QUANTITATIVE RISK ASSESSMENT FOR THE FISHWATER FLATS WASTEWATER TREATMENT WORKS BIOGAS PROJECT AT PORT ELIZABETH

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- RISCOM does not design equipment or processes.

Mike Oberholzer is a professional engineer, holds a Bachelor of Science in Chemical Engineering and is an approved signatory for MHI risk assessments, thereby meeting the competency requirements of SANAS for assessment of the risks of hazardous components, including fires, explosions and toxic releases.

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QUANTITATIVE RISK ASSESSMENT FOR THE FISHWATER FLATS WASTEWATER TREATMENT WORKS BIOGAS PROJECT AT PORT ELIZABETH

EXECUTIVE SUMMARY

1 INTRODUCTION

The Nelson Mandela Bay Metropolitan Municipality (NMBMM) proposes to upgrading and modernise their Fishwater Flats (FWF) Wastewater Treatment Works (WWTW) (hereinafter referred to as FWF WWTW), in Port Elizabeth, with the construction of a biogas facility that would beneficiate the sludge to produce methane. Methane would then be used to cogenerate of heat and electricity.

1.1 Study Objectives

The risk assessment was completed for the purposes of an environmental impact assessment (EIA), conducted by EOH Coastal & Environmental Services. For the purposes of the EIA, this risk assessment has the main objective to determine any fatal flaws that would prevent the project from proceeding. This differs from a Major Hazard Installation (MHI) risk assessment, which will determine if the project could be constructed and operate with risks to employees and the public at an acceptable level.

The risk assessment should have a statement from a professional person covering the following questions:

1. Whether the proposed project would likely be considered an MHI;
2. If it is likely to be considered an MHI, whether it would meet the requirements of the MHI regulations and whether the risks could be engineered or managed to meet acceptable risks;
3. Whether there are any factors that will prevent the project from proceeding to the next phase of construction or whether the project could continue under certain conditions or mitigations;
4. Whether there are any special requirements that local authorities need to know when evaluating the proposal.
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 upgrade of the FWF WWTW facility in Port Elizabeth. This risk assessment is limited to the proposed biogas facility only.

This risk assessment was conducted with the following terms of reference:

- The development of accidental spill and fire scenarios for the storage facility;
- Using generic failure rate data (tanks, pumps, valves, flanges, pipework, gantry, couplings, etc.), the determination of the probability of each accident scenario;
- For each incident developed in Step 2, the determination of the consequences (thermal radiation, domino effect, toxic cloud formation, etc.);
- The calculation of maximum individual risk (MIR) values taking into account all accidents, meteorological conditions and lethality.

This risk assessment is for the use of the EIA and is not intended to replace a Major Hazard Installation risk assessment. Furthermore, the assessment covers only acute events and sudden ruptures and not chronic and on-going releases, such as fugitive emissions. It is not intended to be an environmental risk assessment and may not meet specific the requirements of environmental legislation.

1.3 Purpose and Main Activities

The main activity at the proposed bioplant at FWF WWTW facility in Port Elizabeth is the cogeneration of heat and electricity via the combustion of gases produced from the beneficiation of sludge.

1.4 Main Hazards Due to Substance and Process

The main hazards that would occur with a loss of containment of hazardous components at the proposed FWF WWTW biogas facility in Port Elizabeth include exposure to:

- Asphyxiant vapours;
- Thermal radiation from fires;
- Overpressure from explosions.
2 ENVIRONMENT

The proposed biogas plant, as shown in Figure 2-1, would be located a 0.97 ha fenced area within the footprint of the existing FWF WWTW. The FWF WWTW is located on John Tallant Road adjacent to Deal Party and is accessible indirectly from the N2. The works is located next to the Swartkops River Estuary.

The land use surrounding the FWF WWTW facility:

- To the north is undeveloped;
- To the east is the N2 and the ocean;
- To the south is John Tallant Road and industrial
- To the west is undeveloped.

![Map showing location of proposed FWF WWTW facility in Port Elizabeth](image)

**Figure 2-1:** Location of the proposed FWF WWTW facility in Port Elizabeth (courtesy EOH)
3 PROCESS DESCRIPTION

3.1 Site

The Biogas Plant will be contained in its own fenced-off area within the boundaries of the FWF WWTW, which is located on Erf 419, Swartkops in Ward 60 along John Tallant Road, Port Elizabeth. The Biogas Plant will be designed and constructed independently of the FWF WWTW, as shown in Figure 3-1.

Figure 3-1: Site layout

3.2 Process Description

A simplified flow diagram of the process is shown in Figure 3-2.

Sludge from the belt filters at 15-25°C would be heated to approximately 35°C and fed continuously into the digesters.

The anaerobic digestion plant is designed according to the principle of the single stage, mesophilic digestion (25-40°C) using a 6.5 % sludge concentration continually fed to the digesters. Based on a retention time of 15 days, the sludge would be reduced by approximately 45% producing biogas consisting of approximately 60% methane and 40% carbon dioxide plus small quantities of hydrogen, nitrogen, hydrogen sulphide and water.

The digesters would consist of 2 x 8548 m³ vertical, agitated tanks, with a possible additional digester in phase II.

The average biogas produced for phase I would be 998 Nm³/h increasing to 1409 Nm³/h in phase II.

The gas from the digesters would be stored in gas holders. The volume of the gas holder is would be 5360 m³. Excess gas that cannot be used will be burnt via a gas flare.

Gas holder and gas flare will be implemented according to the biogas production of phase II.
Figure 3-2:  Simplified process flow diagram for the anaerobic digestion

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 on site is given in Table 3-1.

Table 3-1: Summary of hazardous components to be stored on site

<table>
<thead>
<tr>
<th>Item</th>
<th>Component.</th>
<th>Inventory</th>
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<tr>
<td>Gas holder</td>
<td>Biogas (methane and carbon dioxide)</td>
<td>5360 m³</td>
</tr>
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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 and asphyxiant releases at the FWF WWTW facility in Port Elizabeth. 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 facility 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 FWF WWTW and their contractors to ensure that all engineering designs would be 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 bylaws.

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

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

Methane generated during the process would not be compressed and would not be classified as a notifiable substance. No other materials generated or stored on site would be classified as a notifiable substance.

5.2 Toxic and Asphyxiant Releases

Carbon dioxide is a significant portion of biogas with the other major component being methane. Carbon dioxide is not considered an acutely toxic component but could displace oxygen causing asphyxiation.

The 1% fatality from large carbon dioxide releases would not extend beyond the site’s boundary with no offsite impacts predicted.

5.3 Fires

The biogas consists of approximately 60% methane, a highly flammable gas.

The 1% fatality from jet fires due to a release of biogas at the process installations in the worst weather conditions would not extend beyond the site boundary and thus impacts from jet fires would be limited to the immediate vicinity of the fire.

Emergency flaring conditions would release 2114 Nm³/h at 35°C. The flame length under emergency conditions could extend to a maximum length of 15.6 m in still air. In all wind conditions, the thermal radiation level of 4 kW/m² at 1.0 m aboveground would never be exceeded.

No pool fires were predicted from the simulations.

In worst case weather conditions, the LFL for large biogas flash fires would not extend beyond the site boundary resulting in no predicted offsite impacts.

5.4 Vapour Cloud Explosions

Vapour cloud explosions from a loss of containment at the biogas process installations were simulated.

The 1% fatality for vapour cloud explosions from large releases of biogas could extend beyond the site boundary into the undeveloped area to the east reaching the N2 highway.

The risks from vapour cloud explosions were less than 1x10⁻⁶ fatalities per person per year at the site boundary. Thus the risks to the public would be considered acceptable.
5.5 Impacts onto Neighbouring Properties, Residential Areas and MHIs

The land use to the north, east and west is undeveloped, while industrial properties are located to the south.

The only offsite impacts from the proposed project would be vapour cloud explosions from a catastrophic failure of the gas holder, which would extend beyond the site boundary to the east up to the N2 highway.

This project would not result in impacts beyond the southern boundary of the site into the industrial properties.

Residential properties are some distance to the west of the proposed project. As impacts would not extend beyond the western site boundary, there would be no negative impacts on any residential areas.

5.6 Societal Risks

Due to the surrounding areas being unoccupied, the societal risk did not exceed the threshold value and is not shown. It should be noted that the risks to traffic on the N2 are extremely low to be considered trivial. Thus, the contribution of the traffic on the N2 to the societal risks is negligible.

5.7 Major Hazard Installation

This investigation concluded that under the current design conditions the proposed biogas plant at the FWF WWTW facility in Port Elizabeth would not be considered as a Major Hazard Installation. However, this does not imply that the other parts of the FWF WWTW are not Major Hazardous Installation

This study is not intended to replace the Major Hazard Installation risk assessment which should be completed prior to construction of the project.
6 RECOMMENDATIONS

As a result of the risk assessment study conducted for the proposed FWF WWTW facility in Port Elizabeth a number of events were found to have risks beyond the site boundary. These risks could be mitigated to acceptable levels, as shown in the report.

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:

1. Compliance with all statutory requirements, i.e. pressure vessel designs;
2. Compliance with applicable SANS codes, i.e. SANS 10087, SANS 10089, SANS 10108, etc;
3. Incorporation of applicable guidelines or equivalent international recognised codes of good design and practice into the designs;
4. 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;
5. Full 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;
6. 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;
7. Demonstration by FWF WWTW or their contractor that the final designs would reduce the risks posed by the installation to internationally acceptable guidelines;
8. 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;
9. 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);
10. Permission not being granted for increases to the product list or product inventories without redoing part of or the full EIAMA;
11. Final acceptance of the facility risks with an MHI risk assessment that must be completed in accordance to the MHI regulations and that the risk assessment cover the entire facility:
   - Basing such a risk assessment on the final design and including engineering mitigation.
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1 INTRODUCTION

The Nelson Mandela Bay Metropolitan Municipality (NMBMM) proposes to upgrading and modernise their Fishwater Flats (FWF) Wastewater Treatment Works (WWTW) (hereinafter referred to as FWF WWTW), in Port Elizabeth, with the construction of a biogas facility that would beneficiate the sludge to produce methane. Methane would then be used to cogenerate of heat and electricity.

Since off-site incidents may result due to the hazards of some of the material to be stored on or transported onto site, RISCOM (PTY) LTD was commissioned to conduct a risk assessment to quantify the extent of the impacts on and risks to the surrounding communities.

1.1 Legislation

Risk assessments are conducted when required 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 subsections that follow.

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

The National Environmental Management Act (No. 107 of 1998; NEMA) contains the principal South African environmental legislation. Its primary objective is to make provision for cooperative governance by establishing principles for decision making on matters related to the environment, on the formation of institutions that will promote cooperative governance and on establishing procedures for coordinating environmental functions exercised by organs of state as well as to provide for matters connected therewith.

Section 30 of the NEMA 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 Major Hazard Installation (MHI) as defined in the Occupational Health and Safety Act (OHS Act) 85 of 1993 and its MHI regulations.

Section 28 of the NEMA makes provision for anyone who causes pollution or degradation of the environment to be made responsible for the prevention of the occurrence, continuation or reoccurrence of related impacts and for the costs of repair to 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; OHS Act)

The Occupational Health and Safety Act (No. 85 of 1993; OHS Act) is primarily intended for the health and safety of the workers, whereas its 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 (MHI) regulations

The Major Hazard Installation (MHI) regulations (2001) published under Section 43 of the Occupational Health and Safety Act (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 workers and the public to conduct a risk assessment in accordance with the legislation. In accordance with legislation, the risk assessment must be done by an approved inspection authority (AIA), which is registered with the Department of Labour and accredited by the South African Accreditation System (SANAS), **prior to construction of the facility**.

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 workers 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 workers 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 workers and the public.

Notification of the MHI classification 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, essentially consists of six parts, namely:

1. The duties for notification of a Major Hazard Installation (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.

### 1.1.2.2 Pressure Equipment Regulations

These regulations apply to the design, manufacture, operation, repair, modification, maintenance, inspection and testing of pressure equipment, with a design pressure equal to or greater than 50 kPa, with a view to health and safety.
1.1.3 National Building Regulations and Building Standards Act (No. 103 of 1977)

National Building Regulations and Building Standards Act (No. 103 of 1977) governs how buildings should be constructed. The legislation became enforceable as law in September 1985 and two years later was published by the South African Bureau of Standards (SABS) as part of the original Code of Practice for the Application of the National Building Regulations (SABS 0400-1987).

1.2 Study objectives

The risk assessment was completed for the purposes of an environmental impact assessment (EIA), conducted by EOH Coastal & Environmental Services. For the purposes of the EIA, this risk assessment has the main objective to determine any fatal flaws that would prevent the project from proceeding. This differs from a Major Hazard Installation (MHI) risk assessment, which will determine if the project could be constructed and operate with risks to employees and the public at an acceptable level.

The risk assessment should have a statement from a professional person covering the following questions:

1. Whether the proposed project would likely be considered an MHI;
2. If it is likely to be considered an MHI, whether it would meet the requirements of the MHI regulations and whether the risks could be engineered or managed to meet acceptable risks;
4. Whether there are any factors that will prevent the project from proceeding to the next phase of construction or whether the project could continue under certain conditions or mitigations;
5. Whether there are any special requirements that local authorities need to know when evaluating the proposal.

1.3 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 upgrade of the FWF WWTW facility in Port Elizabeth. This risk assessment is limited to the proposed biogas facility only.

This risk assessment was conducted with the following terms of reference:

- The development of accidental spill and fire scenarios for the storage facility;
- Using generic failure rate data (tanks, pumps, valves, flanges, pipework, gantry, couplings, etc.), the determination of the probability of each accident scenario;
- For each incident developed in Step 2, the determination of the consequences (thermal radiation, domino effect, toxic cloud formation, etc.);
- The calculation of maximum individual risk (MIR) values taking into account all accidents, meteorological conditions and lethality.

This risk assessment is for the use of the EIA and is not intended to replace a Major Hazard Installation risk assessment. Furthermore, the assessment covers only acute events and sudden ruptures and not chronic and on-going releases, such as fugitive emissions. It is not
intended to be an environmental risk assessment and may not meet specific the requirements of environmental legislation.

1.4 Assumptions and Limitations

The risk assessment was based on the conceptual designs of the project as presented in the Technical Report. EIA's are intended to suggest mitigation which may alter the design and layout of the project. It is thus understood that detail designs would be required post EIA and Record of Decision to complete the project for construction.

RISCOM used the information provided and made engineering assumptions as described in the document. The accuracy of the document would be limited to the available documents presented at the EIA.

The risk assessment excludes the following:

- Other processes and equipment outside of the biogas project;
- Natural events such as earthquakes and floods;
- Ecological risk assessment;
- An emergency plan.

1.5 Purpose and Main Activities

The main activity at the proposed bioplant at FWF WWTW facility in Port Elizabeth is the cogeneration of heat and electricity via the combustion of gases produced from the beneficiation of sludge.

1.6 Main Hazards Due to Substance and Process

The main hazards that would occur with a loss of containment of hazardous components at the proposed FWF WWTW biogas facility in Port Elizabeth include exposure to:

- Asphyxiating vapours;
- Thermal radiation from fires;
- Overpressure from explosions.

1.7 Software

Physical consequences were calculated with DNV's PHAST v. 6.7 and the data derived was entered into TNO's RISKCURVES v. 9.0.26. All calculations were performed by Mr M P Oberholzer.
2 ENVIRONMENT

2.1 General Background

The proposed biogas plant, as shown in Figure 2-1, would be located a 0.97 ha fenced area within the footprint of the existing FWF WWTW. The FWF WWTW is located on John Tallant Road adjacent to Deal Party and is accessible indirectly from the N2. The works is located next to the Swartkops River Estuary.

The land use surrounding the FWF WWTW facility:

- To the north is undeveloped;
- To the east is the N2 and the ocean;
- To the south is John Tallant Road and industrial;
- To the west is undeveloped.

![Figure 2-1: Location of the proposed FWF WWTW facility in Port Elizabeth (courtesy EOH)](image)
2.2 Meteorology

Meteorological mechanisms govern 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 and the depth of the atmosphere from the surface (known as the mixing layer) define the vertical component. The horizontal dispersion of hazardous vapours in the atmospheric 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 stretching of the plume, and 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 layer depth and to shifts in the wind field.

For this report, the meteorological conditions at Port Elizabeth Airport, as measured by the South African Weather Service, were used as the basis of wind speed and direction, temperature, precipitation and atmospheric humidity and stability.

2.2.1 Surface Winds

Hourly averages of wind speed and direction recorded at Port Elizabeth Airport were obtained from the South African Weather Service for the period from 2004 to 2011.

The wind roses in Figure 2-2 depict seasonal variances of measured wind speeds. In summer months, wind blows predominantly from the southwestern and northeastern quadrants for a range of wind speeds exceeding 10.7 m/s. During the winter months, the wind is predominantly from the western and southwestern quadrants with wind speeds exceeding 10.7 m/s. Calm conditions vary from 3.6–5.8% from summer to winter.

Figure 2-2: Seasonal wind speed as a function of wind direction at Port Elizabeth Airport for the period from 2004 to 2011
2.2.2 Precipitation and Relative Humidity

The long-term rainfall and relative humidity recorded at Port Elizabeth Airport was obtained from the South African Weather Service for the period from 1961 to 1991, as given in Table 2-1.

In Port Elizabeth Airport there is an average annual rainfall of 624 mm with no significant dry or wet season.

The relative humidity typically ranges from 44% (comfortable) to 95% (very humid) over the course of the year, rarely dropping below 20% (dry) and reaching as high as 100% (very humid).

Table 2-1: Long-term rainfall and relative humidity at Port Elizabeth Airport

<table>
<thead>
<tr>
<th>Month</th>
<th>Relative Humidity (%)</th>
<th>Precipitation</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Average Monthly (mm)</td>
<td>Average No. of Days with Less than 1 mm</td>
<td>Highest 24 hour Rainfall (mm)</td>
<td>Year</td>
</tr>
<tr>
<td>January</td>
<td>79</td>
<td>36</td>
<td>9</td>
<td>68</td>
<td>73</td>
</tr>
<tr>
<td>February</td>
<td>81</td>
<td>40</td>
<td>9</td>
<td>121</td>
<td>624</td>
</tr>
<tr>
<td>March</td>
<td>82</td>
<td>54</td>
<td>10</td>
<td>224</td>
<td>112</td>
</tr>
<tr>
<td>April</td>
<td>80</td>
<td>58</td>
<td>9</td>
<td>105</td>
<td>429</td>
</tr>
<tr>
<td>May</td>
<td>78</td>
<td>59</td>
<td>9</td>
<td>76</td>
<td>46</td>
</tr>
<tr>
<td>June</td>
<td>77</td>
<td>62</td>
<td>8</td>
<td>60</td>
<td>46</td>
</tr>
<tr>
<td>July</td>
<td>75</td>
<td>47</td>
<td>8</td>
<td>99</td>
<td>46</td>
</tr>
<tr>
<td>August</td>
<td>78</td>
<td>64</td>
<td>10</td>
<td>77</td>
<td>52</td>
</tr>
<tr>
<td>September</td>
<td>80</td>
<td>62</td>
<td>9</td>
<td>429</td>
<td>52</td>
</tr>
<tr>
<td>October</td>
<td>81</td>
<td>59</td>
<td>11</td>
<td>46</td>
<td>52</td>
</tr>
<tr>
<td>November</td>
<td>79</td>
<td>49</td>
<td>11</td>
<td>52</td>
<td>52</td>
</tr>
<tr>
<td>December</td>
<td>78</td>
<td>34</td>
<td>9</td>
<td>95</td>
<td>46</td>
</tr>
<tr>
<td>Year</td>
<td>73</td>
<td>624</td>
<td>112</td>
<td>429</td>
<td></td>
</tr>
</tbody>
</table>
2.2.3 Temperature

The long-term temperatures recorded at Port Elizabeth Airport were obtained from the South African Weather Service for the period from 1960 to 1991, as given in Table 2-2.

The surrounding region has a temperate climate with the average daily maximum between 16°C and 26°C. Temperatures rarely extend below freezing, with the mean average of the daily temperature above 4°C.

Table 2-2: Long-term temperatures measured at Port Elizabeth Airport

<table>
<thead>
<tr>
<th>Month</th>
<th>Temperature (°C)</th>
<th>Average Daily Maximum</th>
<th>Average Daily Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Highest Recorded</td>
<td></td>
<td></td>
</tr>
<tr>
<td>January</td>
<td>35</td>
<td>26</td>
<td>15</td>
</tr>
<tr>
<td>February</td>
<td>34</td>
<td>25</td>
<td>14</td>
</tr>
<tr>
<td>March</td>
<td>32</td>
<td>24</td>
<td>13</td>
</tr>
<tr>
<td>April</td>
<td>29</td>
<td>21</td>
<td>10</td>
</tr>
<tr>
<td>May</td>
<td>26</td>
<td>19</td>
<td>7</td>
</tr>
<tr>
<td>June</td>
<td>23</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>July</td>
<td>24</td>
<td>17</td>
<td>4</td>
</tr>
<tr>
<td>August</td>
<td>26</td>
<td>19</td>
<td>6</td>
</tr>
<tr>
<td>September</td>
<td>31</td>
<td>23</td>
<td>9</td>
</tr>
<tr>
<td>October</td>
<td>32</td>
<td>24</td>
<td>11</td>
</tr>
<tr>
<td>November</td>
<td>33</td>
<td>24</td>
<td>13</td>
</tr>
<tr>
<td>December</td>
<td>32</td>
<td>25</td>
<td>14</td>
</tr>
<tr>
<td>Year</td>
<td>35</td>
<td>22</td>
<td>10</td>
</tr>
</tbody>
</table>
2.2.4 Atmospheric Stability

Atmospheric stability is frequently categorised into one of six stability classes. These are briefly described in Table 2-3. Atmospheric stability, in combination with wind speed, is important in determining the extent of a particular hazardous vapour 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 at high wind speeds.

Table 2-3: Classification scheme for atmospheric stability

<table>
<thead>
<tr>
<th>Stability Class</th>
<th>Stability Classification</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Very unstable</td>
<td>Calm wind, clear skies, hot conditions during the day</td>
</tr>
<tr>
<td>B</td>
<td>Moderately unstable</td>
<td>Clear skies during the day</td>
</tr>
<tr>
<td>C</td>
<td>Unstable</td>
<td>Moderate wind, slightly overcast conditions during the day</td>
</tr>
<tr>
<td>D</td>
<td>Neutral</td>
<td>Strong winds or cloudy days and nights</td>
</tr>
<tr>
<td>E</td>
<td>Stable</td>
<td>Moderate wind, slightly overcast conditions at night</td>
</tr>
<tr>
<td>F</td>
<td>Very stable</td>
<td>Low winds, clear skies, cold conditions at night</td>
</tr>
</tbody>
</table>

The atmospheric stability for Port Elizabeth Airport, as a function of the wind class, was calculated from hourly weather values supplied by the South African Weather Service from the 1st of January 2004 to the 31st of December 2011, as given in Figure 2-3.

Figure 2-3: Atmospheric stability as a function of wind direction
Calculations for this risk assessment are based on six representative weather classes covering stability conditions of stable, neutral and unstable as well as low and high wind speeds. In terms of Pasquill classes, representative conditions are given in Table 2-4.

Table 2-4: Representative weather classes

<table>
<thead>
<tr>
<th>Stability Class</th>
<th>Wind (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>3</td>
</tr>
<tr>
<td>D</td>
<td>1.5</td>
</tr>
<tr>
<td>D</td>
<td>5</td>
</tr>
<tr>
<td>D</td>
<td>9</td>
</tr>
<tr>
<td>E</td>
<td>5</td>
</tr>
<tr>
<td>F</td>
<td>1.5</td>
</tr>
</tbody>
</table>

As wind velocities are vector quantities (having speed and direction) and blow preferentially in certain directions, it is mathematically incorrect to give an average wind speed over 360° of wind direction; the result would be incorrect risk calculations.

It would also be incorrect to base risk calculations on one wind category, such as 1.5/F for example. In order to obtain representative risk calculations, hourly weather data for wind speed and direction was analysed over a five year period and categorised into the six wind classes for day and night conditions and 16 wind directions. The risk was then determined using contributions from each wind class in various wind directions.

The allocation of observations into the six weather classes is summarised in Table 2-5 with the representative weather classes given in Figure 2-4.

Table 2-5: Allocation of observations into six weather classes

<table>
<thead>
<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>
</thead>
<tbody>
<tr>
<td>&lt; 2.5 m/s</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>D 1.5 m/s</td>
<td>F 1.5 m/s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5 - 6 m/s</td>
<td>B 3 m/s</td>
<td></td>
<td></td>
<td>D 5 m/s</td>
<td></td>
<td>E 5 m/s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 6 m/s</td>
<td></td>
<td></td>
<td></td>
<td>D 9 m/s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2.2.5 Default Meteorological Values

Default meteorological values used in simulations, based on local conditions, are given in Table 2-6.

Table 2-6: Default meteorological values used in simulations, based on local conditions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Default Value (Day)</th>
<th>Default Value (Night)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient temperature (°C)</td>
<td>22</td>
<td>10</td>
</tr>
<tr>
<td>Substrate or bund temperature (°C)</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Water temperature (°C)</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Air pressure (bar)</td>
<td>1.013</td>
<td>1.013</td>
</tr>
<tr>
<td>Humidity (%)</td>
<td>63</td>
<td>95</td>
</tr>
<tr>
<td>Fraction of a 24 hour period</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Mixing height</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

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 Weather Category D9; 230 m for Weather Category E5; and, 50 m for Weather Category F1.5.
3 PROCESS DESCRIPTION

3.1 Site

The Biogas Plant will be contained in its own fenced-off area within the boundaries of the FWF WWTW, which is located on Erf 419, Swartkops in Ward 60 along John Tallant Road, Port Elizabeth. The Biogas Plant will be designed and constructed independently of the FWF WWTW, as shown in Figure 3-1.

![Figure 3-1: Site layout](image)

3.2 Process Description

A simplified flow diagram of the process is shown in Figure 3-2.

Sludge from the belt filters at 15-25°C would be heated to approximately 35°C and fed continuously into the digesters.

The anaerobic digestion plant is designed according to the principle of the single stage, mesophilic digestion (25-40°C) using a 6.5 % sludge concentration continually fed to the digesters. Based on a retention time of 15 days, the sludge would be reduced by approximately 45% producing biogas consisting of approximately 60% methane and 40% carbon dioxide plus small quantities of hydrogen, nitrogen, hydrogen sulphide and water.

The digesters would consist of 2 x 8548 m³ vertical, agitated tanks, with a possible additional digester in phase II.

The average biogas produced for phase I would be 998 Nm³/h increasing to 1409 Nm³/h in phase II.

The gas from the digesters would be stored in gas holders. The volume of the gas holder is would be 5360 m³. Excess gas that cannot be used will be burnt via a gas flare.

Gas holder and gas flare will be implemented according to the biogas production of phase II.
3.2.1 Assumptions Used in this Study

Due to limited design information supplied in the design basis, the following assumptions would be made:

1. The digesters would operate slightly above atmospheric pressure, but below the classification of a pressure vessel.
2. The gas holder would consist of an expanding gas holder. An empty gas holder would have the top section resting within the water sealing fluid. As gas enters the holder, the top section would rise to the limit of the gas holder. A water seal of 0.5 m would prevent gas escaping from the gas holder.
3. The flare height would be set at 10 m.
4. No pilot light would be used on the flare and thus excludes fuels to maintain a pilot light.
5. The biogas composition would be 60 vol % methane and the remainder gas being carbon monoxide.
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 on site is given in Table 3-1.

Table 3-1: Summary of hazardous components to be stored on site

<table>
<thead>
<tr>
<th>Item</th>
<th>Component.</th>
<th>Inventory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas holder</td>
<td>Biogas (methane and carbon dioxide)</td>
<td>5360 m³</td>
</tr>
</tbody>
</table>
4 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;
- The type and design of containers, vessels or pipelines;
- The quantity of material that could be involved in an airborne release;
- The 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 in storage 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.

4.1 Notifiable Substances

The General Machinery Regulation\(^1\), section 8 and its Schedule A on notifiable substances requires any employer who has a substance equal to or exceeding the quantity as listed in the regulation to notify the divisional director. A site is classified as a Major Hazard Installation if it contains one or more notifiable substances or if the off-site risk is sufficiently high. The latter can only be determined from a quantitative risk assessment.

Methane generated during the process would not be compressed and would not be classified as a notifiable substance. No other materials generated or stored on site would be classified as a notifiable substance.

---

\(^1\) The General Machinery Regulation GMR is a regulation under the Occupational Health and Safety Act 85 of 1993
4.2 Substance Hazards

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

4.2.1 Chemical Properties

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

4.2.1.1 Methane

Methane is a colourless gas in atmospheric conditions with a characteristic mild sweet odour.

Methane is a fire and explosion hazard when it is exposed to heat and flame. The lower explosive limit (LEL) of methane is 5% v/v (5% gas to 95% air measured by volume) and the upper explosive limit (UEL) is 15% v/v.

It is not considered toxic but may displace oxygen in high concentrations acting as an asphyxiant. Chronic and long-term effects are not severe and are not listed.

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

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

Carbon dioxide is a colourless, odourless and non-flammable gas. As it is denser than air, it could accumulate in confined areas and low points displacing oxygen and possibly resulting in asphyxiation hazards. Typical oxygen deficiencies effects are given in Table 4-1.

<table>
<thead>
<tr>
<th>Oxygen Content of Air</th>
<th>Signs and Symptoms of Persons at Rest</th>
</tr>
</thead>
<tbody>
<tr>
<td>15%–19.5%</td>
<td>Decreased ability to work strenuously. May impair coordination and may induce symptoms in persons with coronary, pulmonary or circulatory problems.</td>
</tr>
<tr>
<td>12%–15%</td>
<td>Respiration deepens, increased pulse rate and impaired coordination, perception and judgment.</td>
</tr>
<tr>
<td>10%–12%</td>
<td>Further increase in rate and depth of respiration, further increase in pulse rate, performance failure, giddiness, poor judgment and blue lips.</td>
</tr>
<tr>
<td>8%–10%</td>
<td>Mental failure, nausea, vomiting, fainting, unconsciousness, ashen face and blue lips.</td>
</tr>
<tr>
<td>6%–8%</td>
<td>Eight minutes may be fatal in 50-100% of exposures; six minutes may be fatal in 25-50% of exposures; and, after four to five minutes there may be recovery with treatment.</td>
</tr>
<tr>
<td>4%–6%</td>
<td>Coma in 40 seconds; convulsions, respiration ceases and death.</td>
</tr>
</tbody>
</table>

It is normally stored as a liquid at low temperatures and elevated pressures. Exposure to liquid carbon dioxide can cause frostbite.

It can only be absorbed into the body by inhalation, with resultant asphyxiation risks.

4.2.1.3 Corrosive Liquids

Corrosive liquids considered under this subsection are those components that have a low or high pH and that may cause burns if they come into contact with people or may attack and cause failure of equipment.

The materials generated and reacted would not be in high enough concentrations to be considered highly corrosive.

4.2.2 Reactive Components

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

All components to be stored on or delivered to site are considered thermally stable in atmospheric conditions. The reaction with air is covered under the subsection dealing with ignition probabilities.
4.2.3 Flammable and Combustible Components

Flammable and combustible components are those that can ignite and give a number of possible 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.

Methane and hydrogen sulphide are considered highly flammable with fire and explosion hazards. The flammable components are listed in Table 4-2.

Table 4-2: Flammable and combustible components to be stored on or delivered to site

<table>
<thead>
<tr>
<th>Compound</th>
<th>Flashpoint (°C)</th>
<th>Boiling Point (°C)</th>
<th>LFL (vol. %)</th>
<th>UFL (vol. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>-103.7</td>
<td>-42</td>
<td>5</td>
<td>15</td>
</tr>
</tbody>
</table>

4.2.4 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.

Carbon dioxide is not considered toxic but will act as an asphyxiant by replacing oxygen.

The emergency response planning guideline (ERPG) values are given in Table 4-3.

Table 4-3: Guideline levels for toxic and asphyxiant components

<table>
<thead>
<tr>
<th>Compound</th>
<th>ERPG-1</th>
<th>ERPG-2</th>
<th>ERPG-3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mg/m³</td>
<td>ppm</td>
<td>mg/m³</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>54 000</td>
<td>30 000</td>
<td>54 000</td>
</tr>
</tbody>
</table>

4.2.5 Physical Properties

The physical properties used in the simulations were based on the DIPPR¹ data base.

4.2.6 Substances not Considered in this Study

Substances not considered in this study include:
- Workshop gases;
- Hydrogen sulphide due to the very small quantities produced and excluded from the vendor’s mass balance

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¹ Design Institute for Physical Properties
5 PHYSICAL AND CONSEQUENCE MODELLING

In order to establish the impacts following an accident, it is necessary first to estimate: the physical process of the spill (i.e. rate and size); the spreading of the spill; the evaporation from the spill; the 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. This merely illustrates the significance and the extent of the impact in the event of a release. The consequences would be due to toxic and asphyxiant vapours, thermal radiation or explosion overpressures. The consequences may be described in various formats. The simplest methodology follows a comparison of predicted concentrations (or thermal radiation or overpressures) to short-term 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 the 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. risk level) is in turn estimated from this probit (risk characterisation).

The 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 subsections.

5.1 Multiple Consequence Scenarios

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.

5.1.1 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 5-1. 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.
5.2 Toxic Vapour Clouds

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

A toxic vapour cloud can occur when:

- A toxic gas is released under pressure;
- A toxic liquid spills and evaporates;
- Material combusts forming toxic gases;
- Products react forming toxic gases.

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

The 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, nonlethal injury or irritation for humans and in damage to property. The characterisation of such impacts will be based on the calculation of downwind distances to various acute exposure guidelines.

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

The approach that may be adopted involves the 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; and, the emergency response planning guideline (ERPG).

The approach that may be adopted involves the comparison of predicted concentrations to exposure guidelines. These guidelines include occupational exposure limits, such as the threshold limit values (TLVs), the immediately dangerous to life or health (IDLH) values and, the emergency response planning guideline (ERPGs). In the event that ERPG values are not yet available, temporary emergency exposure limits (TEELs) could be used. ERPG values were developed to represent 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.

This study refers to the ERPG values for emergency response plans and LC₁ (1% fatality based on inhaled dosages derived from probit values) for determining off-site impacts.
5.2.1 Carbon Dioxide

Carbon dioxide is produced as part of the process and occupies approximately 40% of the biogas production by volume. The digesters have little head room and thus the major inventory of carbon dioxide would be stored in the gas holder.

The downwind distances to the emergency response planning guideline limits ERPG-1, ERPG-2 and ERPG-3, respectively, for release scenarios in various weather conditions are given in Table 5-1. ERPG-3 is the maximum air concentration below which it is believed that nearly all individuals could be exposed without experiencing or developing life-threatening health effects. The ERPG-2 concentration is the maximum air concentration below which it is believed nearly all individuals could be exposed without experiencing or developing irreversible or serious health effects or symptoms that could impair an individual’s ability to take protective action. The ERPG-2 is used for emergency planning to indicate the furthest downwind distance to evacuation of nearby populations in the event of a release. As can be seen these endpoints would vary considerably with atmospheric release condition.

Figure 5-2 illustrates the ERPG-2 endpoint distances for a catastrophic failure of the gas holder as well as a loss of containment of the entire gas holder in 10 minutes, at a high wind speed, to illustrate the maximum release under worst case conditions.

The thin lines indicate the shape of the plume from a northerly wind direction, while the thicker lines indicate the extent of the plume from all directions. The northerly wind direction used does not indicate the predominant wind but is used as illustrative purposes only.

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**Figure 5-2:** The extent of impact of air concentrations of carbon dioxide following a large release, using the ERPG-2 value (30 000 ppm)
Table 5-1: Endpoint distances to the ERPG values for carbon dioxide releases

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Incident</th>
<th>Distance to Endpoints (m)</th>
<th>ERPG&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Category 3/B</th>
<th>Category 1.5/D</th>
<th>Category 5/D</th>
<th>Category 9/D</th>
<th>Category 5/E</th>
<th>Category 1.5/F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas holder</td>
<td>Catastrophic failure</td>
<td></td>
<td>ERPG-1</td>
<td>31</td>
<td>23</td>
<td>52</td>
<td>95</td>
<td>43</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ERPG-2</td>
<td>31</td>
<td>23</td>
<td>52</td>
<td>95</td>
<td>43</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ERPG-3</td>
<td>27</td>
<td>22</td>
<td>45</td>
<td>80</td>
<td>38</td>
<td>23</td>
</tr>
<tr>
<td>Gas holder</td>
<td>Release contents in 10 minutes</td>
<td></td>
<td>ERPG-1</td>
<td>17</td>
<td>19</td>
<td>16</td>
<td>14</td>
<td>16</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ERPG-2</td>
<td>17</td>
<td>19</td>
<td>16</td>
<td>14</td>
<td>16</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ERPG-3</td>
<td>11</td>
<td>13</td>
<td>11</td>
<td>9</td>
<td>11</td>
<td>13</td>
</tr>
</tbody>
</table>

1  ERPG-1 = 30 000 ppm  
    ERPG-2 = 30 000 ppm  
    ERPG-3 = 40 000 ppm
Figure 5-3 shows the scenarios with the largest distances to the 1% fatality. The thin line indicates the cloud plume from a northerly wind direction, while the thicker line represents the extent of the plume from all wind directions.

The 1% fatality would not extend beyond the site boundary, and thus no further analysis would be required for carbon dioxide effects.

**LEGEND**

<table>
<thead>
<tr>
<th>SCENARIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue: Gas holder: Catastrophic failure</td>
</tr>
<tr>
<td>Green: Gas holder Release in 10 minutes</td>
</tr>
</tbody>
</table>

**Figure 5-3:** Maximum extent of the 1% fatality for major releases
5.3 **Fires**

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

5.3.1 **Thermal Radiation**

The effect of thermal radiation is very dependent on the type of fire and duration exposed to the thermal radiation. Certain codes, such as the American Petroleum Institute API 520 and API 2000 standards, suggest the maximum heat absorbed by vessels for adequate relief designs to prevent the vessel from failure due to overpressure. Other codes, such as API 510 and BS 5980, give guidelines for the maximum thermal-radiation intensity that act as a guide to equipment layout, as given in Table 5-2.

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

**Table 5-2: Thermal radiation guidelines (BS 5980 1990)**

<table>
<thead>
<tr>
<th>Thermal Radiation Intensity (kW/m²)</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>Will cause no discomfort for long exposure</td>
</tr>
<tr>
<td>2.1</td>
<td>Sufficient to cause pain if unable to reach cover within 40 seconds</td>
</tr>
<tr>
<td>4.5</td>
<td>Sufficient to cause pain if unable to reach cover within 20 seconds</td>
</tr>
<tr>
<td>12.5</td>
<td>Minimum energy required for piloted ignition of wood and melting of plastic tubing</td>
</tr>
<tr>
<td>25</td>
<td>Minimum energy required to ignite wood at indefinitely long exposures</td>
</tr>
<tr>
<td>37.5</td>
<td>Sufficient to cause serious damage to process equipment</td>
</tr>
</tbody>
</table>
Thermal radiation guideline levels for continuous and emergency flaring have been given in the API 521 (2007) standards and are listed in Table 5-3, and the maximum thermal radiation should be evaluated against the guidelines in the table. It should be noted that the maximum thermal radiation would depend on the wind speed, flare design and exit velocity.

### Table 5-3: Recommended design (thermal radiation) for personnel (API 521-2007)

<table>
<thead>
<tr>
<th>Permissible Design Level (kW/m²; Btu/h·ft²)</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.46 (3000)</td>
<td>Maximum radiant heat intensity at any location where urgent emergency action by personnel is required. When personnel enter or work in an area with the potential for radiant heat intensity greater than 6.31 kW/m² (2000 Btu/h·ft²), then radiation shielding or special protective apparel (e.g. a fire approach suit) should be considered. <strong>SAFETY PRECAUTION:</strong> it is important to recognise that personnel with appropriate clothing¹ cannot tolerate thermal radiation at 6.31 kW/m² (2000 Btu/h·ft²) for more than a few seconds.</td>
</tr>
<tr>
<td>6.31 (2000)</td>
<td>Maximum radiant heat intensity in areas where emergency actions lasting up to 30 s can be required of personnel without shielding but with appropriate clothing¹.</td>
</tr>
<tr>
<td>4.73 (1500)</td>
<td>Maximum radiant heat intensity in areas where emergency actions lasting 2–3 min can be required of personnel without shielding but with appropriate clothing¹.</td>
</tr>
<tr>
<td>1.58 (500)</td>
<td>Maximum radiant heat intensity at any location where personnel with appropriate clothing¹ can be continuously exposed.</td>
</tr>
</tbody>
</table>

For pool fires and jet fires CPR 18E suggests the following thermal radiation levels be reported:

- 4 kW/m², the level that glass can withstand, preventing the fire entering a building, and that should be used for emergency planning;
- 10 kW/m², 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/m², 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.

¹ Appropriate clothing consists of a hard hat, long-sleeved shirts with cuffs buttoned, work gloves, long-legged pants and work shoes to minimise direct skin exposure to thermal radiation.
5.3.2 Bund and Pool Fires

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

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

No pool fires were predicted from the simulations.
5.3.3 Jet Fires

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

The thermal radiation from a jet fire resulting from a loss of containment and subsequent ignition from a loss of containment from the gas holder is shown in Figure 5-4. The thin lines indicate a jet fire from a single orientation, while the thicker lines are jet fires from all directions.

The 4 kW/m² is the radiation that would cause pain and second degree burns within 20 seconds. This value is used for emergency planning from fires. The 10 kW/m² thermal radiation, representing the 1% fatality, and would not extend beyond the site boundary. The 35 kW/m² thermal radiation, indicating a 100% fatality and initial damage to steel and could damage equipment in the immediate vicinity.

---

**Figure 5-4:** Thermal radiation isopleths from large jet at the gas holder

<table>
<thead>
<tr>
<th>LEGEND</th>
<th>THERMAL RADIATION (kW/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>35</td>
</tr>
</tbody>
</table>

---
Emergency flaring conditions would release 2114 Nm$^3$/h at 35°C. The flame length under emergency conditions could extend to a maximum length of 15.6 m in still air. Figure 5-5 shows the ground level thermal radiation at varying wind speeds. In all wind conditions, the thermal radiation level of 4 kW/m$^2$ at 1.0 m aboveground would never be exceeded.

As no off-site fatalities would be expected from jet fires, no further analysis would be required.

![Figure 5-5: Thermal radiation as a function of wind speed from emergency flaring](image)

5.3.4 Flash Fires

A loss of containment of flammable materials would mix with air and form a flammable mixture. The cloud of flammable material 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 released material, physical properties of the released gas, 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, with injuries 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.

Methane at 35°C is extremely buoyant and in the event of a release from an unignited flare, the flammable cloud would be formed above the release point and thus no danger to people on the ground.
The flammable limits for flash fires due to various release scenarios are given in Table 5-4. As can be seen the largest distance to the flammable limits would be the catastrophic failure of the gas holder under high wind conditions as shown in Figure 5-6.

In worst case weather conditions, the LFL for large flash fires would not extend beyond the site boundary, but the ½ LFL (evacuation distance) could reach the N2

<table>
<thead>
<tr>
<th>LEGEND</th>
<th>SCENARIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>LFL</td>
<td>Gas holder: Catastrophic failure</td>
</tr>
<tr>
<td>½ LFL</td>
<td>Gas holder: Catastrophic failure</td>
</tr>
<tr>
<td>LFL</td>
<td>Gas holder: Release in 10 min</td>
</tr>
<tr>
<td>½ LFL</td>
<td>Gas holder: Release in 10 min</td>
</tr>
</tbody>
</table>

Figure 5-6: Flash fire limits due to a release of biogas
Table 5-4: Flammable limits for flash-fire scenarios involving biogas releases

<table>
<thead>
<tr>
<th>Equip.</th>
<th>Scenario</th>
<th>Flammability</th>
<th>Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Category 3/B</td>
</tr>
<tr>
<td>Gas holder</td>
<td>Catastrophic failure</td>
<td>LFL</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>½ LFL</td>
<td>43</td>
</tr>
<tr>
<td>Gas holder</td>
<td>Release contents in 10 minutes</td>
<td>LFL</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>½ LFL</td>
<td>17</td>
</tr>
</tbody>
</table>
5.4 Explosions

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 5-5 and Table 5-6 give a more detailed summary of the damage produced by an explosion due to various overpressures.

CPR 18E (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 a probability of death equal to 1.0 for unprotected people in the open;
- 0.7 bar overpressure, corresponding to an almost entire destruction of buildings and 100% fatality for people in the open.
Table 5-5: Summary of consequences of blast overpressure (Clancey 1972)

<table>
<thead>
<tr>
<th>Pressure (Gauge)</th>
<th>Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Psi</td>
<td>kPa</td>
</tr>
<tr>
<td>0.02</td>
<td>0.138</td>
</tr>
<tr>
<td>0.03</td>
<td>0.207</td>
</tr>
<tr>
<td>0.04</td>
<td>0.276</td>
</tr>
<tr>
<td>0.1</td>
<td>0.69</td>
</tr>
<tr>
<td>0.15</td>
<td>1.035</td>
</tr>
<tr>
<td>0.3</td>
<td>2.07</td>
</tr>
<tr>
<td>0.4</td>
<td>2.76</td>
</tr>
<tr>
<td>0.5–1.0</td>
<td>3.45–6.9</td>
</tr>
<tr>
<td>0.7</td>
<td>4.83</td>
</tr>
<tr>
<td>1.0</td>
<td>6.9</td>
</tr>
<tr>
<td>1.0–2.0</td>
<td>6.9–13.8</td>
</tr>
<tr>
<td>1.3</td>
<td>8.97</td>
</tr>
<tr>
<td>2.0</td>
<td>13.8</td>
</tr>
<tr>
<td>2.0–3.0</td>
<td>13.8–20.7</td>
</tr>
<tr>
<td>2.3</td>
<td>15.87</td>
</tr>
<tr>
<td>2.5</td>
<td>17.25</td>
</tr>
<tr>
<td>3.0</td>
<td>20.7</td>
</tr>
<tr>
<td>3.0–4.0</td>
<td>20.7–27.6</td>
</tr>
<tr>
<td>4.0</td>
<td>27.6</td>
</tr>
<tr>
<td>5.0</td>
<td>34.5</td>
</tr>
<tr>
<td>5.0–7.0</td>
<td>34.5–48.3</td>
</tr>
<tr>
<td>7.0</td>
<td>48.3</td>
</tr>
<tr>
<td>7.0–8.0</td>
<td>48.3–55.2</td>
</tr>
<tr>
<td>9.0</td>
<td>62.1</td>
</tr>
<tr>
<td>10.0</td>
<td>69.0</td>
</tr>
<tr>
<td>300</td>
<td>2070</td>
</tr>
</tbody>
</table>
### Table 5-6: 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   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Reactor: cracking               |                   | I   | I   | T    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Pine supports                   |                   | P   | SO  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Utilities: gas meter            |                   | Q   |     |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Utilities: electric transformer |                   | H   | I   | T    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Electric motor                  |                   | H   | I   | I    | V    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Blower                          |                   | Q   |     |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Fractionation column            |                   | R   | T   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Pressure vessel horizontal      |                   | PI  |     |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Utilities: gas regulator        |                   | I   |     | MQ   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Extraction column               |                   | I   |     |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Steam turbine                   |                   | I   |     | M   | S   | V    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Heat exchanger                  |                   | I   | T   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Tank sphere                     |                   | I   |     | I   | T    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Pressure vessel vertical        |                   | I   |     | T    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Pump                            |                   | I   |     | Y    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
5.4.1 Vapour Cloud Explosions (VCEs)

A release of flammable material into the atmosphere could result in the formation of a flash fire, as described in the subsection on flash fires, or a vapour cloud explosion (VCE).

The concentration of the combustible 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 material contained in the vapour cloud between the higher explosive limits (HEL) and the lower explosive limit (LEL), if it ignites, could form a flash fire or a fireball. The sudden detonation of the explosive mass of material would cause overpressures that can result in injury or damage to property.

Figure 5-7 shows the isopleths representing the 0.1 bar blast overpressures from a release of flammable vapours due to various loss-of-containment scenarios under worst-case meteorological conditions. In this case the largest distance to overpressure endpoints would be from a catastrophic failure of the gas holder at a high wind, as represented in the figure.

In these scenarios, the vapours drifted to an ignition point before detonating. This is referred to as a ‘late explosion’. The thin lines indicate overpressures from a northerly wind direction, while the thicker lines indicated the effect area due to all wind directions.

No lethal effects are expected below 0.1 bar overpressure for people in the open. A summary of these overpressures with various scenarios is given in Table 5-7.

The lethal effects from vapour cloud explosions could extend beyond the site boundary reaching the N2, but would not extend into residential areas.

![Diagram showing 0.1 bar overpressures from vapour cloud explosions]

**Legend**

<table>
<thead>
<tr>
<th>SCENARIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Holder: Catastrophic failure</td>
</tr>
<tr>
<td>Gas holder: Release in 10 minutes</td>
</tr>
</tbody>
</table>

**Figure 5-7:** 0.1 bar overpressures from vapour cloud explosions
Table 5-7: Summary of blast overpressures from explosion scenarios for biogas releases

<table>
<thead>
<tr>
<th>Equip.</th>
<th>Scenario</th>
<th>Overpressure (bar)</th>
<th>Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Category 3/B</td>
<td>Category 1.5/D</td>
</tr>
<tr>
<td>Gas holder</td>
<td>Catastrophic failure</td>
<td>0.03</td>
<td>280</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.1</td>
<td>133</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.3</td>
<td>78</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.7</td>
<td>57</td>
</tr>
<tr>
<td>Gas holder</td>
<td>Release contents in 10 minutes</td>
<td>0.03</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.1</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.3</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.7</td>
<td>23</td>
</tr>
</tbody>
</table>
6 RISK ANALYSIS

6.1 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 (of petrol, chlorine, ammonia, etc.) that pose the same hazard wherever present.

Risk, on the other hand, is the probability that a hazard will actually cause damage 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 the 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), titled ‘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 6-1.

Table 6-1: The influence of public perception of risk on the acceptance of that risk, based on the POST report

<table>
<thead>
<tr>
<th>Control</th>
<th>People are more willing to accept risks they impose upon themselves or they consider to be ‘natural’ than to have risks imposed upon them</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dread and Scale of Impact</td>
<td>Fear is greatest where the consequences of a risk are likely to be catastrophic rather than spread over time</td>
</tr>
<tr>
<td>Familiarity</td>
<td>People appear more willing to accept risks that are familiar rather than new risks</td>
</tr>
<tr>
<td>Timing</td>
<td>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)</td>
</tr>
<tr>
<td>Social Amplification and Attenuation</td>
<td>Concern can be increased because of media coverage, graphic depiction of events or reduced by economic hardship</td>
</tr>
<tr>
<td>Trust</td>
<td>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</td>
</tr>
</tbody>
</table>
A risk assessment should be seen as an important component of ongoing preventative actions, aimed at minimising or hopefully avoiding accidents. Reassessments of risk should therefore follow at regular intervals and after any changes that could alter the nature of the hazard, so contributing to the overall prevention programme and emergency response plan of the plant. Risks should be ranked in 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.

6.2 Predicted Risk

The physical and consequence modelling (Section 5) addresses the impact of a release of hazardous materials without taking into account the probability of occurrence. This merely illustrates the significance and the extent of the impact in the event of a release. Section 5 also contains an analysis of the possibility of cascading or knock-on effects due to incidents in the facility and the surrounding industries and suburbs. In Section 6 the likelihood of various incidents is assessed, the consequences calculated and finally the risk for the facility is determined.
6.2.1 Generic Equipment Failure Scenarios

In order to characterise the various failure events and assign a failure frequency, fault trees were constructed starting with a final event and working from the top down to define all initiating events and frequencies. The analysis was completed using published failure rate data. Equipment failures can occur in tanks, pipelines and other items handling hazardous materials. These failures may result in:

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

6.2.1.1 Storage Tanks

Incidents involving storage tanks include catastrophic failure leading to product leakage into the bund and a possible bund fire. A tank-roof failure could result in a possible tank fire. A fracture of the tank nozzle or the transfer pipeline could also result in product leakage into the bund and a possible bund fire.

Typical failure frequencies for atmospheric tanks and pressure vessels are listed, respectively, in Table 6-2 and Table 6-3.

Table 6-2: Failure frequencies for atmospheric tanks

<table>
<thead>
<tr>
<th>Event</th>
<th>Leak Frequency (per item per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small leaks</td>
<td>1x10^{-4}</td>
</tr>
<tr>
<td>Severe leaks</td>
<td>3x10^{-5}</td>
</tr>
<tr>
<td>Catastrophic failure</td>
<td>5x10^{-6}</td>
</tr>
</tbody>
</table>

Table 6-3: Failure frequencies for pressure vessels

<table>
<thead>
<tr>
<th>Event</th>
<th>Failure Frequency (per item per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small leaks</td>
<td>1x10^{-5}</td>
</tr>
<tr>
<td>Severe leaks</td>
<td>5x10^{-7}</td>
</tr>
<tr>
<td>Catastrophic failure</td>
<td>5x10^{-7}</td>
</tr>
</tbody>
</table>

6.2.1.2 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 detected and corrected early. For significant failures, the leak duration may be from 10–30 minutes before detection.

The 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 and each pipe diameter. Furthermore, the failure frequency normally decreases with increasing pipe diameter. The scenarios and failure frequencies for a pipeline apply to pipelines with connections, such as flanges, welds and valves.
The failure data given in Table 6-4 represents the total failure rate, incorporating all failures of whatever size and due to all probable causes. These frequencies are based on an environment where no excessive vibration, corrosion, erosion or thermal cyclic stresses are expected. For potential risk causing significant leaks (e.g. corrosion) the failure rate will be increased by a factor of 10.

Table 6-4: Failure frequencies for process pipes

<table>
<thead>
<tr>
<th>Description</th>
<th>Frequencies of Loss of Containment for Process Pipes (per meter per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Full Bore Rupture</td>
</tr>
<tr>
<td>Nominal diameter &lt; 75 mm</td>
<td>1x10^-6</td>
</tr>
<tr>
<td>75 mm &lt; nominal diameter &lt; 150 mm</td>
<td>3x10^-7</td>
</tr>
<tr>
<td>Nominal diameter &gt; 150 mm</td>
<td>1x10^-7</td>
</tr>
</tbody>
</table>
6.2.1.3 Ignition Probability of Flammable Gases and Liquids

The estimation of the probability of an ignition is a key step in the 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 the effects of release type and location.

The probability of ignition for stationary installations is given in Table 6-5 (along with the classification of flammable substances in Table 6-6). These can be replaced with ignition probabilities related to the surrounding activities. For example, the probability of a fire from a flammable release at an open flame would increase to a value of 1.

Table 6-5: The probability of direct ignition for stationary installations (RIVM 2009)

<table>
<thead>
<tr>
<th>Substance Category</th>
<th>Source-Term Continuous</th>
<th>Source-Term Instantaneous</th>
<th>Probability of Direct Ignition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average to high reactivity</td>
<td>&lt; 10 kg/s 10 – 100 kg/s &gt; 100 kg/s</td>
<td>&lt; 1000 kg 1000 – 10 000 kg &gt; 10 000 kg</td>
<td>0.2 0.5 0.7</td>
</tr>
<tr>
<td>Category 0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low reactivity</td>
<td>&lt; 10 kg/s 10 – 100 kg/s &gt; 100 kg/s</td>
<td>&lt; 1000 kg 1000 – 10 000 kg &gt; 10 000 kg</td>
<td>0.02 0.04 0.09</td>
</tr>
<tr>
<td>Category 1</td>
<td>All flow rates</td>
<td>All quantities</td>
<td>0.065</td>
</tr>
<tr>
<td>Category 2</td>
<td>All flow rates</td>
<td>All quantities</td>
<td>0.0043</td>
</tr>
<tr>
<td>Category 3 Category 4</td>
<td>All flow rates</td>
<td>All quantities</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 6-6: Classification of flammable substances

<table>
<thead>
<tr>
<th>Substance Category</th>
<th>Description</th>
<th>Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 0</td>
<td>Extremely flammable</td>
<td>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</td>
</tr>
<tr>
<td>Category 1</td>
<td>Highly flammable</td>
<td>Liquids, substances and preparations that have a flashpoint of below 21°C</td>
</tr>
<tr>
<td>Category 2</td>
<td>Flammable</td>
<td>Liquids, substances and preparations that have a flashpoint equal to 21°C and less than 55°C</td>
</tr>
<tr>
<td>Category 3</td>
<td></td>
<td>Liquids, substances and preparations that have a flashpoint greater than 55°C and less than or equal to 100°C</td>
</tr>
<tr>
<td>Category 4</td>
<td></td>
<td>Liquids, substances and preparations that have a flashpoint greater than 100°C</td>
</tr>
</tbody>
</table>

---

1 This value is taken from the CPR 18E (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.
6.3 Risk Calculations

6.3.1 Maximum Individual Risk Parameter

Standard individual risk parameters include: average individual risk; weighted individual risk; maximum individual risk; and, the fatal accident rate. The latter parameter is more applicable to occupational exposures. Only the maximum individual risk (MIR) parameter will be used in this assessment. For this parameter the 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 the event multiplied by the likelihood of the event) is not dependent on knowledge of the population at risk. So, it is an easier parameter to use in the predictive mode than the average individual risk and weighted individual risk. The unit of measure is risk of fatality per person per year.

6.3.2 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 in a plant, who may be assumed to be healthy, the adopted exposure assessment applies to an average population group that also includes sensitive subpopulations. Sensitive subpopulation 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 precautions are necessary;
- If a risk falls between these two states that it has been reduced to levels as low as reasonably practicable (ALARP).
This is illustrated in Figure 6-1.

ALARP stands for ‘as low as reasonably practicable’. As used in the UK, it is the region between that which is intolerable, at $1 \times 10^{-4}$ per year, and that which is broadly acceptable, at $1 \times 10^{-6}$ per year. A further lower level of risk of $3 \times 10^{-7}$ per year is applied to either vulnerable or very large populations for land-use planning.

![The ALARP Triangle](image)

**Figure 6-1:** UK HSE decision-making framework
It should be noted that acceptable risks posed to workers are different to those posed to the public. This is due to the fact that workers 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 $1 \times 10^{-4}$ fatalities per person per year it can be demonstrated that there would be no more benefit from further mitigation, sometimes using cost benefit analysis.”
6.4 Risk Scenarios

6.4.1 Accidental Fires and Explosions

Relatively large quantities of combustible, flammable and explosive material is stored at and transported onto the FWF WWTW site, which under suitable conditions may develop into fires and explosions. The risks were calculated using generic failure rates in conjunction with the associated Port Elizabeth weather conditions.

The risk from fires and explosions on site due to a release of biogas, as shown in Figure 6-2, would be considered acceptable as the risk of $1 \times 10^{-6}$ fatalities per person per year did not extend beyond the FWF WWTW site boundary. To this end the proposed biogas plant would not be considered a Major Hazard Installation. As the risk assessment was done on the biogas facility only, this does not imply the entire FWF WWTW would not be classified accordingly.

![Image](image_url)
6.5 Societal Risk Parameter

The risk criteria discussed so far are for individual risks. There is also a need to consider incidents in the light of their effect on many people at the same time. The public response to an incident that may harm many people is thought to be worse than many incidents causing the same number of individual deaths. Compliance with an individual risk criterion is necessary but not always sufficient. Even if it were sufficient, societal risk would also have to be examined in some circumstances. Societal risk is the risk of widespread or large-scale harm from a potential hazard. The implication is that the consequence would be on such a scale as to provoke a major social or political response and may lead to public discussion about regulation in general. Societal risk therefore takes into account the density of the population around a Major Hazard Installation site and takes the form of probability in any one year (F) of an event affecting at least a certain number (N) of people (also known as an FN curve).

The societal risk used in this study is based on the legal requirements of the Netherlands and may differ from risk criteria and requirements in other parts of the world.

Due to the surrounding areas being unoccupied, the societal risk did not exceed the threshold value and is not shown. It should be noted that the risks to traffic on the N2 are extremely low to be considered trivial. Thus, the contribution of the traffic on the N2 to the societal risks is negligible.
7 REDUCTION OF RISK

From the simulations performed, the areas of highest risk have been identified as the release of flammable methane within the biogas. The risks from the proposed biogas plant would not result in unacceptable risk, and thus mitigation would be to the discretion of the management of FWF WWTW.

Implementation of any mitigation should always be done in accordance with recognised engineering practices, using applicable codes and standards.
8 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 and asphyxiant releases at the FWF WWTW facility in Port Elizabeth. 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 facility 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 FWF WWTW and their contractors to ensure that all engineering designs would be 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 bylaws.

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

8.1 Notifiable Substances

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

Methane generated during the process would not be compressed and would not be classified as a notifiable substance. No other materials generated or stored on site would be classified as a notifiable substance.

8.2 Toxic and Asphyxiant Releases

Carbon dioxide is a significant portion of biogas with the other major component being methane. Carbon dioxide is not considered an acutely toxic component but could displace oxygen causing asphyxiation.

The 1% fatality from large carbon dioxide releases would not extend beyond the site’s boundary with no offsite impacts predicted.
8.3 Fires

The biogas consists of approximately 60% methane, a highly flammable gas. The 1% fatality from jet fires due to a release of biogas at the process installations in the worst weather conditions would not extend beyond the site boundary and thus impacts from jet fires would be limited to the immediate vicinity of the fire.

Emergency flaring conditions would release 2114 Nm³/h at 35°C. The flame length under emergency conditions could extend to a maximum length of 15.6 m in still air. In all wind conditions, the thermal radiation level of 4 kW/m² at 1.0 m aboveground would never be exceeded.

No pool fires were predicted from the simulations.

In worst case weather conditions, the LFL for large biogas flash fires would not extend beyond the site boundary resulting in no predicted offsite impacts.

8.4 Vapour Cloud Explosions

Vapour cloud explosions from a loss of containment at the biogas process installations were simulated.

The 1% fatality for vapour cloud explosions from large releases of biogas could extend beyond the site boundary into the undeveloped area to the east reaching the N2 highway.

The risks from vapour cloud explosions were less than 1x10⁻⁶ fatalities per person per year at the site boundary. Thus the risks to the public would be considered acceptable.

8.5 Impacts onto Neighbouring Properties, Residential Areas and Major Hazard Installations

The land use to the north, east and west is undeveloped, while industrial properties are located to the south.

The only offsite impacts from the proposed project would be vapour cloud explosions from a catastrophic failure of the gas holder, which would extend beyond the site boundary to the east up to the N2 highway.

This project would not result in impacts beyond the southern boundary of the site into the industrial properties.

Residential properties are some distance to the west of the proposed project. As impacts would not extend beyond the western site boundary, there would be no negative impacts on any residential areas.

8.6 Societal Risks

Due to the surrounding areas being unoccupied, the societal risk did not exceed the threshold value and is not shown. It should be noted that the risks to traffic on the N2 are extremely low to be considered trivial. Thus, the contribution of the traffic on the N2 to the societal risks is negligible.
8.7 Major Hazard Installation

This investigation concluded that under the current design conditions the proposed biogas plant at the FWF WWTW facility in Port Elizabeth would not be considered as a Major Hazard Installation. However, this does not imply that the other parts of the FWF WWTW are not Major Hazardous Installation.

This study is not intended to replace the Major Hazard Installation risk assessment which should be completed prior to construction of the project.
9 RECOMMENDATIONS

As a result of the risk assessment study conducted for the proposed FWF WWTW facility in Port Elizabeth a number of events were found to have risks beyond the site boundary. These risks could be mitigated to acceptable levels, as shown in the report.

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:

1. Compliance with all statutory requirements, i.e. pressure vessel designs;
2. Compliance with applicable SANS codes, i.e. SANS 10087, SANS 10089, SANS 10108, etc;
3. Incorporation of applicable guidelines or equivalent international recognised codes of good design and practice into the designs;
4. 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;
5. Full 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;
6. 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;
7. Demonstration by FWF WWTW or their contractor that the final designs would reduce the risks posed by the installation to internationally acceptable guidelines;
8. 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;
9. 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);
10. Permission not being granted for increases to the product list or product inventories without redoing part of or the full EIA;
11. Final acceptance of the facility risks with an MHI risk assessment that must be completed in accordance to the MHI regulations and that the risk assessment cover the entire facility:
   - Basing such a risk assessment on the final design and including engineering mitigation.
10 REFERENCES


### 11 ABBREVIATIONS AND ACRONYMS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIA</td>
<td>See Approved Inspection Authority</td>
</tr>
</tbody>
</table>
| 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.

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Liquefied petroleum gas (LPG)</td>
</tr>
<tr>
<td>IA</td>
<td>Liquids that have a closed cup flashpoint of below 23°C and a boiling point below 35°C</td>
</tr>
<tr>
<td>IB</td>
<td>Liquids that have a closed cup flashpoint of below 23°C and a boiling point of 35°C or above</td>
</tr>
<tr>
<td>IC</td>
<td>Liquids that have a closed cup flashpoint of 23°C and above but below 38°C</td>
</tr>
<tr>
<td>II</td>
<td>Liquids that have a closed cup flashpoint of 38°C and above but below 60.5°C</td>
</tr>
<tr>
<td>IIA</td>
<td>Liquids that have a closed cup flashpoint of 60.5°C and above but below 93°C</td>
</tr>
</tbody>
</table>

**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 LC₅₀ 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
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>LFL</td>
<td>Lower Flammable Limit see Flammable Limits</td>
</tr>
<tr>
<td>LOC</td>
<td>See Loss of Containment</td>
</tr>
<tr>
<td>Local Government</td>
<td>Local government is defined in Section 1 of the Local Government Transition Act, 1993 (Act No. 209 of 1993).</td>
</tr>
<tr>
<td>Loss of Containment</td>
<td>Loss of containment (LOC) is the event resulting in a release of material into the atmosphere.</td>
</tr>
</tbody>
</table>
| 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 |
| 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:  
    - The inner zone (> 1x10⁻⁵ fatalities per person per year);  
    - The middle zone (1x10⁻⁵ fatalities per person per year to 1x10⁻⁶ fatalities per person per year);  
    - The outer zone (1x10⁻⁶ fatalities per person per year to ...) |
### Quantitative Risk Assessment for the Fishwater Flats Wastewater Treatment Works BioGas Project at Port Elizabeth

<table>
<thead>
<tr>
<th><strong>3x10^-7</strong> fatalities per person per year;</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 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 C).</td>
</tr>
</tbody>
</table>

### 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:

\[
\text{Risk} = \text{Consequence} \times \text{Frequency of Occurrence}
\]

### 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 |
Republic of South Africa

Department of Labour

Certificate
This is to certify that

RISCOM (PTY) LTD

Has been approved as an
APPROVED INSPECTION AUTHORITY
Type A; Explosive Chemicals, Gases, Flammable Gases, Non-Flammable, Non toxic gases (asphyxiants), Toxic gases and Flammable liquids, Flammable solids, Substances liable to spontaneous combustion, Substances that on contact with water release flammable gasses, Oxidizing substances and organic peroxides, Toxic liquids and Solids.
In terms of the Occupational Health and Safety Act, 1993, read with the Major Hazard Installation Regulations 5(5) (a) regarding risk assessments

Valid From: 27 May 2013
Expires: 26 May 2017

MHI 0005
Certificate Number
CERTIFICATE OF ACCREDITATION

In terms of section 22(2)(b) of the Accreditation for Conformity Assessment, Calibration and Good Laboratory Practice Act, 2006 (Act 19 of 2006), read with sections 23(1), (2) and (3) of the said Act, I hereby certify that:

RISCOM (PTY) LTD
Co. Reg. No.: 2002/019697/07
JOHANNESBURG

Facility Accreditation Number: MHI0013

is a South African National Accreditation System accredited Inspection Body to undertake

**TYPE A** inspection provided that all SANAS conditions and requirements are complied with

This certificate is valid as per the scope as stated in the accompanying schedule of accreditation, Annexure “A”, bearing the above accreditation number for

**THE ASSESSMENT OF RISK ON MAJOR HAZARD INSTALLATIONS**

The facility is accredited in accordance with the recognised International Standard

**ISO/IEC 17020:2012**

The accreditation demonstrates technical competency for a defined scope and the operation of a

quality management system

While this certificate remains valid, the Accredited Facility named above is authorised to use the

relevant SANAS accreditation symbol to issue facility reports and/or certificates

---

Mr R Josias
Chief Executive Officer
Effective Date: 27 May 2013
Certificate Expires: 26 May 2017

This certificate does not, on its own confer authority to act as an Approved Inspection Authority as contemplated in the Major Hazard Installation Regulations. Approval to inspect within the regulatory domain is granted by the Department of Labour.
ANNEXURE A

SCHEDULE OF ACCREDITATION

Facility Number: MHI0013
TYPE A

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</tr>
<tr>
<td>33 Brigish Dr</td>
<td>Cresta</td>
</tr>
<tr>
<td>Northcliff</td>
<td>Johannesburg</td>
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<tr>
<td><a href="mailto:mike@riscom.co.za">mike@riscom.co.za</a></td>
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<tr>
<th>Nominated Representative</th>
<th>Quality Manager</th>
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</thead>
<tbody>
<tr>
<td>Mr M Oberholzer</td>
<td>Mr M Oberholzer</td>
</tr>
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<th>Technical Signatory:</th>
<th>Technical Manager:</th>
</tr>
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<tbody>
<tr>
<td>Mr M Oberholzer</td>
<td>Mr M Oberholzer</td>
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<th>Field of Inspection</th>
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<tr>
<td>1) Explosive chemicals</td>
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<td>2) Gases</td>
<td>Specific Services:</td>
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<tr>
<td>i) Flammable Gases</td>
<td>i) Frequency/ Probability Analysis</td>
</tr>
<tr>
<td>ii) Non-flammable, non toxic gases</td>
<td>ii) Consequence Modelling</td>
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<tr>
<td>(asphyxiants)</td>
<td>iii) Hazard Identification and Analysis including HAZARD and Operability studies (HAZOP)</td>
</tr>
<tr>
<td>iii) Toxic gases</td>
<td>iv) Emergency planning reviews</td>
</tr>
<tr>
<td>3) Flammable solids</td>
<td></td>
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<tr>
<td>4) Flammable solids, substances liable to spontaneous combustion, substances that on contact with water release flammable gases</td>
<td></td>
</tr>
<tr>
<td>5) Oxidizing substances and organic peroxides</td>
<td></td>
</tr>
<tr>
<td>6) Toxic liquids and solids</td>
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Original date of accreditation: 27 May 2005

ISSUED BY THE SOUTH AFRICAN NATIONAL ACCREDITATION SYSTEM
### APPENDIX C: PADHI LAND-PLANNING TABLES

#### 14.1 Development Type Table 1: People at Work, Parking

<table>
<thead>
<tr>
<th>Development Type</th>
<th>Examples</th>
<th>Development Detail and Size</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DT1.1 Workplaces</strong></td>
<td>Offices, factories, warehouses, haulage depots, farm buildings, nonretail markets, builder's yards</td>
<td>Workplaces (predominantly nonretail), providing for less than 100 occupants in each building and less than 3 occupied storeys (Level 1)</td>
<td>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.</td>
</tr>
</tbody>
</table>

**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)
- 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.

| Sheltered workshops, Remploy | 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
- Car parks with picnic areas or at a retail or leisure development or serving a park and ride interchange

Where parking areas are associated with other facilities and developments the sensitivity level and the decision will be based on the facility or development.
### Development Type Table 2: Developments for Use by the General Public

<table>
<thead>
<tr>
<th>Development Type</th>
<th>Examples</th>
<th>Development Detail and Size</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DT2.1 Housing</strong></td>
<td>Houses, flats, retirement flats or bungalows, residential caravans, mobile homes</td>
<td>Developments up to and including 30 dwelling units and at a density of no more than 40 per hectare (Level 2)</td>
<td>Development where people live or are temporarily resident It may be difficult to organise people in the event of an emergency</td>
</tr>
<tr>
<td><strong>Exclusions</strong></td>
<td>Infill, back-land development</td>
<td>DT2.1 x1 Developments of 1 or 2 dwelling units (Level 1)</td>
<td>Minimal increase in numbers at risk</td>
</tr>
<tr>
<td></td>
<td>Larger housing developments</td>
<td>DT2.1 x2 Larger developments for more than 30 dwelling units (Level 3)</td>
<td>Substantial increase in numbers at risk</td>
</tr>
<tr>
<td></td>
<td>Any developments (for more than 2 dwelling units) at a density of more than 40 dwelling units per hectare (Level 3)</td>
<td>DT2.1 x3</td>
<td>High-density developments</td>
</tr>
<tr>
<td><strong>DT2.2 Hotel or Hostel or Holiday Accommodation</strong></td>
<td>Hotels, motels, guest houses, hostels, youth hostels, holiday camps, holiday homes, halls of residence, dormitories, accommodation centres, holiday caravan sites, camping sites</td>
<td>Accommodation up to 100 beds or 33 caravan or tent pitches (Level 2)</td>
<td>Development where people are temporarily resident It may be difficult to organise people in the event of an emergency</td>
</tr>
<tr>
<td><strong>Exclusions</strong></td>
<td>Smaller: guest houses, hostels, youth hostels, holiday homes, halls of residence, dormitories, holiday caravan sites, camping sites</td>
<td>DT2.2 x1 Accommodation of less than 10 beds or 3 caravan or tent pitches (Level 1)</td>
<td>Minimal increase in numbers at risk</td>
</tr>
<tr>
<td></td>
<td>Larger: hotels, motels, hostels, youth hostels, holiday camps, holiday homes, halls of residence, dormitories, holiday caravan sites, camping sites</td>
<td>DT2.2 x2 Accommodation of more than 100 beds or 33 caravan or tent pitches (Level 3)</td>
<td>Substantial increase in numbers at risk</td>
</tr>
<tr>
<td>Development Type</td>
<td>Examples</td>
<td>Development Detail and Size</td>
<td>Justification</td>
</tr>
<tr>
<td>------------------</td>
<td>----------</td>
<td>----------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>DT2.3 Transport Links</td>
<td>Motorway, dual carriageway</td>
<td>Major transport links in their own right i.e. not as an integral part of other developments (Level 2)</td>
<td>Prime purpose is as a transport link. Potentially large numbers exposed to risk but exposure of an individual is only for a short period.</td>
</tr>
<tr>
<td><strong>Exclusions</strong></td>
<td>Estate roads, access roads</td>
<td>DT2.3 x1 Single carriageway roads (Level 1)</td>
<td>Minimal numbers present and mostly a small period of time exposed to risk. Associated with other development.</td>
</tr>
<tr>
<td></td>
<td>Any railway or tram track</td>
<td>DT2.3 x2 Railways (Level 1)</td>
<td>Transient population, small period of time exposed to risk. Periods of time with no population present.</td>
</tr>
<tr>
<td>Development Type</td>
<td>Examples</td>
<td>Development Detail and Size</td>
<td>Justification</td>
</tr>
<tr>
<td>------------------</td>
<td>----------</td>
<td>-----------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>DT2.4 Indoor Use by Public</td>
<td>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</td>
<td>Developments for use by the general public where total floor space is from 250 m² up to 5000 m² (Level 2)</td>
<td>Developments where members of the public will be present (but not resident) Emergency action may be difficult to coordinate</td>
</tr>
</tbody>
</table>

| Exclusions |
|------------------|----------|-----------------------------|---------------|
| DT2.4 x1 Development with less than 250 m² total floor space (Level 1) | Minimal increase in numbers at risk |
| DT2.4 x2 Development with more than 5000 m² total floor space (Level 3) | Substantial increase in numbers at risk |

<p>| DT2.5 Outdoor Use by Public | Food and drink: food festivals, picnic areas Retail: outdoor markets, car boot sales, funfairs | Principally an outdoor development for use by the general public i.e. developments where | Developments where members of the public will be present (but |</p>
<table>
<thead>
<tr>
<th>Development Type</th>
<th>Examples</th>
<th>Development Detail and Size</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>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</td>
<td>people will predominantly be outdoors and not more than 100 people will gather at the facility at any one time (Level 2)</td>
<td>not resident) either indoors or outdoors Emergency action may be difficult to coordinate</td>
<td></td>
</tr>
</tbody>
</table>

**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

<table>
<thead>
<tr>
<th>Development Type</th>
<th>Examples</th>
<th>Development Detail and Size</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DT3.1</strong> Institution Accommodation and Education</td>
<td>Hospitals, convalescent homes, nursing homes, old people's homes with warden on site or 'on call', sheltered housing, nurseries, créches, schools and academies for children up to school leaving age</td>
<td>Institutional, educational and special accommodation for vulnerable people or that provides a protective environment (Level 3)</td>
<td>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.</td>
</tr>
<tr>
<td><strong>Exclusions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hospitals, convalescent homes, nursing homes, old people's homes, sheltered housing</td>
<td>24-hour care where the site on the planning application being developed is larger than 0.25 hectare (Level 4)</td>
<td>Substantial increase in numbers of vulnerable people at risk</td>
</tr>
<tr>
<td></td>
<td>Schools, nurseries, créches</td>
<td>Day care where the site on the planning application being developed is larger than 1.4 hectare (Level 4)</td>
<td>Substantial increase in numbers of vulnerable people at risk</td>
</tr>
<tr>
<td><strong>DT3.2</strong> Prisons</td>
<td>Prisons, remand centres</td>
<td>Secure accommodation for those sentenced by court, or awaiting trial, etc. (Level 3)</td>
<td>Places providing detention. Emergency action and evacuation may be very difficult.</td>
</tr>
</tbody>
</table>
## 14.4 Development Type Table 4: Very Large and Sensitive Developments

<table>
<thead>
<tr>
<th>Development Type</th>
<th>Examples</th>
<th>Development Detail and Size</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DT4.1 Institutional Accommodation</strong></td>
<td>Hospitals, convalescent homes, nursing homes, old people’s homes, sheltered housing</td>
<td>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)</td>
<td>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.</td>
</tr>
<tr>
<td><strong>DT4.2 Very Large Outdoor Use by Public</strong></td>
<td>Nurseries, crèches, schools for children up to school leaving age</td>
<td>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)</td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td>Theme parks, large sports stadia and events, open air markets, outdoor concerts, pop festivals</td>
<td>Predominantly open air developments where there could be more than 1000 people present (Level 4)</td>
<td>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.</td>
</tr>
</tbody>
</table>
15 APPENDIX D: MATERIAL SAFETY DATA SHEETS

15.1 Methane

Methyl hydride
CH₄
Molecular mass: 16.0 (cylinder)
ICSC # 0291

ICSC: 0291

CAS # 74-82-8
RTECS # PA1490000
UN # 1971
EC # 601-001-00-4

February 10, 2000 Validated

TYPES OF HAZARD/EXPOSURE

ACUTE HAZARDS/SYMPTOMS

FIRE
Extremely flammable.

NO open flames, NO sparks, and NO smoking.

FIRST AID/FIRE FIGHTING

Closed system, In case of fire: keep ventilation, explosion-cylinder cool by spraying proof electrical with water. Combat fire equipment and lighting from a sheltered handtools.

EXPLOSION
Gas/air mixtures are explosive.

EXPOSURE

• INHALATION
Suffocation. See Notes.
Ventilation. Breathing Fresh air, rest. Artificial concentration.
Recommendation if high respiration if indicated.
Refer for medical attention.

ON CONTACT WITH Cold-insulating gloves. LIQUID: FROSTBITE.

• SKIN
ON CONTACT WITH Safety goggles. LIQUID: FROSTBITE.

• EYES
ON CONTACT WITH Water for several minutes
First rinse with plenty of water for several minutes (remove contact lenses if easily possible), then take to a doctor.

• INGESTION

SPILLAGE DISPOSAL
Personal protection: self- Fireproof. Cool. Ventilation contained breathing along the floor and ceiling.

STORAGE
apparatus. Evacuate danger area! Consult an expert!

VENTILATION
Remove all ignition sources. NEVER

PACKAGING & LABELLING
F+ symbol
R: 12
S: 2-9-16-33
UN Hazard Class: 2.1
direct water jet on liquid.

Prepared in the context of cooperation between the International Programme on Chemical Safety & the Commission of the European Communities (C) IPCS CEC 1994. No modifications to the International version have been made except to add the OSHA PELs, NIOSH RELs and NIOSH IDLH values.

**ICSC: 0291**

**METHANE**

**PHYSICAL STATE; APPEARANCE:**
COLOURLESS, COMPRESSED OR LIQUEFIED GAS, WITH NO ODOUR.

**PHYSICAL DANGERS:**
The gas is lighter than air.

**CHEMICAL DANGERS:**

**INHALATION RISK:**
On loss of containment this gas can cause suffocation by lowering the oxygen content of the air in confined areas.

**Routes of Exposure:**
The substance can be absorbed into the body by inhalation.

**OCCUPATIONAL EXPOSURE LIMITS:**
TLV: (aliphatic hydrocarbons gases, Alkane C1-C4) 1000 ppm (as TWA) (ACGIH 2005). MAK not established.

**PHYSICAL PROPERTIES**
Boiling point: -161°C
Melting point: -183°C
Flash point: Flammable Gas
Auto-ignition temperature: 537°C
Solubility in water, ml/100 ml at 20°C: 3.3
Relative vapour density (air = 1): log Pow: 1.09

**ENVIRONMENTAL DATA**
Density of the liquid at boiling point: 0.42 kg/l. High concentrations in the air cause a deficiency of oxygen with the risk of unconsciousness or death. Check oxygen content before entering area. Turn leaking cylinder with the leak up to prevent escape of gas in liquid state. After use for welding, turn valve off; regularly check tubing, etc., and test for leaks with soap and water. The measures mentioned in section PREVENTION are applicable to production, filling of cylinders, and storage of the gas. Other UN number: 1972 (refridgerated liquid), Hazard class: 2.1. Card has been partly updated in October 2005. See section Emergency Response.

Transport Emergency Card: TEC (R)-20G1F
NFPA Code: H 1; F 4; R 0;

**ADDITIONAL INFORMATION**

**ICSC: 0291**

**METHANE**
IMPORTANT LEGAL NOTICE:

Neither NIOSH, the CEC or the IPCS nor any person acting on behalf of NIOSH, the CEC or the IPCS is responsible for the use which might be made of this information. This card contains the collective views of the IPCS Peer Review Committee and may not reflect in all cases all the detailed requirements included in national legislation on the subject. The user should verify compliance of the cards with the relevant legislation in the country of use. The only modifications made to produce the U.S. version is inclusion of the OSHA PELs, NIOSH RELs and NIOSH IDLH values.

- Page last reviewed: July 22, 2015
- Page last updated: July 1, 2014
- Content source:
15.2 Carbon Dioxide

ICSC: 0021

Carbonic acid gas
Carbonic anhydride
CO₂
Molecular mass: 44.0 (cylinder)
ICSC # 0021

CAS # 124-38-9
RTECS # FF6400000
UN # 1013
October 10, 2006 Validated

FIRE
Not combustible.
In case of fire in the surroundings: use appropriate extinguishing media.

EXPLOSION
Containers may burst in the heat of a fire!
In case of fire: keep cylinder cool by spraying with water. Combat fire from a sheltered position.

EXPOSURE
Fresh air, rest. Artificial respiration may be needed. Refer for medical attention.

• INHALATION
ON CONTACT WITH LIQUID: FROSTBITE.
ON FROSTBITE: rinse with plenty of water, do NOT remove clothes. Refer for medical attention.

• SKIN
On contact with liquid: Safety goggles or several minutes (remove contact lenses if easily possible), then take to a doctor.

• EYES

• INGESTION
Personal protection: self-contained breathing apparatus. Ventilation. NEVER direct water jet on liquid.

Fireproof if in building. Cool. Ventilation along the floor.
UN Hazard Class: 2.2
Signal: Warning
Cylinder
May be harmful if inhaled
Contains refrigerated gas; may cause cryogenic burns or injury

Prepared in the context of cooperation between the International Programme on Chemical Safety & the Commission of the European Communities (C) IPCS CEC 1994. No modifications to the International version have been made except to add the OSHA PELs, NIOSH RELs and NIOSH IDLH values.

ICSC: 0021
CARBON DIOXIDE

ICSC: 0021
PHYSICAL STATE; APPEARANCE:
ODOURLESS, COLOURLESS
COMPRESSED LIQUEFIED GAS.

PHYSICAL DANGERS:
The gas is heavier than air and may accumulate in low ceiling spaces causing deficiency of oxygen. Build up of static electricity can occur at fast flow rates and may ignite any explosive mixtures present. Free-flowing liquid condenses to form extremely cold dry ice.

CHEMICAL DANGERS:
The substance decomposes on heating above 2000°C producing toxic carbon monoxide.

INHALATION RISK:
On loss of containment this liquid evaporates very quickly causing supersaturation of the air with serious risk of suffocation when in confined areas.

RECOMMENDED EXPOSURE LIMITS:
TLV: 5000 ppm as TWA; 30000 ppm as STEL; (ACGIH 2006).
MAK: 5000 ppm, 9100 mg/m³;
Peak limitation category: II(2); (DFG 2006).
OSHA PEL†: TWA 5000 ppm (9000 mg/m³)
NIOSH REL: TWA 5000 ppm (9000 mg/m³) ST 30,000 ppm (54,000 mg/m³)
NIOSH IDLH: 40,000 ppm See: 124389
Sublimation point: -79°C
Solubility in water, ml/100 ml at 20°C: 88
Vapour pressure, kPa at 20°C: 5720

NOTES
Carbon dioxide is given off by many fermentation processes (wine, beer, etc.) and is a major component of flue gas. High concentrations in the air cause a deficiency of oxygen with the risk of unconsciousness or death. Check oxygen content before entering area. No odour warning if toxic concentrations are present. Turn leaking cylinder with the leak up to prevent escape of gas in liquid state. Other UN classification numbers for transport are: UN 1845 carbon dioxide, solid (Dry ice); UN 2187 carbon dioxide refrigerated liquid.

Transport Emergency Card: TEC (R)-20S1013 or 20G2A

ADDITIONAL INFORMATION
ICSC: 0021
(C) IPCS, CEC, 1994
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modifications made to produce the U.S. version is inclusion of the OSHA PELs, NIOSH RELs and NIOSH IDLH values.

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- Content source: Centers for Disease Control and Prevention