wheeler Energy Ltd (Reading, UK).**

Technical Safety Engineer *at Wood Group Mustang Engineering Ltd*

November 2012 – March 2014 (Woking, Surrey, UK)

- I conducted **firewater demand calculation, firewater pump specification** and compiled **utility flow diagram (UFD)** at concept stage engineering design of **offshore** platforms in the **North Sea** for **Norwegian** clients. Additionally, I determined the requirements for hydrants, hose reels and oscillating monitors on the platform and displayed these on layout diagrams. I managed subcontractors compiling safety studies; work was performed as per Norwegian regulations (**NORSOK**) and other client-specific technical guidance documents.

- I was scribe and team member in several hazardous operability studies (**HAZOP**), simultaneous operations (**SIMOPs**) and hazard identification (**HAZID**) workshops for offshore projects in the North Sea. The workshops were conducted with guidance from the **ISO 17776 standard**. I was responsible for participating in the studies, and, as scribe in some, capturing information by use of guidewords compiling and issuing reports.

- On the Subsea Well Response Project (SWRP) project aimed at worldwide preparation for a consortium of major oil companies to cap and contain well control incidents similar to the BP Macondo well blowout in the Gulf of Mexico in 2010, I was responsible for:
    - Selecting blowout capping and containment system components which present minimal negative health and safety impact on personnel responding to the blowout, and to ensure minimal negative environmental impact from the response activities. (**ALARP Demonstration** of concept options)
    - Managing the compilation of a **Health, Safety and Environment (HSE) Philosophy** document to provide guidelines to ensure that the project in general complied with all codes and standards managing the HSE risks of the project to be ALARP.

Safety & Risk Consultant *at ERM (Environmental Resources Management Ltd)*

January 2010 – November 2012 (Johannesburg, South Africa and London, UK)

- Compiled and project-managed numerous **Quantified Risk Assessments (QRAs)** of on-shore facilities in Scotland, Ghana and South Africa to ensure company compliance with the United Kingdom's **COMAH Regulations** and with **South Africa's Occupational Health & Safety Regulations** as well as with the requirements of the **International Finance Corporation (IFC)**. The hazardous consequences and risks were associated with materials such as flammable hydrocarbons and toxic gases such as chlorine and hydrogen sulphide. Work was done for clients including TOTAL, Chevron, Xstrata, Lonmin, ArcelorMittal, SASOL and PetroSA.
- Compiled **Emergency Response Plans** for natural gas reception and processing facilities in the Delta region of Nigeria, and LPG storage and reticulation facilities in Gauteng, South Africa. Reviewed existing emergency response plans for numerous industrial facilities in South Africa to ensure their adequacy.
- Scribed **Hazard Identification Studies (HAZIDs)** in Houston and Cape Town for a crude oil refinery (under pre-feasibility stage of design) and associated bulk fuel storage and rail, road and ship storage and transfer facilities.
- Had Extensive liaison with:
    - The South African **Department of Labour** to ensure compliance to the **Major Hazardous Installation (MHI) Regulations**;
    - **South African National Accreditation System (SANAS)** to ensure quality of inspection authorities accredited to perform Quantified Risk Assessments of industrial facilities and
    - Emergency Services authorities to ensure maximum emergency preparedness for industrial facilities.

Process Engineer at Hatch Africa (Pty) Ltd

January 2008 – end 2009 (Johannesburg)

- Performed concept-level process engineering design including process option investigation selection for the mixing and drying of smelter concentrate; was involved with hydrometallurgical process design including development of block flow diagrams, mass balances and preparation of process option reports for zinc metal production facility.
- Pre-feasibility process design of platinum group metal (PGM) smelter off-gas treatment, pyrometallurgical and hydrometallurgical process facilities includingthe preparation of PGM smelter operating expenses (OPEX) for mining and metals extraction facilities.
- Delivered performance management of a PGM furnace. Was involved in the performance evaluation and redesign of a solvent extraction (SX) system at an operating concentrator and base metal refinery in Zambia.
- Clients included Kansanshi Copper in Zambia, Anglo American, Lonmin, Rio Tinto, Barrick Platinum sites in Richards Bay, Rustenburg and Polokwane in South Africa.

Education

Heriot-Watt University

Currently enrolled in MSc in Safety, Risk & Reliability Engineering
Commenced January 2016 (via distance learning)

University of Cape Town

BSc in Chemical Engineering

January 2004 – graduated December 2007

Skills & Hobbies

- Risk & safety engineering – oil and gas on and off shore (DNV Phast, ERM RiskPlot, ERM ViewRisk software)
- Project management and budget control
- HAZID & HAZOP-scribing, firewater demand calculation
- Client Engagement and Sales
- Languages:
    - English,
    - South African languages: Afrikaans, Zulu, Sotho, Xhosa, Shangaan, Sepedi, Setswana.

- Keen musician who independently released a hip hop album in 2009 in South Africa and performed numerous times with a live hip hop band at gigs in Johannesburg.

Referees

- Dr. Martyn Ramsden of ERM Manchester. Martyn.Ramsden@erm.com
- Dr. Beki Hlatshwayo of Tongaat-Hulett, KwaZulu-Natal, South Africa. DrABHTier2@vodamail.co.za.
- Mr. Dylan Campbell of PetroSA, Cape Town, South Africa. Dylan.Campbell@petrosa.co.za.

13 APPENDIX C: MATERIAL SAFETY DATA SHEETS (MSDS)

13.1 Chlorine MSDS (overleaf)

SAFETY DATA SHEET

according to Regulation (EC) No. 1907/2006
Version 5.6 Revision Date 03.01.2018
Print Date 10.04.2018
GENERIC EU MSDS - NO COUNTRY SPECIFIC DATA - NO OEL DATA

SECTION 1: Identification of the substance/mixture and of the company/undertaking

1.1 Product identifiers

Product name	:	Chlorine
Product Number	:	295132
Brand	:	Aldrich
Index-No.	:	017-001-00-7
REACH No.	:	A registration number is not available for this substance as the substance or its uses are exempted from registration, the annual tonnage does not require a registration or the registration is envisaged for a later registration deadline.
CAS-No.	:	7782-50-5

1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Laboratory chemicals, Manufacture of substances

1.3 Details of the supplier of the safety data sheet

Company : Sigma-Aldrich (Pty.) Ltd.
17 Pomona Street
Aviation Park, Unit 4
KEMPTON PARK
1619 SOUTH AFRICA

Telephone : +27 11 979 1188
Fax : +27 11 979 1119

1.4 Emergency telephone number

Emergency Phone #

SECTION 2: Hazards identification

2.1 Classification of the substance or mixture

Classification according to Regulation (EC) No 1272/2008
Oxidizing gases (Category 1), H270
Gases under pressure (Compressed gas), H280
Acute toxicity, Inhalation (Category 3), H331
Skin irritation (Category 2), H315
Eye irritation (Category 2), H319
Specific target organ toxicity - single exposure (Category 3), Respiratory system, H335
Acute aquatic toxicity (Category 1), H400

For the full text of the H-Statements mentioned in this Section, see Section 16.

2.2 Label elements

Labelling according Regulation (EC) No 1272/2008
Pictogram

Signal word	Danger

Hazard statement(s)

H270	May cause or intensify fire; oxidizer.
H280	Contains gas under pressure; may explode if heated.
H315	Causes skin irritation.
H319	Causes serious eye irritation.
H331	Toxic if inhaled.
H335	May cause respiratory irritation.
H400	Very toxic to aquatic life.

Precautionary statement(s)

P220	Keep/Store away from clothing/ combustible materials.
P244	Keep valves and fittings free from oil and grease.
P261	Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.
P304 + P340 + P311	IF INHALED: Remove person to fresh air and keep comfortable for breathing. Call a POISON CENTER/doctor.
P403 + P233	Store in a well-ventilated place. Keep container tightly closed.
P410 + P403	Protect from sunlight. Store in a well-ventilated place.

Supplemental Hazard Statements	none

2.3 Other hazards

This substance/mixture contains no components considered to be either persistent, bioaccumulative and toxic (PBT), or very persistent and very bioaccumulative (vPvB) at levels of 0.1% or higher.

SECTION 3: Composition/information on ingredients

3.1 Substances

Formula	:	Cl_2
Molecular weight	:	70,91 g/mol
CAS-No.	:	7782-50-5
EC-No.	:	231-959-5
Index-No.	:	017-001-00-7

Hazardous ingredients according to Regulation (EC) No 1272/2008

Component		Classification	Concentration
Chlorine			
CAS-No. EC-No. Index-No.	7782-50-5 231-959-5 017-001-00-7	Ox. Gas 1; Press. Gas Compr. Gas; Acute Tox. 3; Skin Irrit. 2; Eye Irrit. 2; STOT SE 3; Aquatic Acute 1; H270, H280, H331, H315, H319, H335, H400 M-Factor - Aquatic Acute: 100	<= 100 %

For the full text of the H-Statements mentioned in this Section, see Section 16.

SECTION 4: First aid measures

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance.

If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

In case of skin contact
Wash off with soap and plenty of water. Take victim immediately to hospital. Consult a physician.

In case of eye contact
Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician.

If swallowed
Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

4.3 Indication of any immediate medical attention and special treatment needed
No data available

SECTION 5: Firefighting measures

5.1 Extinguishing media

Suitable extinguishing media
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

5.2 Special hazards arising from the substance or mixture
No data available

5.3 Advice for firefighters
Wear self-contained breathing apparatus for firefighting if necessary.

5.4 Further information
Use water spray to cool unopened containers.

SECTION 6: Accidental release measures

6.1 Personal precautions, protective equipment and emergency procedures
Wear respiratory protection. Avoid breathing vapours, mist or gas. Ensure adequate ventilation.
Evacuate personnel to safe areas.
For personal protection see section 8.

6.2 Environmental precautions
Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

6.3 Methods and materials for containment and cleaning up
Contain spillage, and then collect with an electrically protected vacuum cleaner or by wet-brushing and place in container for disposal according to local regulations (see section 13).

6.4 Reference to other sections
For disposal see section 13.

SECTION 7: Handling and storage

7.1 Precautions for safe handling
Avoid contact with skin and eyes. Avoid inhalation of vapour or mist.
Keep away from sources of ignition - No smoking.
For precautions see section 2.2.

7.2 Conditions for safe storage, including any incompatibilities
Store in cool place. Keep container tightly closed in a dry and well-ventilated place.

Contents under pressure.

7.3 Specific end use(s)
Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

SECTION 8: Exposure controls/personal protection

8.1 Control parameters

Components with workplace control parameters

8.2 Exposure controls

Appropriate engineering controls
Avoid contact with skin, eyes and clothing. Wash hands before breaks and immediately after handling the product.

Personal protective equipment

Eye/face protection
Face shield and safety glasses Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin protection
Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

The selected protective gloves have to satisfy the specifications of EU Directive 89/686/EEC and the standard EN 374 derived from it.

Full contact
Material: Fluorinated rubber
Minimum layer thickness: 0,7 mm
Break through time: 480 min
Material tested:Vitoject® (KCL 890 / Aldrich Z677698, Size M)

Splash contact
Material: Fluorinated rubber
Minimum layer thickness: 0,7 mm
Break through time: 480 min
Material tested:Vitoject® (KCL 890 / Aldrich Z677698, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

Body Protection
Complete suit protecting against chemicals, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Respiratory protection
Where risk assessment shows air-purifying respirators are appropriate use a full-face respirator with multi-purpose combination (US) or type AXBEK (EN 14387) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Control of environmental exposure
Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

SECTION 9: Physical and chemical properties

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: Compressed gas Colour: yellow
b)	Odour	pungent
c)	Odour Threshold	No data available
d)	pH	1,8 at 6,4 g/l at 20 °C
e)	Melting point/freezing point	Melting point/range: -101 °C - lit.
f)	Initial boiling point and boiling range	-34 °C - lit.
g)	Flash point	Not applicable
h)	Evaporation rate	No data available
i)	Flammability (solid, gas)	No data available
j)	Upper/lower flammability or explosive limits	No data available
k)	Vapour pressure	6.399 hPa at 20 °C
l)	Vapour density	2,44 - (Air = 1.0)
m)	Relative density	1,563 g/cm3 at -33,99 °C
n)	Water solubility	ca.10 g/l at 20 °C
o)	Partition coefficient: n-octanol/water	No data available
p)	Auto-ignition temperature	No data available
q)	Decomposition temperature	No data available
r)	Viscosity	No data available
s)	Explosive properties	No data available
t)	Oxidizing properties	The substance or mixture is classified as oxidizing with the category 1.

9.2 Other safety information

Relative vapour density 2,44 - (Air = 1.0)

SECTION 10: Stability and reactivity

10.1 Reactivity
No data available

10.2 Chemical stability
Stable under recommended storage conditions.

10.3 Possibility of hazardous reactions
No data available

10.4 Conditions to avoid
No data available

10.5 Incompatible materials
Alcohols

10.6 Hazardous decomposition products

Hazardous decomposition products formed under fire conditions. - Nature of decomposition products not known.
Other decomposition products - No data available
In the event of fire: see section 5

SECTION 11: Toxicological information

11.1 Information on toxicological effects

Acute toxicity
LC50 Inhalation - Rat - 1 h - 293 ppm

Skin corrosion/irritation
No data available

Serious eye damage/eye irritation
No data available

Respiratory or skin sensitisation
No data available

Germ cell mutagenicity
Human
lymphocyte
Cytogenetic analysis

Mouse
sperm

Carcinogenicity

Carcinogenicity - Rat - Oral
Tumorigenic:Equivocal tumorigenic agent by RTECS criteria. Leukaemia

Carcinogenicity - Monkey - Inhalation
Tumorigenic:Neoplastic by RTECS criteria. Lungs, Thorax, or Respiration:Tumors.

This product is or contains a component that is not classifiable as to its carcinogenicity based on its IARC, ACGIH, NTP, or EPA classification.

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

Reproductive toxicity

Reproductive toxicity - Rat - Oral
Effects on Newborn: Biochemical and metabolic.

Specific target organ toxicity - single exposure
May cause respiratory irritation.

Specific target organ toxicity - repeated exposure
No data available

Aspiration hazard
No data available

Additional Information
RTECS: FO2100000

Material is extremely destructive to tissue of the mucous membranes and upper respiratory tract, eyes, and skin., Cough, Shortness of breath, Headache, Nausea

SECTION 12: Ecological information

12.1 Toxicity

Toxicity to fish	LC50 - Oncorhynchus mykiss (rainbow trout) - 0,014 mg/l - 96,0 h
Toxicity to daphnia and other aquatic invertebrates	EC50 - Daphnia magna (Water flea) - 0,019 mg/l - 24 h

12.2 Persistence and degradability
No data available

12.3 Bioaccumulative potential
No data available

12.4 Mobility in soil
No data available

12.5 Results of PBT and vPvB assessment
This substance/mixture contains no components considered to be either persistent, bioaccumulative and toxic (PBT), or very persistent and very bioaccumulative (vPvB) at levels of 0.1% or higher.

12.6 Other adverse effects
Very toxic to aquatic life.

SECTION 13: Disposal considerations

13.1 Waste treatment methods

Product
Burn in a chemical incinerator equipped with an afterburner and scrubber but exert extra care in igniting as this material is highly flammable. Offer surplus and non-recyclable solutions to a licensed disposal company.

Contaminated packaging
Dispose of as unused product.

SECTION 14: Transport information

14.1 UN number

ADR/RID: 1017	IMDG: 1017	IATA: 1017

14.2 UN proper shipping name
ADR/RID: CHLORINE
IMDG: CHLORINE
IATA: Chlorine
Passenger Aircraft: Not permitted for transport
Cargo Aircraft: Not permitted for transport

14.3 Transport hazard class(es)

ADR/RID: 2.3 (5.1, 8)	IMDG: 2.3 (5.1, 8)	IATA: 2.3 (5.1)(8)

14.4 Packaging group

ADR/RID: -	IMDG: -	IATA: -

14.5 Environmental hazards

ADR/RID: yes	IMDG Marine pollutant: yes	IATA: no

14.6 Special precautions for user
No data available

SECTION 15: Regulatory information

15.1 Safety, health and environmental regulations/legislation specific for the substance or mixture
This safety datasheet complies with the requirements of Regulation (EC) No. 1907/2006.

15.2 Chemical safety assessment
For this product a chemical safety assessment was not carried out

SECTION 16: Other information

Full text of H-Statements referred to under sections 2 and 3.

H270	May cause or intensify fire; oxidizer.
H280	Contains gas under pressure; may explode if heated.
H315	Causes skin irritation.
H319	Causes serious eye irritation.
H331	Toxic if inhaled.
H335	May cause respiratory irritation.
H400	Very toxic to aquatic life.

Further information

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

13.2 Natural Gas MSDS (overleaf)

SAFETY DATA SHEET

according to Regulation (EC) No. 1907/2006
Version 5.1 Revision Date 24.06.2014
Print Date 10.04.2018
GENERIC EU MSDS - NO COUNTRY SPECIFIC DATA - NO OEL DATA

SECTION 1: Identification of the substance/mixture and of the company/undertaking

1.1 Product identifiers

Product name	:	Methane
Product Number	:	463035
Brand	:	Aldrich
Index-No.	:	601-001-00-4
REACH No.	:	A registration number is not available for this substance as the substance or its uses are exempted from registration, the annual tonnage does not require a registration or the registration is envisaged for a later registration deadline.
CAS-No.	:	74-82-8

1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Laboratory chemicals, Manufacture of substances

1.3 Details of the supplier of the safety data sheet

Company : Sigma-Aldrich (Pty.) Ltd.
17 Pomona Street
Aviation Park, Unit 4
KEMPTON PARK
1619 SOUTH AFRICA

Telephone : +27 11 979 1188
Fax : +27 11 979 1119

1.4 Emergency telephone number

Emergency Phone # :

SECTION 2: Hazards identification

2.1 Classification of the substance or mixture

Classification according to Regulation (EC) No 1272/2008
Flammable gases (Category 1), H220
Gases under pressure (Compressed gas), H280

For the full text of the H-Statements mentioned in this Section, see Section 16.

Classification according to EU Directives 67/548/EEC or 1999/45/EC
F+ Extremely flammable R12

For the full text of the R-phrases mentioned in this Section, see Section 16.

2.2 Label elements

Labelling according Regulation (EC) No 1272/2008
Pictogram

Signal word Danger

Hazard statement(s)
H220 Extremely flammable gas.
H280 Contains gas under pressure; may explode if heated.

Precautionary statement(s)	
P210	Keep away from heat/sparks/open flames/hot surfaces. - No smoking.
P410 + P403	Protect from sunlight. Store in a well-ventilated place.
Supplemental Hazard Statements	none

2.3 Other hazards - none

SECTION 3: Composition/information on ingredients

3.1 Substances

Formula	:	CH_4
Molecular Weight	:	16,04 g/mol
CAS-No.	:	74-82-8
EC-No.	:	200-812-7
Index-No.	:	601-001-00-4

No components need to be disclosed according to the applicable regulations.

For the full text of the H-Statements and R-Phrases mentioned in this Section, see Section 16

SECTION 4: First aid measures

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance.

If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

In case of skin contact
Wash off with soap and plenty of water. Consult a physician.

In case of eye contact
Flush eyes with water as a precaution.

If swallowed
Do NOT induce vomiting. Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

4.3 Indication of any immediate medical attention and special treatment needed
no data available

SECTION 5: Firefighting measures

5.1 Extinguishing media

Suitable extinguishing media
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

5.2 Special hazards arising from the substance or mixture
Carbon oxides

5.3 Advice for firefighters
Wear self contained breathing apparatus for fire fighting if necessary.

5.4 Further information
Use water spray to cool unopened containers.

SECTION 6: Accidental release measures

6.1 Personal precautions, protective equipment and emergency procedures

Avoid breathing vapours, mist or gas. Ensure adequate ventilation. Remove all sources of ignition. Evacuate personnel to safe areas. Beware of vapours accumulating to form explosive concentrations. Vapours can accumulate in low areas.
For personal protection see section 8.

6.2 Environmental precautions

Prevent further leakage or spillage if safe to do so. Do not let product enter drains.

6.3 Methods and materials for containment and cleaning up

Clean up promptly by sweeping or vacuum.

6.4 Reference to other sections

For disposal see section 13.

SECTION 7: Handling and storage

7.1 Precautions for safe handling

Avoid inhalation of vapour or mist.
Keep away from sources of ignition - No smoking.Take measures to prevent the build up of electrostatic charge.
For precautions see section 2.2.

7.2 Conditions for safe storage, including any incompatibilities

Store in cool place. Keep container tightly closed in a dry and well-ventilated place.

Contents under pressure.

7.3 Specific end use(s)

Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

SECTION 8: Exposure controls/personal protection

8.1 Control parameters

Components with workplace control parameters

8.2 Exposure controls

Appropriate engineering controls

Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.

Personal protective equipment

Eye/face protection

Face shield and safety glasses Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin protection

Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

The selected protective gloves have to satisfy the specifications of EU Directive 89/686/EEC and the standard EN 374 derived from it.

Full contact
Material: Fluorinated rubber
Minimum layer thickness: 0,7 mm
Break through time: 480 min
Material tested:Vitoject® (KCL 890 / Aldrich Z677698, Size M)

Splash contact

Material: Nitrile rubber
Minimum layer thickness: 0,4 mm
Break through time: 60 min
Material tested:Camatril® (KCL 730 / Aldrich Z677442, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

Body Protection
impervious clothing, Flame retardant antistatic protective clothing, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Respiratory protection
Where risk assessment shows air-purifying respirators are appropriate use a full-face respirator with multi-purpose combination (US) or type AXBEK (EN 14387) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Control of environmental exposure
Prevent further leakage or spillage if safe to do so. Do not let product enter drains.

SECTION 9: Physical and chemical properties

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: gaseous Colour: colourless
b)	Odour	no data available
c)	Odour Threshold	no data available
d)	pH	no data available
e)	Melting point/freezing point	Melting point/range: -183 °C - lit.
f)	Initial boiling point and boiling range	-161 °C - lit.
g)	Flash point	-188 °C - closed cup
h)	Evapouration rate	no data available
i)	Flammability (solid, gas)	no data available
j)	Upper/lower flammability or explosive limits	Upper explosion limit: 15 %(V) Lower explosion limit: 5 %(V)
k)	Vapour pressure	no data available
l)	Vapour density	0,55 - (Air = 1.0)
m)	Relative density	0,716 g/cm3 at 25 °C
n)	Water solubility	3,5 g/l at 17 °C
o)	Partition coefficient: n-octanol/water	no data available
p)	Auto-ignition temperature	no data available

q)	Decomposition temperature	no data available
r)	Viscosity	no data available
s)	Explosive properties	no data available
t)	Oxidizing properties	no data available

9.2 Other safety information

Relative vapour density 0,55 - (Air = 1.0)

SECTION 10: Stability and reactivity

10.1 Reactivity
no data available

10.2 Chemical stability
Stable under recommended storage conditions.

10.3 Possibility of hazardous reactions
no data available

10.4 Conditions to avoid
Heat, flames and sparks. Extremes of temperature and direct sunlight.

10.5 Incompatible materials
Strong oxidizing agents

10.6 Hazardous decomposition products
Other decomposition products - no data available
In the event of fire: see section 5

SECTION 11: Toxicological information

11.1 Information on toxicological effects

Acute toxicity
no data available

Skin corrosion/irritation
no data available

Serious eye damage/eye irritation
no data available

Respiratory or skin sensitisation
no data available

Germ cell mutagenicity
no data available

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

Reproductive toxicity
no data available

Specific target organ toxicity - single exposure
no data available

Specific target organ toxicity - repeated exposure
no data available

Aspiration hazard
no data available

Additional Information
RTECS: PA1490000

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

SECTION 12: Ecological information

12.1 Toxicity
no data available

12.2 Persistence and degradability
no data available

12.3 Bioaccumulative potential
no data available

12.4 Mobility in soil
no data available

12.5 Results of PBT and vPvB assessment
PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

12.6 Other adverse effects

no data available

SECTION 13: Disposal considerations

13.1 Waste treatment methods

Product
Burn in a chemical incinerator equipped with an afterburner and scrubber but exert extra care in igniting as this material is highly flammable. Offer surplus and non-recyclable solutions to a licensed disposal company.

Contaminated packaging
Dispose of as unused product.

SECTION 14: Transport information

14.1 UN number

ADR/RID: 1971	IMDG: 1971	IATA: 1971

14.2 UN proper shipping name
ADR/RID: METHANE, COMPRESSED
IMDG: METHANE, COMPRESSED
IATA: Methane, compressed
Passenger Aircraft: Not permitted for transport

14.3 Transport hazard class(es)

ADR/RID: 2.1	IMDG: 2.1	IATA: 2.1

14.4 Packaging group

ADR/RID: -	IMDG: -	IATA: -

14.5 Environmental hazards

ADR/RID: no	IMDG Marine pollutant: no	IATA: no

14.6 Special precautions for user
no data available

SECTION 15: Regulatory information

This safety datasheet complies with the requirements of Regulation (EC) No. 1907/2006.

15.1 Safety, health and environmental regulations/legislation specific for the substance or mixture

no data available

15.2 Chemical Safety Assessment

For this product a chemical safety assessment was not carried out

SECTION 16: Other information

Full text of H-Statements referred to under sections 2 and 3.

H220	Extremely flammable gas.
H280	Contains gas under pressure; may explode if heated.

Full text of R-phrases referred to under sections 2 and 3

R12	Extremely flammable.

Further information

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

13.3 Diesel MSDS (overleaf)

Engen Dieselube 500 Super

SAFETY DATA SHEET

Revision Date : 02.12.2009

1. PRODUCT AND COMPANY IDENTIFICATION

Product name	:	Engen Dieselube 500 Super
Product use	:	Automotive lubricant
Supplier	:	Engen Petroleum Limited (Tel: 021-403 4911, a/h: 021-403 4099)
Health Emergency Telephone	:	021-689 5227 (Red Cross Poison Service)
Transport Emergency Telephone	:	011-975 1278/83 (Hazchemwise)
Customer Service Centre	:	0860 036 436 (Sales and Technical Information)
Engen Website	:	http://www.engen.co.za/

2. HAZARDS IDENTIFICATION

Emergency response data : Amber Liquid. DOT ERG No. - Not applicable.

GHS Classification:

Health		
Acute inhalation toxicity	May be harmful if inhaled. Hazard category 4.	Warning
Acute oral toxicity	May be harmful if swallowed. Hazard category 5.	Warning
Skin irritation	Practically non-irritating. Hazard category 3.	Warning
Eye irritation	Mild irritant. Hazard category 2B.	Warning
Environmental		
Aquatic toxicity :	Hazard category 3. Toxic to fish, aquatic organisms and wildlife.	Warning
Physical		
Flammability :	Combustible liquid. This product is non-flammable.	Warning

GHS Labels/Pictograms:

Hazard Statements

Combustible liquid. May cause mild eye irritation. May be harmful if swallowed or inhaled.

Precautionary Statements

Response
IN CASE OF FIRE: use Carbon dioxide, foam or dry chemical for extinction. IF IN EYES: Rinse cautiously with water for several minutes. IF SWALLOWED: Get medical attention if you feel unwell. IF INHALED: Remove to fresh air and keep at rest in a position comfortable for breath.

Disposal
Do not discharge into lakes, streams, ponds and ground water supply.

See Section 11 for further health effects/toxicological data.

3. COMPOSITION/INFORMATION ON INGREDIENTS

Engen Dieselube 500 Super

Chemical name	CAS-No.	Weight%
Base oils		> 90,00
Additives		< 10,00

See Section 8 for Exposure Limits (if applicable).

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4. FIRST AID MEASURES

Inhalation	:	Not expected to be a problem. However, if respiratory irritation occurs due to excessive vapour or mist exposure, seek immediate medical assistance. If breathing has stopped, assist ventilation with mechanical device or use mouth-to-mouth resuscitation.
Skin contact	:	Remove contaminated clothing. Dry wipe exposed skin and cleanse with hand cleaner, soap and water. Launder contaminated clothing before reuse. (See Section 16 - Injection Injury)
Eye contact	:	Flush thoroughly with water. If irritation occurs call a doctor.
Ingestion	:	Not expected to be a problem. However, if discomfort occurs seek medical attention. Do not induce vomiting.

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5. FIRE-FIGHTING MEASURES

Extinguishing media	:	Carbon dioxide, foam, dry chemical and water fog.
Special fire fighting procedure	:	Water or foam may cause frothing. Use water to keep fire exposed containers cool. Water spray may be used to flush spills away from exposure. Prevent runoff from fire control or dilution from entering streams, municipal sewers, or drinking water supply.
Special protective equipment for firefighters	:	For fires in enclosed areas, fire fighters must use Self-Contained Breathing Apparatus.
Unusual fire and explosive hazards	:	None.
Products of decomposition	:	Fumes, smoke, carbon monoxide, sulphur oxides, aldehydes and other decomposition products, in the case of incomplete combustion.
Flash Point	:	222 °C (ASTM D-92)
Upper Explosion Limit (UEL)	:	7,0 %(V)
Lower Explosion Limit (LEL)	:	0,9 %(V)
NFPA Hazard Id	:	Health: 0; Flammability: 1; Reactivity: 0

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6. ACCIDENTAL RELEASE MEASURES

Procedure if material is released or spilled	:	Report spills/releases as required to appropriate authorities.
Methods for cleaning up	:	LAND SPILL: Shut off source taking normal safety precautions. Take measures to minimize the effects on ground water. Recover by pumping using explosion-proof equipment or contain spilled liquid with sand or other suitable absorbent and remove mechanically into containers. If necessary, dispose of absorbed residues as directed in Section 13. WATER SPILL: Notify port and relevant authorities. Confine with booms if skimming equipment is available to recover the spill for later recycling or disposal. Warn other ships in the vicinity. If allowed by regulatory authorities the

		use of suitable dispersants should be considered where recommended in local oil spill procedures.
Personal precautions	:	See Section 8.
Environmental precautions	:	Prevent spill from entering municipal sewers, water sources or low lying areas. Advise the relevant authorities if contaminations have occurred.

7. HANDLING AND STORAGE

Safe handling advice	:	No special precautions are necessary beyond normal good hygiene practices.
Storage information	:	Keep containers closed when not in use. Do not store in open or unlabelled containers. Do not store near heat sources, sparks, flames, strong oxidizing agents and combustible materials.
Storage and handling procedures	:	Prevent small spills and leakages to avoid slip hazard.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Limits (OELs)

Components	CAS-No.	Source	TWA	Value	Notations

LTEL: Long Term Exposure Limits - Time Weight Average (TWA) over 8 hours.

STEL: Short Term Exposure Limits - Time Weight Average (TWA) over 15 Minutes

Note: Limits Shown for guidance only. Follow applicable regulations.

Personal Protection Equipment (PPE)

Engineering controls	:	If mists are generated, use ventilation, local exhaust or enclosures to control below exposure limits.
Respiratory protection	:	Approved respiratory equipment must be used when mist concentrations exceed the recommended exposure limits.
Eye protection	:	If splash with liquid is possible, chemical type goggles should be worn.
Skin and body protection	:	No special equipment required. However, if frequent splashing or liquid contact is likely to occur, wear oil impervious gloves and clothing. Good personal hygiene practices should always be followed.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance	:	Liquid.
Colour	:	Amber
Odour	:	Mild
Solubility	:	Negligible
Boiling point	:	> 316 °C
Flash Point	:	222 °C (ASTM D-92)
Upper Explosion Limit (UEL)	:	7,0 %(V)
Lower Explosion Limit (LEL)	:	0,9 %(V)
Vapour pressure	:	< 0,1 hPa
Density	:	0,8830 g/cm3 @ (ASTM D-4052)
Pour point	:	-27 °C
Viscosity, kinematic	:	116,6 mm2/s @ 40 °C (ASTM D-445) 15,50 mm2/s @ 100 °C (ASTM D-445)

10. STABILITY AND REACTIVITY

Stability	:	Stable.
Conditions to avoid	:	Extreme heat and high energy sources of ignition, such as sparks and static electricity.
Materials to avoid	:	Strong oxidizers.
Hazardous decomposition products	:	Fumes, smoke, carbon monoxide, sulphur oxides, aldehydes and other decomposition products, in the case of incomplete combustion.

11. TOXICOLOGICAL INFORMATION

Acute oral toxicity	:	(Rats): Practically non-toxic (LD50: Greater than 2000 mg/kg). Based on testing of similar products and/or components. Warning Hazard category 5. May be harmful if swallowed.
Acute dermal toxicity	:	(Rabbits): Practically non-toxic (LD50: greater than 2000 mg/kg). Based on testing of similar products and/or the components. Warning Hazard category 3. May be harmful in contact with skin.
Acute inhalation toxicity	:	(Rats): Harmful (LC50: greater than 10 but less than 20mg/l) 4 hours. Based on testing of similar products and/or the components. Warning Hazard category 4. May be harmful if inhaled.
Skin irritation	:	(Rabbits): Practically non-irritating. (Primary Irritation Index: greater than 0.5 but less than 3). Based on testing of similar products and/or the components. Warning Hazard category 3. Causes mild skin irritation.
Eye irritation	:	(Rabbits): Mild irritant. (Draize score: greater than 6 but 15 or less). Based on testing of similar products and/or the components. Warning Hazard category 2B. May cause mild eye irritation.
Respiratory and skin sensitization	:	Not expected to be sensitizing based on tests of this product, components, or similar products.
Germ cell mutagenicity	:	This product tested negative in a series of mutagenic tests.
Carcinogenicity	:	Chronic mouse skin painting studies of severely solvent refined mineral base oils showed no evidence of carcinogenic effects. Synthetic base oils have been tested in the Ames assay and other tests of mutagenicity with negative results. These base oils are not expected to be carcinogenic with chronic dermal exposures. Used petrol engine oils have shown evidence of skin carcinogenic activity in laboratory tests when no effort was made to wash the oil off between applications. Used oil from diesel engines did not produce this effect.
Reproductive toxicity (Teratogenicity)	:	No teratogenic effects would be expected from dermal exposure, based on laboratory developmental toxicity studies of major components in this formulation and/or materials of similar composition.
Specific target organ toxicity (STOT) - single exposure	:	Although an acute inhalation study was not performed with this product, a variety of mineral and synthetic oils, such as those in this product, have been tested. These samples had virtually no effect other than a nonspecific inflammatory response in the lung to the aerosolized mineral oil. The presence of additives in other tested formulations (in approximately the same amounts as in the present formulation) did not alter the observed effects.
Specific target organ toxicity	:	No significant adverse effects were found in studies using repeated

(STOT) - repeated exposure		dermal applications of similar formulations to the skin of laboratory animals for 13 weeks at doses significantly higher than those expected during normal industrial exposure. The animals were evaluated extensively for effects of exposure (haematology, serum chemistry, urinalysis, organ weights, microscopic examination of tissues etc.). Repeated and/or prolonged exposure may cause irritation to the skin, eyes or respiratory tract.
Aspiration hazard	:	Overexposure to oil mist may result in oil droplet deposition and/or granuloma formation.

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12. ECOLOGICAL INFORMATION

Ecotoxicity effects

Toxicity to fish	:	(Salmon) LC/EC50: 8.1 mg/l at 96 hours.
Toxicity to aquatic organisms	:	(Daphnia magna) LC/EC50: 6 mg/l at 48 hours. (Green algae) LC/EC50: 9.4 mg/l at 8 hours.

Elimination information (persistence and degradability)

Biodegradability	:	This product is expected to be inherently biodegradable.
Mobility	:	Adsorption to sediment and soil will be the predominant behaviour.
Bioaccumulation	:	Minimal owing to low water solubility.

Further information on ecology

Remarks	:	In the absence of specific environmental data for this product, this assessment is based on information for representative substances.

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13. DISPOSAL CONSIDERATIONS

Waste disposal	:	Product is suitable for burning in an enclosed, controlled burner for fuel value or disposal by supervised incineration. Such burning may be limited pursuant to the Resource Conservation and Recovery Act. In addition, the product is suitable for processing by an approved recycling facility or can be disposed of at any government approved waste disposal facility. Use of these methods is subject to user compliance with applicable laws and regulations and considerations of product characteristics at time of disposal.
Contaminated packaging	:	Empty containers retain residue (liquid and/or vapour) and can be dangerous. DO NOT PRESSURIZE, CUT, WELD, BRAZE, SOLDER, DRILL, GRIND OR EXPOSE SUCH CONTAINERS TO HEAT, FLAME, SPARKS, STATIC ELECTRICITY, OR OTHER SOURCES OF IGNITION; THEY MAY EXPLODE AND CAUSE INJURY OR DEATH. Do not attempt to refill or clean container since residue is difficult to remove. Empty drums should be completely drained, properly bunged and promptly returned to a drum reconditioner. All containers should be disposed of in an environmentally safe manner and in accordance with governmental regulations.
Other regulations	:	The unused product, in our opinion, is not specifically listed by the EPA as a hazardous waste (40 CFR, Part 261D), nor is it formulated to contain materials which are listed hazardous wastes. It does not exhibit the hazardous characteristics of ignitability, corrosivity, or reactivity and is not formulated with contaminants as determined by the Toxicity Characteristic Leaching Procedure (TCLP). However, used product may be regulated.
Flash Point	:	222 °C (ASTM D-92)

14. TRANSPORT INFORMATION

Note	:	This product is not regulated by the following: U.S. DOT (CFR), ADR, IATA and IMDG.
Static Accumulator (50 picosiemens or less)	:	Yes

15. REGULATORY INFORMATION

US OSHA Hazard Communication Standard	:	When used for its intended purposes, this product is not classified as hazardous in accordance with OSHA 29 CFR 1910.1200.
Governmental Inventory Status	:	All components comply with TSCA, EINECS/ELINCS, AICS, METI, DSL, KECI, ENCS, PICCS and IECSC.
EU Labelling	:	Product is not dangerous as defined by the European Union Dangerous Substances/Preparations Directives. EU labelling not required.

SARA

U.S. Superfund Amendments and Reauthorization Act SARA Title III	:	This product contains no "EXTREMELY HAZARDOUS SUBSTANCES".
SARA (311/312) Reportable Hazard Categories	:	None

The following product ingredients are cited on the lists below

Chemical name	CAS-No.	Concentration [%]	List Citations
Base oils		> 90,00	Not listed
Additives		< 10,00	Not listed

Regulatory List Searched

1 = ACGIH ALL	6 = IARC 1	11 = TSCA 4	17 = CA P65	22 = MI 293
2 = ACGIH A1	7 = IARC 2A	12 = TSCA 5a2	18 = CA RTK	23 = MN RTK
3 = ACGIH A2	8 = IARC 2B	13 = TSCA 5e	19 = FL RTK	24 = NJ RTK
4 = NTP CARC	9 = OSHA CARC	14 = TSCA 6	20 = IL RTK	25 = PA RTK
5 = NTP SUS	10 = OSHA Z	15 = TSCA 12b	21 = LA RTK	26 = RI RTK

Code Key: CARC = Carcinogen; SUS = Suspected Carcinogen

16. OTHER INFORMATION

Note: Engen products do not contain PCBs.

INJECTION INJURY WARNING: If product is injected into or under the skin, or into any part of the body, regardless of the appearance of the wound or its size, the individual should be evaluated immediately by a doctor as a surgical emergency. Even though initial symptoms from high pressure injection may be minimal or absent, early surgical treatment within the first few hours may significantly reduce the ultimate extent of injury.

Note: No significant changes have been made to this Safety Data Sheet since the previous date.

Disclaimer

Engen Dieselube 500 Super

Information given herein is offered in good faith as accurate, but without guarantee. Conditions of use and suitability of the product for particular uses are beyond our control; all risks of use of the product are therefore assumed by the user and we expressly disclaim all warranties of every kind and nature, including warranties of merchantability and fitness for a particular purpose in respect to the use or suitability of the product. Nothing is intended as a recommendation for uses which infringe valid patents or as extending license under valid patents. Appropriate warnings and safe handling procedures should be provided to handlers and users.

Prepared by	:	Product Safety Specialist Corporate Health, Safety, Environment and Quality Department Engen Petroleum Limited P.O.Box 35, Cape Town, 8000
Telephone	:	(021) 403 4805 / 4911 (Office Hours) (021) 403 4099 (After Hours) 083 628 4415 (Cellular)

13.4 Hydrogen MSDS (overleaf)

SAFETY DATA SHEET

according to Regulation (EC) No. 1907/2006
Version 5.4 Revision Date 02.10.2017
Print Date 07.04.2018
GENERIC EU MSDS - NO COUNTRY SPECIFIC DATA - NO OEL DATA

SECTION 1: Identification of the substance/mixture and of the company/undertaking

1.1 Product identifiers

Product name	:	Hydrogen
Product Number	:	295396
Brand	:	Aldrich
Index-No.	:	001-001-00-9
REACH No.	:	A registration number is not available for this substance as the substance or its uses are exempted from registration, the annual tonnage does not require a registration or the registration is envisaged for a later registration deadline.
CAS-No.	:	1333-74-0

1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Laboratory chemicals, Manufacture of substances

1.3 Details of the supplier of the safety data sheet

Company	:	Sigma-Aldrich (Pty.) Ltd. 17 Pomona Street Aviation Park, Unit 4 KEMPTON PARK 1619 SOUTH AFRICA
Telephone	:	+27 11 979 1188
Fax	:	+27 11 979 1119

1.4 Emergency telephone number

Emergency Phone #

SECTION 2: Hazards identification

2.1 Classification of the substance or mixture

Classification according to Regulation (EC) No 1272/2008
Flammable gases (Category 1), H220
Gases under pressure (Compressed gas), H280

For the full text of the H-Statements mentioned in this Section, see Section 16.

2.2 Label elements

Labelling according Regulation (EC) No 1272/2008

Pictogram

Signal word: Danger

Hazard statement(s)

H220	Extremely flammable gas.
H280	Contains gas under pressure; may explode if heated.

Precautionary statement(s)	
P210	Keep away from heat, hot surfaces, sparks, open flames and other ignition sources. No smoking.
P377	Leaking gas fire: Do not extinguish, unless leak can be stopped safely.
P381	Eliminate all ignition sources if safe to do so.
P410 + P403	Protect from sunlight. Store in a well-ventilated place.
Supplemental Hazard Statements	none

2.3 Other hazards

This substance/mixture contains no components considered to be either persistent, bioaccumulative and toxic (PBT), or very persistent and very bioaccumulative (vPvB) at levels of 0.1% or higher.

SECTION 3: Composition/information on ingredients

3.1 Substances

Formula	:	H_2
Molecular weight	:	2,02 g/mol
CAS-No.	:	1333-74-0
EC-No.	:	215-605-7
Index-No.	:	001-001-00-9

No components need to be disclosed according to the applicable regulations.

For the full text of the H-Statements mentioned in this Section, see Section 16.

SECTION 4: First aid measures

4.1 Description of first aid measures

General advice

Consult a physician. Show this safety data sheet to the doctor in attendance.

If inhaled

If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

In case of skin contact

Wash off with soap and plenty of water. Consult a physician.

In case of eye contact

Flush eyes with water as a precaution.

If swallowed

Do NOT induce vomiting. Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

4.3 Indication of any immediate medical attention and special treatment needed

No data available

SECTION 5: Firefighting measures

5.1 Extinguishing media

Suitable extinguishing media

Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

5.2 Special hazards arising from the substance or mixture

No data available

5.3 Advice for firefighters
Wear self-contained breathing apparatus for firefighting if necessary.

5.4 Further information
Use water spray to cool unopened containers.

SECTION 6: Accidental release measures

6.1 Personal precautions, protective equipment and emergency procedures
Avoid breathing vapours, mist or gas. Ensure adequate ventilation. Remove all sources of ignition. Evacuate personnel to safe areas. Beware of vapours accumulating to form explosive concentrations. Vapours can accumulate in low areas.
For personal protection see section 8.

6.2 Environmental precautions
Prevent further leakage or spillage if safe to do so. Do not let product enter drains.

6.3 Methods and materials for containment and cleaning up
Clean up promptly by sweeping or vacuum.

6.4 Reference to other sections
For disposal see section 13.

SECTION 7: Handling and storage

7.1 Precautions for safe handling
Avoid inhalation of vapour or mist.
Keep away from sources of ignition - No smoking.Take measures to prevent the build up of electrostatic charge.
For precautions see section 2.2.

7.2 Conditions for safe storage, including any incompatibilities
Store in cool place. Keep container tightly closed in a dry and well-ventilated place.

Contents under pressure.

7.3 Specific end use(s)
Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

SECTION 8: Exposure controls/personal protection

8.1 Control parameters

Components with workplace control parameters

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.

Personal protective equipment

Eye/face protection
Face shield and safety glasses Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin protection
Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

The selected protective gloves have to satisfy the specifications of EU Directive 89/686/EEC and the standard EN 374 derived from it.

Splash contact
Material: butyl-rubber

Minimum layer thickness: 0,3 mm
Break through time: 120 min
Material tested:Butoject® (KCL 897 / Aldrich Z677647, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

Body Protection
Impervious clothing, Flame retardant antistatic protective clothing., The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Respiratory protection
Where risk assessment shows air-purifying respirators are appropriate use a full-face respirator with multi-purpose combination (US) or type AXBEK (EN 14387) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Control of environmental exposure
Prevent further leakage or spillage if safe to do so. Do not let product enter drains.

SECTION 9: Physical and chemical properties

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: Compressed gas Colour: colourless
b)	Odour	No data available
c)	Odour Threshold	No data available
d)	pH	No data available
e)	Melting point/freezing point	Melting point/range: -259,2 °C - lit.
f)	Initial boiling point and boiling range	-252,8 °C - lit.
g)	Flash point	< -150 °C - closed cup
h)	Evaporation rate	No data available
i)	Flammability (solid, gas)	No data available
j)	Upper/lower flammability or explosive limits	Upper explosion limit: 74,2 %(V) Lower explosion limit: 4 %(V)
k)	Vapour pressure	No data available
l)	Vapour density	0,08
m)	Relative density	No data available
n)	Water solubility	0,00196 g/l at 0 °C
o)	Partition coefficient: n-octanol/water	No data available
p)	Auto-ignition temperature	No data available
q)	Decomposition	No data available

	temperature	
r)	Viscosity	No data available
s)	Explosive properties	No data available
t)	Oxidizing properties	No data available

9.2 Other safety information

Relative vapour density 0,08

SECTION 10: Stability and reactivity

10.1 Reactivity
No data available

10.2 Chemical stability
Stable under recommended storage conditions.

10.3 Possibility of hazardous reactions
No data available

10.4 Conditions to avoid
Heat, flames and sparks.

10.5 Incompatible materials
Oxidizing agents

10.6 Hazardous decomposition products
Other decomposition products - No data available
In the event of fire: see section 5

SECTION 11: Toxicological information

11.1 Information on toxicological effects

Acute toxicity
No data available

Skin corrosion/irritation
No data available

Serious eye damage/eye irritation
No data available

Respiratory or skin sensitisation
No data available

Germ cell mutagenicity
No data available

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

Reproductive toxicity
No data available

Specific target organ toxicity - single exposure
No data available

Specific target organ toxicity - repeated exposure
No data available

Aspiration hazard
No data available

Additional Information
RTECS: MW8900000

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

SECTION 12: Ecological information

12.1 Toxicity
No data available

12.2 Persistence and degradability
No data available

12.3 Bioaccumulative potential
No data available

12.4 Mobility in soil
No data available

12.5 Results of PBT and vPvB assessment
This substance/mixture contains no components considered to be either persistent, bioaccumulative and toxic (PBT), or very persistent and very bioaccumulative (vPvB) at levels of 0.1% or higher.

12.6 Other adverse effects

No data available

SECTION 13: Disposal considerations

13.1 Waste treatment methods

Product
Burn in a chemical incinerator equipped with an afterburner and scrubber but exert extra care in igniting as this material is highly flammable. Offer surplus and non-recyclable solutions to a licensed disposal company.

Contaminated packaging
Dispose of as unused product.

SECTION 14: Transport information

14.1 UN number

ADR/RID: 1049	IMDG: 1049	IATA: 1049

14.2 UN proper shipping name
ADR/RID: HYDROGEN, COMPRESSED
IMDG: HYDROGEN, COMPRESSED
IATA: Hydrogen, compressed
Passenger Aircraft: Not permitted for transport

14.3 Transport hazard class(es)

ADR/RID: 2.1	IMDG: 2.1	IATA: 2.1

14.4 Packaging group

ADR/RID: -	IMDG: -	IATA: -

14.5 Environmental hazards

ADR/RID: no	IMDG Marine pollutant: no	IATA: no

14.6 Special precautions for user
No data available

SECTION 15: Regulatory information

15.1 Safety, health and environmental regulations/legislation specific for the substance or mixture
This safety datasheet complies with the requirements of Regulation (EC) No. 1907/2006.

15.2 Chemical safety assessment

For this product a chemical safety assessment was not carried out

SECTION 16: Other information

Full text of H-Statements referred to under sections 2 and 3.

H220	Extremely flammable gas.
H280	Contains gas under pressure; may explode if heated.

Further information

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

13.5 LPG MSDS (overleaf)

A Member of The Linde Group

MATERIAL SAFETY DATA SHEET (MSDS)
LIQUEFIED PETROLEUM GAS AND PROPANE

Please ensure that this MSDS is received by the appropriate person

DATE: March 2017 Version 3

Ref. No.: MS111

1 PRODUCT AND COMPANY IDENTIFICATION

PRODUCT IDENTIFICATION

Product Name:	HANDIGAS (LIQUEFIED PETROLEUM GAS)
Chemical Formula:	C3H8 PLUS C4 H10 PLUS C3 H6
Trade name:	Handigas
Colour Coding:	Plascon Dark Admiralty Grey (SABS 1091 – G.12) body, with a Handigas decal affixed to the cylinder. All cylinders fitted with an internal eductor tube for liquid withdrawal shall be clearly marked with two Yellow (B.49) stripes painted diametrically opposite each other along the length of the cylinder.
Valve:	Brass 5/8 inch BSP left hand female, either single or two-way outlet.
Company Identification:	African Oxygen Limited 23 Webber Street Johannesburg, 2001 Tel. No: (011) 490-0400 Fax. No: (011) 490-0506

EMERGENCY NUMBER 0860 020202 or +27(0) 11 821 3000 (24 hours)

2 COMPOSITION/INFORMATION ON INGREDIENTS

Chemical Name	Butane / Propane / Propylene
Chemical Family	Aliphatic Hydrocarbon
CAS NO.	BUTANE 106-97-8 UN NO.1075 Propane 74-98-6 UN No. 1978 Propylene 115-07-01 UN No. 1077
UN No.	1075
ERG No.	115
Hazchem Warning	2A Flammable gas

3 HAZARDS IDENTIFICATION

Vapourised liquefied petroleum gas is highly flammable and can form explosive mixtures with air. The vapourised liquid does not support life. It can act as a simple asphyxiant by diluting the concentration of oxygen in the air below the levels necessary to support life. It can act as a simple asphyxiant.

Adverse Health effects

The liquefied petroleum gases are non-toxic. Prolonged inhalation of high concentrations has an anaesthetic effect

Chemical Hazards

Propane and butane (known as extensively in commercial and popular terms as Lpgas or LPG) have an extremely wide range of domestic, industrial, commercial, agricultural and internal combustion engine uses. It is estimated that two gases, un-mixed and in mixtures, have several thousand industrial applications and many more in other fields. Their very broad application stems from their occurrences as hydrocarbons between natural gas and natural gasoline, and from their corresponding properties. As a result of their wide application, misuse could result in serious chemical hazards.

Biological Hazards.

Contact with the liquid phase of liquefied petroleum gases with the skin can result in frostbite.

Vapour Inhalation

As the vapourised liquid act as a simple asphyxiant death may result from errors in judgement, confusion, or loss of consciousness which prevents self-rescue. At low oxygen concentrations, unconsciousness and death may occur in seconds without warning.

Eye Contact	The liquid can cause severe burn-like injuries.
Skin Contact	Contact with the liquid phase can cause severe burn-like injuries.
Ingestion	No known effect

Hazard Category 1

Danger
Extremely flammable gas

4 FIRST AID MEASURES

Prompt medical attention is mandatory in all cases of overexposure to vapourised liquefied petroleum gas. Rescue personnel should be equipped with self-contained breathing apparatus. In the case of frostbite from contact with the liquid phase, place the frost bitten part in warm water, about 40 -42 ℃. If warm water is not available. Or is impractical to use, wrap the affected part gently in blankets. Encourage the patient to exercise the affected part whilst it is being warmend. Do not remove clothing whilst frosted. Conscious persons should be assisted to an uncontaminated area and inhale fresh air. Quick removal from the contaminated area is most important. Unconscious persons should be removed to an uncontaminated area, and given mouth-to-mouth resuscitation and supplemental oxygen.

Eye contact **(with liquid phase)**
Eye contact Immediately flush with large quantities Of tepid water, or with sterile saline solution. Seek medical attention
Skin Contact See above for handling of frostbite
Ingestion No known effect

5 FIRE FIGHTING MEASURES

Extinguish media

Do not extinguish fire unless the leakage can be stopped. DO NOT USE WATER JET. Use dry chemical, CO2 or foam.

Specific Hazards

The rupturing of cylinders or bulk containers due to excessive exposure to fire could result in a BLEVE (Boiling Liquid expanding Vapour Explosion), with disastrous effects. As the flammability limits in the air for the main constituents of liquefied petroleum gas vary between approximately 2 and 11% by vol, extreme care must be taken when handling leaks.

Emergency actions

If possible shut off the source of spillage. Evacuate area. Post notices "No Naked lights – No Smoking". Prevent liquid or vapour from entering sewers, basements and workpits. Keep cylinders or bulk vessels cool by spraying with water if exposed to fire. If tanker has overturned, do not attempt to right or move it. CONTACT THE NEAREST AFROX BRANCH.

Protective Clothing

Self contained breathing apparatus. Safety gloves and shoes, or boots, should be worn when handling containers.

Environmental precautions.

Vapourised liquefied petroleum gas is heavier than air and could form pockets of oxygen-deficient atmosphere in low lying areas.

6 ACCIDENTAL RELEASE MEASURES

Personal Precautions

Do not enter any area where liquefied petroleum gas has been spilled unless tests have shown that it is safe to do so.

Environmental Precautions.

The danger of widespread formation of explosive LPG/Air mixtures should be taken into account. Accidental ignition could result in massive explosion.

Small spills

DO NOT extinguish the fire unless the leakage can be stopped immediately. Once the fire has been extinguished and all spills have been stopped, ventilate the area.

Large spills

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Stop the source if it can be done without risk. Contain the leaking liquid, with sand or earth, or disperse with special water/fog spray nozzle. Allow to evaporate. Restrict access to the area until completion of the clean-up procedure. Ventilate the area using forced-draught if necessary. All electrical equipment must be flameproof.

7 HANDLING AND STORAGE

Cylinders containing liquefied petroleum gas should only be handled and stored in the vertical position. Cylinders should never been rolled. Do not allow cylinders to slide or come into contact with sharp edges and they should be handled carefully. Ensure that cylinders are stored away from oxidants. Comply with local legislation..

8 EXPOSURE CONTROLS/PERSONAL PROTECTION

Occupational Exposure Hazards.
As vaporised LPG is a simple asphyxiant, avoid any areas where spillage has taken place.

Engineering control measures.
Engineering control measures are preferred to reduce exposure to Oxygen-depleted atmospheres. General methods include forced-draught ventilation, separate from other exhaust ventilation, separate from other exhaust ventilation systems. Ensure that all electrical equipment is flameproof.

Personal Protection.
Self-contained breathing apparatus should always be worn when entering area where oxygen depletion may have occurred. Safety goggles, gloves and shoes, or boots, should be worn when handling containers.
Skin. Wear loose-fitting overalls, preferably without pockets.
.

9 PHYSICAL AND CHEMICAL PROPERTIES

Physical Data

Specific Volume @ 20°C & 101,325 kPa	471ml/g
Auto ignition temperature	450°C
Relative density (Air=1) @101,325kPa	+-1,75
Flammability in air	2,2-9.5%
Colour – Liquid	Clear
Taste	None
Odour	EthylMercaptan
Specification	SANS 1174

10 STABILITY AND REACTIVITY

Conditions to avoid
The dilution of the oxygen concentration in the atmosphere to levels which cannot support life. The formation of explosive gas/air mixtures.

Incompatible Materials
Any common, commercially available metal may be used with commercial (or higher) grades of liquefied petroleum gases because they are non-corrosive, though installations must be designed to withstand the pressure involved and must comply with all state local regulations**.**

Hazardous Decomposition Products.
The constituents of liquefied petroleum gas are relatively stable. However, on combustion, toxic compositions, typically carbon monoxide, may be formed, depending on conditions.

11 TOXICOLOGICAL INFORMATION

Acute Toxicity	TLV 1000 VPM
Skin & eye contact	No known effect.
Carcinogenicity	Severe cold burns can result in carcinoma

(For Further information see Section3.Adverse Health Effects)

12 ECOLOGICAL INFORMATION

Vapourised liquefied petroleum gas is heavier than air, and can cause pockets of oxygen-depleted atmosphere in low-lying areas. It does not pose a hazard to the ecology, unless the gas/air is ignited.

13 DISPOSAL CONSIDERATIONS

Disposal Methods Disposal of Propane, as with other flammable gases, should be undertaken only by personnel familiar with the gas and the procedures for disposal. Contact the supplier for instructions. In general, should it become necessary to dispose of Propane, the best procedure, as for other flammable gases, is to burn them in suitable burning unit available in the plant. This should be done in accordance with appropriate regulations.

Disposal of packaging The disposal of cylinders must only be handled by the gas supplier.

14 TRANSPORT INFORMATION

ROAD TRANSPORTATION

Road Transportation		
UN No.	1075	
ERG No.	115	
Hazchem warning	2A-Flammable gas	
SEA TRANSPORTATION		
IMDG	1075	
Label	Flammable gas	
AIR TRANSPORTATION		
ICAO/IATA Code	1075	
Class	2.1	
Packaging group		
Packaging instructions	Cargo	200
	Passenger	Forbidden
Maximum Quantity allowed	Cargo	150kg
	Passenger	Forbidden

15 REGULATORY INFORMATION

SUPPLEMENT TO SANS 10234:2008
Edition 1
Annex A Index No. 608-011-00-8

Hazard & Precautionary statement codes

H220	Extremely Flammable Gas
P210	Keep away from heat/sparks/open flames/ hot surfaces – NO SMOKING (Manufacture, supplier or the competent authority to specify ignition sources)
P377	Leaking gas fire: Do not extinguish unless leak can be stopped safely
P381	Eliminate all ignition sources if safe to do so
P403	Store in a well-ventilated place

16 OTHER INFORMATION

Bibliography
Handbook of Compressed Gases - 3rd Edition
Matheson. Matheson Gas Data Book - 6th Edition
Supplement to SANS 10234 – List of classification and labelling of chemicals in accordance with Globally Harmonized System (GHS)

EXCLUSION OF LIABILITY
Whilst AFROX made best endeavour to ensure that the information contained in this publication is accurate at the date of publication, AFROX does not accept liability for an inaccuracy or liability arising from the use of this information, or the use, application, adaptation or process of any products described herein.

13.6 Ammonia MSDS (overleaf)

SAFETY DATA SHEET

according to Regulation (EC) No. 1907/2006
Version 5.3 Revision Date 04.11.2016
Print Date 10.04.2018
GENERIC EU MSDS - NO COUNTRY SPECIFIC DATA - NO OEL DATA

SECTION 1: Identification of the substance/mixture and of the company/undertaking

1.1 Product identifiers

Product name	:	Ammonia
Product Number	:	09682
Brand	:	Sigma-Aldrich
Index-No.	:	007-001-00-5
REACH No.	:	A registration number is not available for this substance as the substance or its uses are exempted from registration, the annual tonnage does not require a registration or the registration is envisaged for a later registration deadline.
CAS-No.	:	7664-41-7

1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Laboratory chemicals, Manufacture of substances

1.3 Details of the supplier of the safety data sheet

Company : Sigma-Aldrich (Pty.) Ltd.
17 Pomona Street
Aviation Park, Unit 4
KEMPTON PARK
1619 SOUTH AFRICA

Telephone : +27 11 979 1188
Fax : +27 11 979 1119

1.4 Emergency telephone number

Emergency Phone #

SECTION 2: Hazards identification

2.1 Classification of the substance or mixture

Classification according to Regulation (EC) No 1272/2008
Flammable gases (Category 2), H221
Gases under pressure (Compressed gas), H280
Acute toxicity, Inhalation (Category 3), H331
Skin corrosion (Category 1B), H314
Acute aquatic toxicity (Category 1), H400
Chronic aquatic toxicity (Category 1), H410

For the full text of the H-Statements mentioned in this Section, see Section 16.

2.2 Label elements

Labelling according Regulation (EC) No 1272/2008
Pictogram

Signal word Danger

Hazard statement(s)	
H221	Flammable gas.
H280	Contains gas under pressure; may explode if heated.
H314	Causes severe skin burns and eye damage.
H331	Toxic if inhaled.
H410	Very toxic to aquatic life with long lasting effects.
Precautionary statement(s)	
P210	Keep away from heat, hot surfaces, sparks, open flames and other ignition sources. No smoking.
P280	Wear protective gloves/ protective clothing/ eye protection/ face protection.
P304 + P340 + P310	IF INHALED: Remove person to fresh air and keep comfortable for breathing. Immediately call a POISON CENTER/doctor.
P305 + P351 + P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P377	Leaking gas fire: Do not extinguish, unless leak can be stopped safely.
P403	Store in a well-ventilated place.
Supplemental Hazard Statements	none

2.3 Other hazards

This substance/mixture contains no components considered to be either persistent, bioaccumulative and toxic (PBT), or very persistent and very bioaccumulative (vPvB) at levels of 0.1% or higher.

SECTION 3: Composition/information on ingredients

3.1 Substances

Formula	:	H_3N
Molecular weight	:	17,03 g/mol
CAS-No.	:	7664-41-7
EC-No.	:	231-635-3
Index-No.	:	007-001-00-5

Hazardous ingredients according to Regulation (EC) No 1272/2008

Component		Classification	Concentration
Ammonia, anhydrous			
CAS-No. EC-No. Index-No.	7664-41-7 231-635-3 007-001-00-5	Flam. Gas 2; Press. Gas Compr. Gas; Acute Tox. 3; Skin Corr. 1B; Aquatic Acute 1; Aquatic Chronic 1; H221, H280, H331, H314, H400, H410 M-Factor - Aquatic Acute: 1	<= 100 %

For the full text of the H-Statements mentioned in this Section, see Section 16.

SECTION 4: First aid measures

4.1 Description of first aid measures

General advice

Consult a physician. Show this safety data sheet to the doctor in attendance.

If inhaled

If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

In case of skin contact
Take off contaminated clothing and shoes immediately. Wash off with soap and plenty of water. Take victim immediately to hospital. Consult a physician.

In case of eye contact
Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician.

If swallowed
Do NOT induce vomiting. Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

4.3 Indication of any immediate medical attention and special treatment needed
No data available

SECTION 5: Firefighting measures

5.1 Extinguishing media

Suitable extinguishing media
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

5.2 Special hazards arising from the substance or mixture
No data available

5.3 Advice for firefighters
Wear self-contained breathing apparatus for firefighting if necessary.

5.4 Further information
Use water spray to cool unopened containers.

SECTION 6: Accidental release measures

6.1 Personal precautions, protective equipment and emergency procedures
Wear respiratory protection. Avoid breathing vapours, mist or gas. Ensure adequate ventilation. Remove all sources of ignition. Evacuate personnel to safe areas. Beware of vapours accumulating to form explosive concentrations. Vapours can accumulate in low areas.
For personal protection see section 8.

6.2 Environmental precautions
Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

6.3 Methods and materials for containment and cleaning up
Contain spillage, and then collect with an electrically protected vacuum cleaner or by wet-brushing and place in container for disposal according to local regulations (see section 13).

6.4 Reference to other sections
For disposal see section 13.

SECTION 7: Handling and storage

7.1 Precautions for safe handling
Avoid contact with skin and eyes. Avoid inhalation of vapour or mist.
Keep away from sources of ignition - No smoking.Take measures to prevent the build up of electrostatic charge.
For precautions see section 2.2.

7.2 Conditions for safe storage, including any incompatibilities
Store in cool place. Keep container tightly closed in a dry and well-ventilated place.

7.3 Specific end use(s)
Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

SECTION 8: Exposure controls/personal protection

8.1 Control parameters

Components with workplace control parameters

8.2 Exposure controls

Appropriate engineering controls
Avoid contact with skin, eyes and clothing. Wash hands before breaks and immediately after handling the product.

Personal protective equipment

Eye/face protection
Tightly fitting safety goggles. Faceshield (8-inch minimum). Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin protection
Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

The selected protective gloves have to satisfy the specifications of EU Directive 89/686/EEC and the standard EN 374 derived from it.

Full contact
Material: butyl-rubber
Minimum layer thickness: 0,3 mm
Break through time: 480 min
Material tested:Butoject® (KCL 897 / Aldrich Z677647, Size M)

Splash contact
Material: butyl-rubber
Minimum layer thickness: 0,3 mm
Break through time: 480 min
Material tested:Butoject® (KCL 897 / Aldrich Z677647, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

Body Protection
Complete suit protecting against chemicals, Flame retardant antistatic protective clothing., The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Respiratory protection
Where risk assessment shows air-purifying respirators are appropriate use a full-face respirator with multi-purpose combination (US) or type AXBEK (EN 14387) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Control of environmental exposure
Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

10.6 Hazardous decomposition products
Hazardous decomposition products formed under fire conditions. - Nitrogen oxides (NOx)
Other decomposition products - No data available
In the event of fire: see section 5

SECTION 11: Toxicological information

11.1 Information on toxicological effects

Acute toxicity
No data available

LC50 Inhalation - Rat - 4 h - 2000 ppm

Skin corrosion/irritation
No data available

Serious eye damage/eye irritation
No data available

Respiratory or skin sensitisation
No data available

Germ cell mutagenicity
No data available

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

Reproductive toxicity
No data available

Specific target organ toxicity - single exposure
No data available

Specific target organ toxicity - repeated exposure
No data available

Aspiration hazard
No data available

Additional Information
RTECS: BO0875000

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

Liver - Irregularities - Based on Human Evidence

SECTION 12: Ecological information

12.1 Toxicity
No data available

Toxicity to daphnia and other aquatic invertebrates	LC50 - Daphnia magna (Water flea) - 25,4 mg/l - 48 h

12.2 Persistence and degradability
No data available

12.3 Bioaccumulative potential
No data available

12.4 Mobility in soil
No data available

12.5 Results of PBT and vPvB assessment

SECTION 9: Physical and chemical properties

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: Compressed gas
b)	Odour	No data available
c)	Odour Threshold	No data available
d)	pH	No data available
e)	Melting point/freezing point	-78 °C
f)	Initial boiling point and boiling range	-33 °C at 1.013 hPa
g)	Flash point	132 °C - closed cup
h)	Evaporation rate	No data available
i)	Flammability (solid, gas)	No data available
j)	Upper/lower flammability or explosive limits	Upper explosion limit: 25 %(V) Lower explosion limit: 15 %(V)
k)	Vapour pressure	6.402 hPa at 15,50 °C 8.866 hPa at 21 °C
l)	Vapour density	0,59 - (Air = 1.0)
m)	Relative density	0,590 g/cm3
n)	Water solubility	soluble
o)	Partition coefficient: n-octanol/water	No data available
p)	Auto-ignition temperature	No data available
q)	Decomposition temperature	No data available
r)	Viscosity	No data available
s)	Explosive properties	No data available
t)	Oxidizing properties	No data available

9.2 Other safety information

Relative vapour density 0,59 - (Air = 1.0)

SECTION 10: Stability and reactivity

10.1 Reactivity
No data available

10.2 Chemical stability
Stable under recommended storage conditions.

10.3 Possibility of hazardous reactions
No data available

10.4 Conditions to avoid
Heat, flames and sparks.

10.5 Incompatible materials
Oxidizing agents, Iron, Zinc, Copper, Silver/silver oxides, Cadmium/cadmium oxides, Alcohols, acids, Halogens, Aldehydes

This substance/mixture contains no components considered to be either persistent, bioaccumulative and toxic (PBT), or very persistent and very bioaccumulative (vPvB) at levels of 0.1% or higher.

12.6 Other adverse effects

Very toxic to aquatic life with long lasting effects.

No data available

SECTION 13: Disposal considerations

13.1 Waste treatment methods

Product

Burn in a chemical incinerator equipped with an afterburner and scrubber but exert extra care in igniting as this material is highly flammable. Offer surplus and non-recyclable solutions to a licensed disposal company.

Contaminated packaging

Dispose of as unused product.

SECTION 14: Transport information

14.1 UN number

ADR/RID: 1005	IMDG: 1005	IATA: 1005

14.2 UN proper shipping name

ADR/RID: AMMONIA, ANHYDROUS
IMDG: AMMONIA, ANHYDROUS
IATA: Ammonia, anhydrous
Passenger Aircraft: Not permitted for transport
Cargo Aircraft: Not permitted for transport

14.3 Transport hazard class(es)

ADR/RID: 2.3 (8)	IMDG: 2.3 (8)	IATA: 2.3 (8)

14.4 Packaging group

ADR/RID: -	IMDG: -	IATA: -

14.5 Environmental hazards

ADR/RID: yes	IMDG Marine pollutant: yes	IATA: no

14.6 Special precautions for user

No data available

SECTION 15: Regulatory information

15.1 Safety, health and environmental regulations/legislation specific for the substance or mixture

This safety datasheet complies with the requirements of Regulation (EC) No. 1907/2006.

15.2 Chemical safety assessment

For this product a chemical safety assessment was not carried out

SECTION 16: Other information

Full text of H-Statements referred to under sections 2 and 3.

H221	Flammable gas.
H280	Contains gas under pressure; may explode if heated.
H314	Causes severe skin burns and eye damage.
H331	Toxic if inhaled.
H400	Very toxic to aquatic life.
H410	Very toxic to aquatic life with long lasting effects.

Further information

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

14 APPENDIX D: PADHI LAND-PLANNING TABLES

14.1 Development Type Table 1: People at Work, Parking

Development Type	Examples	Development Detail and Size	Justification
DT1.1 Workplaces	Offices, factories, warehouses, haulage depots, farm buildings, nonretail markets, builder's yards	Workplaces (predominantly nonretail), providing for less than 100 occupants in each building and less than 3 occupied storeys (Level 1)	Places where the occupants will be fit and healthy and could be organised easily for emergency action Members of the public will not be present or will be present in very small numbers and for a short time
	Exclusions		
		DT1.1 x1 Workplaces (predominantly nonretail) providing for 100 or more occupants in any building or 3 or more occupied storeys in height (Level 2 except where the development is at the major hazard site itself, where it remains Level 1)	Substantial increase in numbers at risk with no direct benefit from exposure to the risk
	Sheltered workshops, Remploy	DT1.1 x2 Workplaces (predominantly nonretail) specifically for people with disabilities (Level 3)	Those at risk may be especially vulnerable to injury from hazardous events or they may not be able to be organised easily for emergency action
DT1.2 Parking Areas	Car parks, truck parks, lockup garages	Parking areas with no other associated facilities (other than toilets; Level 1)	
	Exclusions		
	Car parks with picnic areas or at a retail or leisure development or serving a park and ride interchange	DT1.2 x1 Where parking areas are associated with other facilities and developments the sensitivity level and the decision will be based on the facility or development	

14.2 Development Type Table 2: Developments for Use by the General Public

Development Type	Examples	Development Detail and Size	Justification
DT2.1 Housing	Houses, flats, retirement flats or bungalows, residential caravans, mobile homes	Developments up to and including 30 dwelling units and at a density of no more than 40 per hectare (Level 2)	Development where people live or are temporarily resident It may be difficult to organise people in the event of an emergency
	Exclusions		
	Infill, back-land development	DT2.1 x1 Developments of 1 or 2 dwelling units (Level 1)	Minimal increase in numbers at risk
	Larger housing developments	DT2.1 x2 Larger developments for more than 30 dwelling units (Level 3)	Substantial increase in numbers at risk
		DT2.1 x3 Any developments (for more than 2 dwelling units) at a density of more than 40 dwelling units per hectare (Level 3)	High-density developments
DT2.2 Hotel or Hostel or Holiday Accommodation	Hotels, motels, guest houses, hostels, youth hostels, holiday camps, holiday homes, halls of residence, dormitories, accommodation centres, holiday caravan sites, camping sites	Accommodation up to 100 beds or 33 caravan or tent pitches (Level 2)	Development where people are temporarily resident It may be difficult to organise people in the event of an emergency
	Exclusions		
	Smaller: guest houses, hostels, youth hostels, holiday homes, halls of residence, dormitories, holiday caravan sites, camping sites	DT2.2 x1 Accommodation of less than 10 beds or 3 caravan or tent pitches (Level 1)	Minimal increase in numbers at risk
	Larger: hotels, motels, hostels, youth hostels, holiday camps, holiday homes, halls of residence, dormitories, holiday	DT2.2 x2 Accommodation of more than 100 beds or 33 caravan or tent pitches (Level 3)	Substantial increase in numbers at risk

Development Type	Examples	Development Detail and Size	Justification
	caravan sites, camping sites		
DT2.3 Transport Links	Motorway, dual carriageway	Major transport links in their own right i.e. not as an integral part of other developments (Level 2)	Prime purpose is as a transport link Potentially large numbers exposed to risk but exposure of an individual is only for a short period
	Exclusions		
	Estate roads, access roads	DT2.3 x1 Single carriageway roads (Level 1)	Minimal numbers present and mostly a small period of time exposed to risk Associated with other development
	Any railway or tram track	DT2.3 x2 Railways (Level 1)	Transient population, small period of time exposed to risk Periods of time with no population present

Development Type	Examples	Development Detail and Size	Justification
DT2.4 Indoor Use by Public	Food and drink: restaurants, cafes, drive-through fast food, pubs Retail: shops, petrol filling station (total floor space based on shop area not forecourt), vehicle dealers (total floor space based on showroom or sales building not outside display areas), retail warehouses, super-stores, small shopping centres, markets, financial and professional services to the public Community and adult education: libraries, art galleries, museums, exhibition halls, day surgeries, health centres, religious buildings, community centres. adult education, 6th form college, college of FE Assembly and leisure: Coach or bus or railway stations, ferry terminals, airports, cinemas, concert or bingo or dance halls, conference centres, sports or leisure centres, sports halls, facilities associated with golf courses, flying clubs (e.g. changing rooms, club house), indoor go kart tracks	Developments for use by the general public where total floor space is from 250 m^2 up to 5000 m^2 (Level 2)	Developments where members of the public will be present (but not resident) Emergency action may be difficult to coordinate
	Exclusions		
		DT2.4 x1 Development with less than 250 m^2 total floor space (Level 1)	Minimal increase in numbers at risk
		DT2.4 x2 Development with more than 5000 m^2 total floor space (Level 3)	Substantial increase in numbers at risk
DT2.5 Outdoor Use by Public	Food and drink: food festivals, picnic areas	Principally an outdoor development for use by the general public	Developments where members of the public will

Development Type	Examples	Development Detail and Size	Justification
	Retail: outdoor markets, car boot sales, funfairs Community and adult education: open-air theatres and exhibitions Assembly and leisure: coach or bus or railway stations, park and ride interchange, ferry terminals, sports stadia, sports fields or pitches, funfairs, theme parks, viewing stands, marinas, playing fields, children's play areas, BMX or go kart tracks, country parks, nature reserves, picnic sites, marquees	i.e. developments where people will predominantly be outdoors and not more than 100 people will gather at the facility at any one time (Level 2)	be present (but not resident) either indoors or outdoors Emergency action may be difficult to coordinate
	Exclusions		
	Outdoor markets, car boot sales, funfairs picnic area, park and ride interchange, viewing stands, marquees	DT2.5 x1 Predominantly open-air developments likely to attract the general public in numbers greater than 100 people but up to 1000 at any one time (Level 3)	Substantial increase in numbers at risk and more vulnerable due to being outside
	Theme parks, funfairs, large sports stadia and events, open air markets, outdoor concerts, pop festivals	DT2.5 x2 Predominantly open-air developments likely to attract the general public in numbers greater than 1000 people at any one time (Level 4)	Very substantial increase in numbers at risk, more vulnerable due to being outside Emergency action may be difficult to coordinate

14.3 Development Type Table 3: Developments for Use by Vulnerable People

Development Type	Examples	Development Detail and Size	Justification
DT3.1 Institutional Accommodation and Education	Hospitals, convalescent homes, nursing homes, old people's homes with warden on site or 'on call', sheltered housing, nurseries, crèches, schools and academies for children up to school leaving age	Institutional, educational and special accommodation for vulnerable people or that provides a protective environment (Level 3)	Places providing an element of care or protection Because of age, infirmity or state of health the occupants may be especially vulnerable to injury from hazardous events Emergency action and evacuation may be very difficult
	Exclusions		
	Hospitals, convalescent homes, nursing homes, old people's homes, sheltered housing	DT3.1 x1 24-hour care where the site on the planning application being developed is larger than 0.25 hectare (Level 4)	Substantial increase in numbers of vulnerable people at risk
	Schools, nurseries, crèches	DT3.1 x2 Day care where the site on the planning application being developed is larger than 1.4 hectare (Level 4)	Substantial increase in numbers of vulnerable people at risk
DT3.2 Prisons	Prisons, remand centres	Secure accommodation for those sentenced by court, or awaiting trial, etc. (Level 3)	Places providing detention Emergency action and evacuation may be very difficult

14.4 Development Type Table 4: Very Large and Sensitive Developments

Development Type	Examples	Development Detail and Size	Justification
Note: all Level 4 developments are by exception from Level 2 or 3 and are reproduced in this table for convenient reference			
DT4.1 Institutional Accommodation	Hospitals, convalescent homes, nursing homes, old people's homes, sheltered housing	Large developments of institutional and special accommodation for vulnerable people (or that provide a protective environment) where 24-hour care is provided and where the site on the planning application being developed is larger than 0.25 hectare (Level 4)	Places providing an element of care or protection Because of age or state of health the occupants may be especially vulnerable to injury from hazardous events Emergency action and evacuation may be very difficult The risk to an individual may be small but there is a larger societal concern
	Nurseries, crèches, schools for children up to school leaving age	Large developments of institutional and special accommodation for vulnerable people (or that provide a protective environment) where day care (not 24-hour care) is provided and where the site on the planning application being developed is larger than 1.4 hectare (Level 4)	Places providing an element of care or protection Because of a the occupants may be especially vulnerable to injury from hazardous events Emergency action and evacuation may be very difficult The risk to an individual may be small but there is a larger societal concern
DT4.2 Very Large Outdoor Use by Public	Theme parks, large sports stadia and events, open air markets, outdoor concerts, pop festivals	Predominantly open air developments where there could be more than 1000 people present (Level 4)	People in the open air may be more exposed to toxic fumes and thermal radiation than if they were in buildings Large numbers make emergency action and evacuation difficult The risk to an individual may be small but there is a larger societal concern