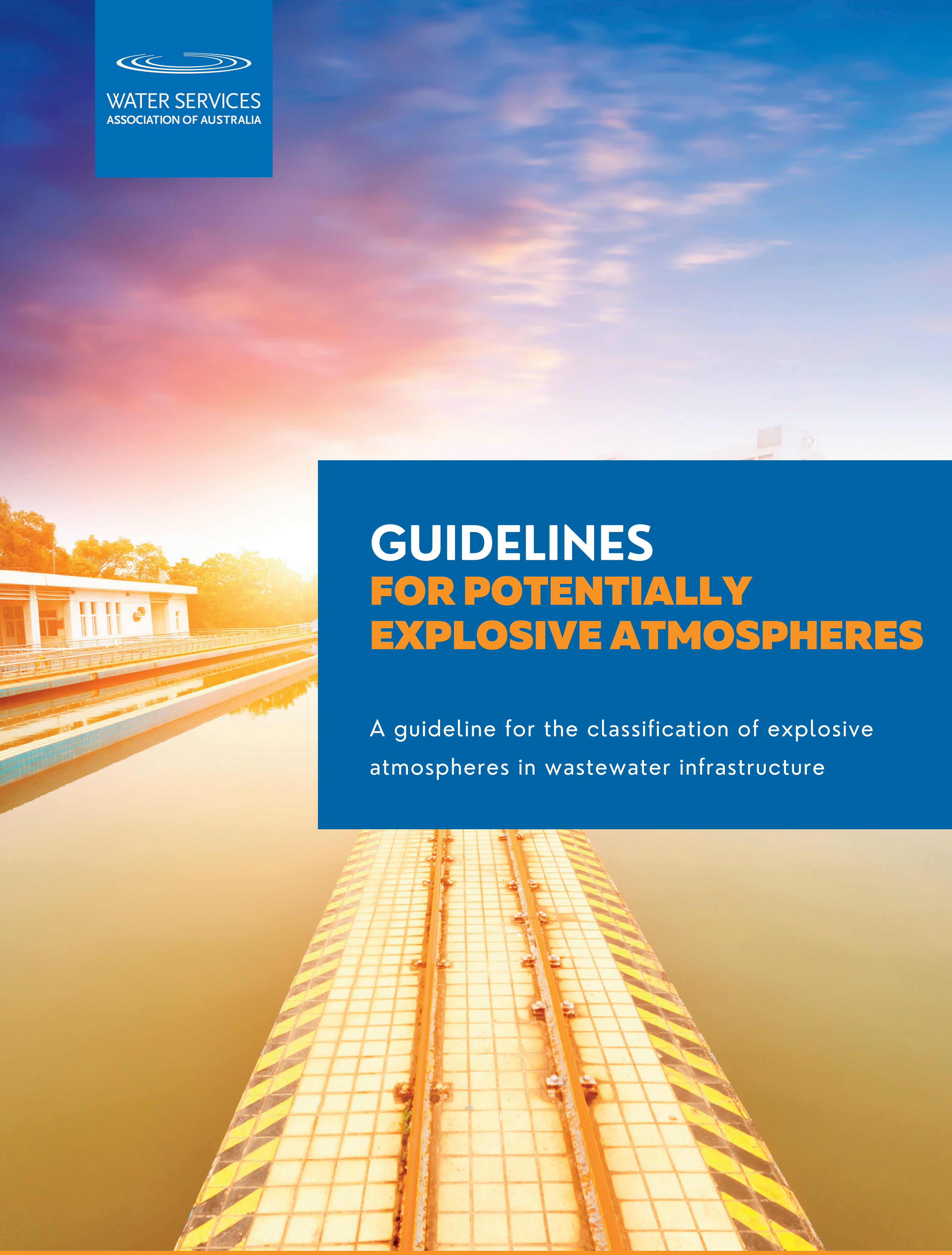

WATER SERVICES
ASSOCIATION OF AUSTRALIA

GUIDELINES
FOR POTENTIALLY EXPLOSIVE ATMOSPHERES

A guideline for the classification of explosive atmospheres in wastewater infrastructure

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About WSAA

The Water Services Association of Australia (WSAA) is the peak body that connects the Australian urban water industry, representing over 70 public and privately owned water or water related organisations. Our members provide water and wastewater services to over 20 million customers in Australia and New Zealand.

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Project outcomes contribute to the following UN Sustainable Development Goals:

For more information about the water industry's contribution see Global Goals for Local Communities: Urban water advancing the UN Sustainable Development Goals.

Revision History

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1.1	29/06/2023	Updates to drawings (section 10) and evaporations formula.

TABLE OF CONTENTS

EXECUTIVE SUMMARY 8

PREFACE 10

GLOSSARY 12

RELEVANT STANDARDS REFERENCE LIST 17

1. INTRODUCTION 19

1.1 Need for the guideline 19

1.2 Explosive atmospheres, duty of care and relevant legislation 20

1.3 Industry engagement 23

1.4 Structure 24

1.5 Use of the guideline 25

1.5.1 High probability locations 25

1.6 Areas not considered 26

1.6.1 Toxicity 26

1.6.2 Chemical compatibility 27

1.6.3 Dust hazards 27

1.6.4 Sources of ignition 28

1.6.5 Prescription of hazardous areas 29

2. FLAMMABLE ATMOSPHERES IN THE SEWERAGE SYSTEM 30

2.1 Contaminants of concern 30

2.1.1 Methane and hydrogen sulphide 30

2.1.2 Hydrocarbons 33

2.1.3 Volatile Organic Compounds 34

2.2 Likely sources 35

2.3 Difficulty in measurement 39

2.4 Examples of explosive atmospheres in wastewater and associated assets 40
2.4.1 Fuel dumps 41
2.4.2 Illegal drug manufacturing 41
2.4.3 Industrial catchment pumping station 42
2.4.4 Inverted siphon 43
2.4.5 Sewer running alongside gas line 43
2.4.6 Inlet works 43
2.4.7 Sludge infrastructure explosions 44
2.4.8 Storage of flammable materials 45

3. MONITORING OF EXPLOSIVE ATMOSPHERES 46
3.1 Purpose 46
3.2 Instrumentation 47
3.3 Limitations and accuracy 48
3.4 Sampling campaigns 49
3.4.1 Methodologies 50
3.4.2 Limitations on use and interpretation of data 57

4. INTERACTION WITH STANDARDS AND GUIDELINES 59
4.1 Relevant standards and guidelines 59
4.1.1 Australian standards and guidelines 59
4.1.2 International standards and guidelines 61
4.2 Guidance on use and interpretation of standards 63
4.2.1 Prescriptive vs risk-based approach 63
4.2.2 Abnormal vs. catastrophic operating conditions 64
4.2.3 Control of atmospheric concentration of substances 66
4.2.4 Ventilation 67
4.2.5 Equipment protection level and classification 68
4.3 Network specific interactions 69
4.3.1 Pumping station zoning 69
4.3.2 Classification mechanism 70
4.4 Treatment plant specific interactions 71
4.5 Current state of knowledge 71

5. METHOD OF CLASSIFICATION FOR LINEAR INFRASTRUCTURE 72

5.1 Overview....................72

5.2 Threshold value for network installations....................73

5.3 Monitoring history....................75

5.4 Catchment features....................76

5.4.1 Hydraulic features....................77
5.4.2 Catchment composition....................78
5.4.3 Security....................81
5.4.4 Abnormal operation....................82
5.4.5 Baseline zonal classification....................86

5.5 Mitigation Measures....................88

5.5.1 Monitoring and source control....................89
5.5.2 Isolation and bypass....................90
5.5.3 Ventilation....................91
5.5.4 Ventilation adjusted zonal classification....................102

5.6 Additional considerations in zoning....................104

5.6.1 Consequence....................104

5.7 Classification documentation....................104

5.8 Competency....................105

6. METHOD OF CLASSIFICATION FOR WASTEWATER TREATMENT PLANT ASSETS....................106

6.1 Considerations for treatment plant classification....................106

6.1.1 Threshold value for treatment plants....................106
6.1.2 Security and criticality....................108
6.1.3 Abnormal operation....................109

6.2 Unit process classifications....................111

6.2.1 Pre-treatment....................111
6.2.2 Primary treatment....................112
6.2.3 Secondary treatment....................113
6.2.4 Solids treatment....................113
6.2.5 Tertiary treatment....................117

6.2.6 Chemical storage 117
6.2.7 Odour control facilities 118

7. ZONAL EXTENTS FOR LINEAR ASSETS 119

7.1 Zoning of linear assets 119

7.1.1 Limits of application 119
7.1.2 Example classifications 119

8. EMERGENCY RESPONSE RECOMMENDATIONS 122

8.1 Linear infrastructure responses 122

8.1.1 Gas leak 122
8.1.2 Major trade waste discharge or illegal dump 123
8.1.3 Notification of authorities 125

8.2 Treatment plant responses 125

8.2.1 Standard operating procedures 125
8.2.2 Emergency preparedness 126

9. EXAMPLES 127

9.1 Pumping station (industrial) 128

9.2 Pump station in chain of pump station 129

9.3 Odour control unit on PS 130

9.4 Discharge maintenance hole 133

9.5 Maintenance hole 134

9.6 Pump station (municipal) 135

10. HAZARDOUS ZONE DRAWINGS 137

10.1 Linear infrastructure 137

10.1.1 Maintenance hole/scour pit 137
10.1.2 Wet well/dry well 137
10.1.3 Wet well/valve chamber 137
10.1.4 Emergency storage tank 137
10.1.5 Air valve pit/air valve 137

EXECUTIVE SUMMARY

Around Australia, in both regional and urban areas, flammable atmospheres requiring specific management and equipment occur in municipal wastewater assets. This can occur due to a variety of substances being present and not just the possible presence of methane or hydrogen sulphide that has traditionally been used to classify hazardous areas associated with municipal wastewater assets. These flammable or explosive atmospheres have been responsible for incidents and near misses over the past 20 years, including:

- An explosion in a digester gas cogeneration system causing injury to a worker.
- An explosion in a residential home, where methane gas backflowing from a pumping station was ignited, causing damage to a customer's bathroom.
- An ignition of the atmosphere underneath a wet well pumping station, which had become flammable due to an illegal dump of industrial waste causing forceful ejection of the pumping station lid and upstream maintenance hole covers.
- Ignition of the atmosphere at an inlet works due to repair work on a connected pipe.

Incidents and near misses have increased water agency awareness of the risks associated with explosive atmospheres. Many have developed internal management plans to address the specific risks explosive atmospheres pose to their organisation.

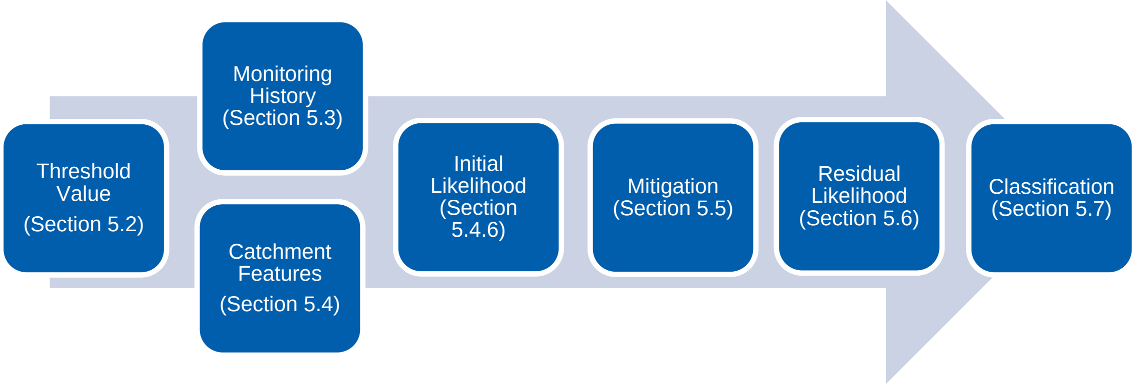
The Australian Standards for equipment design, selection and maintenance in a hazardous area are comprehensive. Industry feedback is that there are skilled and knowledgeable hazardous area professionals available to assist water agencies in the design, installation and maintenance of hazardous area equipment. However, water agencies have found that the classification of hazardous areas for municipal wastewater infrastructure can vary widely amongst hazardous area professionals. For this reason, this guideline focuses on the classification of these assets.

This document provides a consistent basis from which water agencies can determine their approach to hazardous area classification in their asset base. Guidance is divided into two categories: one aimed at wastewater networks (comprised of assets such as maintenance holes, pump stations and rising mains) and the other at wastewater treatment plants.

A review of national and international literature such as guidelines, water agency specification documents and Australian and industry standards was undertaken. The literature review has allowed information from other jurisdictions to inform an interpretation of local standards and assist in the development of this guideline.

An overview of common contaminants of concern in the wastewater sewerage network flowing into treatment plants is presented along with examples from Australian practice. This is followed by a description of monitoring techniques describing sampling technologies, methods and campaigns to assist in determining the likelihood of hazardous areas and flammable atmospheres associated with the asset.

A guided risk assessment applied using simplified examples is provided to support water agencies when assessing the hazardous area classification of wastewater assets. The risk assessment approach ideally uses sampling data collected on contaminants and their possible grades of release. However, it is also applicable in the absence of such data (for example, with a planned new asset). A visual indication of this process is provided below.



Key aspects of the wastewater system are assessed for their contribution to a potentially explosive atmosphere and include hydraulic features, catchment composition, location and foreseeable misuse. Possible ignition sources are also considered.

Guidance on mitigation measures is also provided, which can be used to mitigate or reduce the likelihood of an explosive atmosphere occurring. Ventilation 'best practice' is briefly described with a reference asset used as an example of calculating ventilation rates for network assets. The calculations used for the reference asset are described in sufficient detail such that they can be applied to common network assets such as maintenance holes, pump stations and emergency storage tanks. Having defined availability of ventilation in terms of common wastewater industry practice and providing criteria for good and fair ventilation, the change in likelihood of explosive atmosphere associated with ventilation is provided for the user to apply. A final likelihood is then established, considering any mitigation measures employed. Examples of classification are provided, demonstrating the operation of the methodology in common wastewater scenarios.

In general, treatment plant unit processes are more likely to have uniform or predictable operating conditions, which simplifies the collection of data regarding potentially explosive atmospheres. Due to this predictability, the guideline recommends the use of established hazardous area classification techniques outlined in the latest version of AS/NZS 60079.10.1 to classify these processes. To assist hazardous area professionals in their classifications of treatment plant assets, some aspects to consider during the classification process are presented. In addition, a range of commonly installed treatment unit processes are described, and a minimum suggested classification is provided for reference and consideration by the classification professional.

Having described the methods by which classifications can be made, some suggestions are made for the development of emergency response procedures to respond to common scenarios in both the wastewater network and within wastewater treatment plants. Key to this is early and ongoing communication with local emergency services.

Finally, a set of sample drawings have been produced based on these guideline recommendations. In accordance with the provisions in AS/NZS 60079.10.1 (see clause A.1.(c) of Supplement 1), these drawings are provided as examples of indicative industry practice with the intention that they can be modified based on the details of the particular situation.

PREFACE

This document has been prepared by WSAA with the assistance of Stantec Australia Pty Ltd, and with the valuable contributions of the working group of water agencies, to provide guidance in the management of potentially explosive atmospheres in wastewater treatment plants and wastewater networks. It is not intended to replace the role of expert opinion and advice for hazardous area classification. Rather, the document aims to provide guidance to hazardous area professionals who are currently making decisions regarding hazardous area classification and to inform other technical professionals not directly involved, such as wastewater infrastructure operators, design engineers and maintenance personnel. It is important to note that this guideline does not supersede or overrule any relevant Australian standard or legislation and is to be read in conjunction with these standards and the relevant legislation for the jurisdiction where the classification is taking place.

As part of the development of this document, a survey of the working group of water agencies was undertaken. The results of the survey were also followed with interviews with the relevant stakeholders. The consensus among the stakeholders surveyed was that there was a higher degree of confidence in their organisation's ability to undertake (or procure services to assist in undertaking) the design, installation and maintenance of hazardous areas. Confidence was lower in the ability to effectively classify wastewater assets, with a particular emphasis on network assets such as pump stations, gravity mains and others. For this reason, this guideline is focussed primarily on addressing hazardous area classification for wastewater assets.

The following assumptions have been made about the infrastructure in place at the water agency:

- Pumping stations have some minimal security to discourage ease of foreseeable misuse, such as lockable covers. Maintenance holes are such that members of the public cannot easily remove lids, that is, that specialist tooling such as lid lifters or bolt cutters are required to significantly dislodge the lids. This is to ensure that a minimum level of security can be assumed, providing protection from foreseeable misuse.
- All equipment and systems are maintained in good working condition and not used outside of their specified design envelope. This would include adhering to any equipment manufacturer's instructions.
- Maintenance and engineering personnel (whether internal or external) are sufficiently experienced in the requirements of working in hazardous areas. In general, these personnel should be competent as described in AS/NZS 60079.14 and AS 4761.1. This should be assessed by water agencies based on their circumstances, that is, local availability of specialist skills. This ensures equipment is maintained such that the Equipment Protection Level (EPL) is not compromised.

A hazardous area in the context of this guideline refers to an area in which an explosive or flammable atmosphere can form under certain conditions with air. Areas classified as non-hazardous in accordance with this guideline might not necessarily be safe in all respects, as toxic and chemical hazards might still remain.

The effects of an explosion are often difficult to quantify; for this reason, existing Australian standards do not address the consequence of an explosion and classify areas solely on the likelihood of explosion occurring. There are broadly two categories of explosion which can occur: detonation or deflagration. Detonation is supersonic combustion, driving compressed unburnt gas ahead of a shockwave. Deflagration is subsonic combustion, driven by heat. In certain circumstances which are difficult to model due to the complex chemical and physical chemical reactions involved, deflagration can transition to detonation. This can be extremely dangerous, as the shockwave associated with the detonation can cause damage at significant distances away from the source of the original combustion. Further information on this topic can be found in Appendix B.

It is the objective of this document to set out guidelines for the classification of areas where flammable gas or vapour risks might arise, covering the range of activities required (monitoring, ventilation, design guidance and more) prior to establishing an EPL and selecting hazardous area equipment. Hazardous area definitions throughout this document are as per those listed in AS/NZS 60079.10.1 and other parts of the AS/NZS 60079 series. It is intended that the guidelines be applied as part of a water agency's ongoing risk management, allowing for the prioritising of assets (both existing and new) for assessment. Note that this guideline is not intended for use during operational works, where safe systems of work should be in place to protect workers from potential hazardous atmospheres.

This guideline has been written to be simple to understand by a technical professional with experience in the water and wastewater sector. However, classification of assets should ultimately be provided by an experienced hazardous area classification professional who is appropriately trained in accordance with AS 4761.1. Many of these professionals have backgrounds in other technical industries with hazardous area requirements, such as oil and gas, where the levels of uncertainty are often lower. This guideline could be used as a reference and, in certain cases can be used as a tool, to inform their decision making for the specific challenges of the water industry.

GLOSSARY

Abbreviation	Definition
AS	Australian Standard
ACPH	Air Changes Per Hour
BAL	Bushfire Attack Level, a means of measuring the severity of a building's potential exposure to ember attack, radiant heat and direct flame contact. It is measured in increments of radiant heat (expressed in kW/m^2)
BOD	Biochemical oxygen demand (BOD). The amount of oxygen utilised by microorganisms in the process of decomposition of organic material in wastewater, usually over a period of five days at 20°C
CIBSE	Chartered Institution of Building Services Engineers, an organisation in the UK dealing with building services engineering (mechanical, electrical, hydraulic, fire)
CFD	Computational Fluid Dynamics
COD	Chemical oxygen demand (COD). A measure of oxygen required to oxidise organic and inorganic matter in wastewater by a strong chemical oxidant
DBYG	Dial Before You Dig
Deflagration	Combustion which propagates through a gas or across the surface of an explosive mixture at subsonic speeds, driven by the transfer of heat
Detonation	A flammable mixture of gas which has supersonic flame propagation velocities and substantial overpressures of up to 2 megapascals (MPa). The mechanism of detonation propagation is a powerful pressure wave that compresses the unburnt gas ahead of the wave to a temperature above the autoignition temperature, rather than the conduction of heat
DDT	Deflagration to detonation transition. A phenomenon in ignitable mixtures of a flammable vapour/gas and air (or oxygen) when a sudden transition takes place from a deflagration type of combustion to a detonation type of explosion
EEHA	Electrical Equipment in Hazardous Areas
EPL	Equipment Protection Level. Assignment of the reliability of equipment to not act as an ignition source considering both the likelihood and consequence of ignition of a flammable gas or vapour. Equipment Protection Levels applicable to this guide are Ga (very high level of protection), Gb (high level of protection) and Gc (enhanced level of protection). The capital "G" denotes use in gaseous environments
Explosive (gas) atmosphere	Mixture with air, under atmospheric conditions, of flammable substances in the form of gas or vapour which, after ignition, permits self-sustaining propagation

Abbreviation	Definition
Extent of zone	Distance in any direction from the source of release to the point where the gas/air mixture has been diluted by air to a value below the lower explosive/flammability limit[1]
FAE	Fuel Air Explosive, such as thermobaric bombs
FID	Flame Ionisation Detector, a type of monitoring technology
FIP	Fire Indicating Panel. A panel which shows the fire department information about a building's heat, smoke and ventilation sensors in a single location
Flammable gas/vapour	Gas or vapour which, when mixed with air in certain proportions, will form an explosive or flammable gas atmosphere
Flammable liquid	Liquid capable of producing flammable vapour under any foreseeable operating condition
GC-MS	Gas Chromatography – Mass Spectrometry. A type of sampling technology
Grade of release **(Continuous grade, Primary grade, Secondary grade)**	There are three basic grades of release, listed below in order of decreasing frequency and likelihood of the explosive gas atmosphere being present: - Continuous grade. Release which is continuous or is expected to occur periodically or occasionally during normal operation - Primary Grade. Release which can be expected to occur periodically or occasionally during normal operation - Secondary Grade. Release which is not expected to occur in normal operation. If it does occur, is likely to do so infrequently and for short periods
Hazardous (gas) area	From the standard AS/NZS IEC 60079.10.1: 2022. [An] area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of equipment are required. From the federal safety model code of practice (*Model Work Health and Safety Regulations*, 2022): *"(a) an explosive gas is present in the atmosphere in a quantity that requires special precautions to be taken for the construction, installation and use of plant; or* *(b) a combustible dust is present, or could reasonably be expected to be present, in the atmosphere in a quantity that requires special precautions to be taken for the construction, installation and use of plant."*[2]
Hazardous atmosphere	From the federal safety model code of practice (as above): *"(2) An atmosphere is a hazardous atmosphere if:* *(a) the atmosphere does not have a safe oxygen level; or*

[1] **This includes a safety margin and is based on assumed initial conditions**

[2] **Model WHS regulations**

Abbreviation	Definition
	(b) the concentration of oxygen in the atmosphere increases the fire risk; or *(c) the concentration of flammable gas, vapour, mist or fumes exceeds 5% of the LEL for the gas, vapour, mist or fumes; or* *(d) combustible dust is present in a quantity and form that would result in a hazardous area."*[3] Note that this definition has not yet been adopted for use in every state and territory.
HRT	Hydraulic Residence Time
H_2S	Hydrogen Sulphide
IEC	International Electrotechnical Commission
IGEM	Institution of Gas Engineers and Managers. The professional engineering institution for gas in the UK
IR	Infrared
LEL/LFL	Lower Explosive or Flammability Limit. The concentration of flammable gas, vapour or mist in air below which an explosive gas atmosphere will not be formed
Linear Infrastructure	An asset related to moving wastewater through sewerage network, such as maintenance hole or pumping station
MB	Methanogenic Bacteria
MH	Maintenance Hole
MTBF	Mean Time Between Failures. A measure of the failure rate of a plant item
Normal operation	Situation where equipment is operating within its designed parameters Note 1: Minor releases of flammable material may be a part of normal operation. For example, releases from seals which rely on wetting by the fluid which is being pumped are considered minor releases Note 2: Failures (such as the breakdown of pump seals, flange gaskets or spillages caused by accidents) which involve urgent repair or shutdown are not considered to be part of normal operation nor are they considered to be catastrophic Note 3: Normal operation includes both start up and shutdown conditions
Network	A term for the various pipes, maintenance holes, pumping stations, holding tanks, etc. which make up the sewerage system
Non-hazardous area	An area in which an explosive gas atmosphere is not expected to be present in quantities such as to require special precautions for the construction, installation and use of equipment

[3] Model WHS regulations

Abbreviation	Definition
PCBU	Person Conducting a Business or Undertaking. A WHS term in NSW and QLD for the entity or person ultimately responsible for the safety of those working for them
PID	Photo-Ionisation Detector. A type of monitoring technology
ppmv	Parts per million by volume. A measure of the concentration of substance (liquid or solid) within another substance
RF	Radio Frequency
RTU	Remote Telemetry Unit
SOP	Standard Operating Procedure. Describes how a process is operated during start up, shut down, automatic and any emergency scenarios. Some overlap with UPG
Source of release	A point or location from which a gas, vapour, mist or liquid may be released into the atmosphere so that an explosive gas atmosphere could be formed
SRB	Sulphate Reducing Bacteria
SRT	Solids Residence Time
Threshold Value	A value, in percent LFL, above which the likelihood of explosion is deemed suitable for classification as a hazardous area. Ranges from 5% LFL (most conservative) to 40% LFL (least conservative)
UK HSE	United Kingdom Health and Safety Executive. A work, health and safety regulator similar to SafeWork Australia
UPG	Unit Process Guidelines. Describe the performance characteristics of a process, validation criteria and operating modes. Some overlap with SOP
UEL/UFL	Upper Explosive or Flammability Limit. The concentration of flammable gas, vapour or mist in air above which an explosive gas atmosphere will not be formed
WHS	Workplace Health and Safety
Vapour pressure (P_v)	Pressure exerted when a solid or liquid is in equilibrium with its own vapour. It is a function of the substance and temperature
Ventilation	Movement of air and its replacement with fresh air due to the effects of wind, temperature gradients or artificial means (for example, fans and extractors)
VOC	Volatile Organic Compound
VT	Ventilation Threshold value. The modified threshold value for the selection of a ventilation rate. Ranges from 5% LFL (most conservative) to 25% LFL (least conservative)
Zones **(Zone 0, Zone 1, Zone 2)**	Hazardous areas are classified into zones based upon the frequency of the occurrence and duration of an explosive gas atmosphere as follows: Zone 0: An area in which an explosive gas atmosphere is present continuously or for long periods or frequently Zone 1: An area in which an explosive gas atmosphere is likely to occur in normal operation occasionally

Abbreviation	Definition
	Zone 2: An area in which an explosive gas atmosphere is not likely to occur in normal operation although if it does occur will exist for a short period only

RELEVANT STANDARDS REFERENCE LIST

Standard	Standard Name
AS 1375:2013	Industrial fuel-fired appliances
AS 1768:2021	Lightning protection
AS/NZS 3000:2018	Electrical installations (known as the Australian/New Zealand Wiring Rules)
AS/NZS 3814:2018	Industrial and commercial gas-fired appliances
AS 4761.1: 2018	Competencies for working with electrical equipment for hazardous areas (EEHA)
AS/NZS 5601.1:2022	Gas installations, Part 1: General installations
AS/NZS 60079.10.1: 2009	Explosive atmospheres, Part 10.1: Classification of areas — Explosive gas atmospheres
AS/NZS IEC 60079.10.1: 2022	Explosive atmospheres, Part 10.1: Classification of areas — Explosive gas atmospheres
AS/NZS IEC 60079.10.1:2022 Sup 1:2022	Explosive atmospheres — Classification of areas — Explosive gas atmospheres — Commentary (Supplement 1 to AS/NZS IEC 60079.10.1:2022)
AS/NZS 60079.10.2:2016	Explosive dust atmospheres
AS/NZS 60079.13:2019	Explosive atmospheres equipment protection by pressurized room 'p' and artificially ventilated room 'v' (IEC 60079-13:2017 (ED 2.0), MOD)
AS/NZS 60079.14:2022	Explosive atmospheres, Part 14: Design selection, erection and initial inspection (IEC 60079-14:2013 (ED.5.0) MOD)
AS/NZS 60079.17	Explosive atmospheres, Part 17: Electrical installations inspection and maintenance (IEC 60079-17, Ed. 5.0 (2013) MOD)
AS/NZS 60079.29.1:2017 + A1	Explosive atmospheres gas detectors - Performance requirements of detectors for flammable gases
AS/NZS 60079.29.2 :2016	Explosive atmospheres gas detectors - Selection, installation, use and maintenance of detectors for flammable gases and oxygen
AS/NZS 60079.29.4:2011	Explosive atmospheres gas detectors - Performance requirements of open path detectors for flammable gases (Reconfirmed 2022)
CLC/TR 50427:2004	Assessment of inadvertent ignition of flammable atmospheres by radio-frequency radiation – Guide
IEC 60079-10-1: 2020	Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmosphere

Standard	Standard Name
DIN EN 1127-1:2019	Explosive atmospheres - Explosion prevention and protection - Part 1: Basic concepts and methodology
(IGEM)/SR/25	Edition 2. Hazardous area classification of natural gas installations
NFPA 820	Standard for fire protection in wastewater treatment and collection facilities

1. INTRODUCTION

Around Australia, the sewerage system encompasses thousands of kilometres of pipework, maintenance structures and pumping stations, and hundreds of treatment plants. Managing the potential for explosive and flammable atmospheres in these assets is critical to the safety of workers and the public.

1.1 Need for the guideline

In both regional and urban areas potentially flammable atmospheres are occurring in wastewater assets as decaying sewage generates gases or as non-sewage substances are introduced into the sewerage system. Flammable or explosive atmospheres have been responsible for incidents and near misses over the past 20 years, such as the below examples from the Australian wastewater industry:

- Explosion in a digester gas cogeneration system causing injury to a worker.
- Explosion in a residential home, where methane gas backflowing from a pumping station was ignited, causing damage to a resident's bathroom. This is a significant near miss.
- Ignition of the atmosphere underneath a wet well pumping station causing forceful ejection of the pumping station lid and maintenance hole lids. This is a significant near miss.
- Ignition of the atmosphere at an inlet works due to repair work on a connected pipe. This is a significant near miss.

These and other incidents nationally and internationally have increased awareness of issues regarding explosive atmospheres in wastewater assets. As a result, many water agencies have created their own internal management plans to advise on minimum standards regarding potentially explosive atmospheres. These plans have been aimed primarily at assets in treatment plants and have generally been developed in isolation or with limited cross-collaboration with broader industry.

While there are relevant Australian standards for the determination of zoning and selection of equipment in hazardous areas, the existing standards can be ambiguous as to their direct application to common water industry practices. Internationally there are examples of wastewater assets being zoned using a risk-based approach, using both national level guidelines and those developed by individual water agencies.

To provide a unified, nationally accepted approach, the working group identified three key issues:

- Hazardous area consultants from different industry backgrounds are unaware of the specifics of wastewater collection and treatment, leading to a lack of consistency in asset classification across asset bases.

- A lack of broad industry knowledge regarding hazardous atmospheres and their causes in wastewater linear infrastructure.
- The desire to provide a framework which could provide consistency and reference to industry on the classification of wastewater networks and treatment plants, while providing some flexibility which allows for the circumstances unique to each water agency.

This document aims to address these knowledge gaps and provide a consistent basis from which water agencies can determine their approach to hazardous area management in their asset base. This content is intended to inform and recommend rather than prescribe, as it is recognised that each agency will have different standards and risk frameworks. It is also intended that this document be live, evolving along with ongoing industry feedback, data sharing and changing Australian standards and legislation.

1.2 Explosive atmospheres, duty of care and relevant legislation

A hazardous area is defined in AS/NZS 60079.10.1:2022 as:

> *"[An] area in which an explosive gas atmosphere is or may be expected to be present, in quantities such that special precautions for the construction, installation and use of equipment are required"*

This aligns with the definition provided in the *Model Work Health and Safety Regulations,* most recently updated in 2022:

> *"(a) an explosive gas is present in the atmosphere in a quantity that requires special precautions to be taken for the construction, installation and use of plant"*[4]

Equipment in a hazardous area in any new installation is required to be classified in accordance with AS/NZS 60079.10.1 (or AS/NZS 60079.10.2 for areas with potential for formation of explosive atmospheres due to combustible dusts) by *Electrical Installations "Wiring Rules"* AS/NZS 3000:2018. Compliance with the *Wiring Rules* is a mandatory legal requirement. In NSW, for example, compliance with AS/NZS 3000:2018 is required under the *Gas and Electricity (Consumer Safety) Regulation 2018*[5]. In Victoria, compliance is required in accordance with the *Electricity Safety (General) Regulations 2019*[6]. All states and territories reference the *Wiring Rules* in their electrical safety legislations or regulations.

Persons Conducting a Business or Undertaking (PCBUs) are responsible for classification of hazardous areas, according to Clause 7.7.2.1 of AS/NZS 3000:2018.

> *"The responsibility for classification of a hazardous area (see Clause 1.4.15) rests with the persons or parties in control of the installation. The requirements are*

[4] **Model WHS regulations**

[5] **Gas and Electricity (Consumer Safety) Regulation 2018**

[6] **Electricity Safety (General) Regulations 2019**

contained in AS/NZS 60079.10.1 for gas or vapour and AS/NZS 60079.10.2 for combustible dust"

Both the federal Safe Work Australia *Model Work Health and Safety Regulations* and some of the state legislations which have adopted the text of the *Model Work Health and Safety Regulations* in their entirety, refer to hazardous atmospheres. A hazardous atmosphere is defined as follows:

"(2) An atmosphere is a hazardous atmosphere if:

(a) the atmosphere does not have a safe oxygen level; or

(b) the concentration of oxygen in the atmosphere increases the fire risk; or

(c) the concentration of flammable gas, vapour, mist or fumes exceeds 5% of the LEL[7] for the gas, vapour, mist or fumes; or

(d) combustible dust is present in a quantity and form that would result in a hazardous area."[8]

Managing the risks of hazardous or explosive atmospheres in the workplace is a requirement in the model code of practice issued by Safe Work Australia, the federal safety regulatory authority[9]. This code of practice states that:

"*A person conducting a business or undertaking must manage the risk to health and safety associated with a hazardous atmosphere or an ignition source in a hazardous atmosphere at the workplace.*"[10]

A <u>hazardous atmosphere</u> and a <u>hazardous area</u> are therefore defined differently. Management of both hazardous areas and atmospheres is a requirement of workplace health and safety legislation, depending on the legislation of the state in question. Both require management of the air volume of a space, to ensure that the Lower Flammability Limit or Lower Explosive Limit (LFL/LEL) of any gas, vapour, mist or fumes is controlled below a certain threshold. The value of this threshold for **hazardous atmospheres** (intended to prevent harm with personnel access) is significantly less than that for **hazardous areas** (intended to prevent explosions).

To resolve this discrepancy, the Australian Standard committee "Classification of hazardous areas due to explosive atmospheres" (committee number MS-011) in 2022 issued a ruling to AS/NZS 60079.10.1 to clarify their position on the 5% LEL value mandated for hazardous atmospheres being used for hazardous area design. The text of the ruling is as follows:

"*Question: Do hazardous area classifications need to account for concentrations of flammable gas or vapour in air as low as 5% LEL as indicated in the WHS regulations*

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[7] **LEL is Lower Explosive Limit, also called Lower Flammability Limit, the minimum concentration of a substance in air at which an ignition can cause an explosion**

[8] **Model WHS regulations**

[9] **Each State in Australia has their own Work Health Safety regulator which determines whether a Code of Practice defined by Safe Work Australia is applicable to that State.**

[10] **SafeWork Australia, Managing Risks of Hazardous Chemicals in the Workplace: Code of Practice, 2020, ISBN 978-0-642-78335-6**

from several states, New Zealand, and the Safe Work Australia model WHS regulations for hazardous atmospheres?

Ruling: No. Hazardous area classification to all editions of AS/NZS 60079.10.1 is intended to account for potential concentrations above a value of 5% LEL. The value selected may depend on the application and safety factors used. Situations where the concentrations are unlikely to exceed 25% LEL would typically result in a classification of non-hazardous.

For example: AS/NZS 60079.10.1: 2022 Figure D.1 is not based on flammable gas concentrations as low as 5% and AS/NZS 60079.13 and AS/NZS 60079.29.2 recommend values much higher than 5% LEL for both alarm and/or isolation of non-Ex electrical equipment as relevant to the application."

A further ruling clarifies that this applies to the other pillar of hazardous area design, AS/NZS 60079.14 as below:

"*Question: Is Ex Equipment needed where the concentration of flammable gas or vapour is as low as 5% of the LEL as indicated in the WHS regulations from several states, New Zealand, and the Safe Work Australia model WHS regulations for hazardous atmospheres?*

Ruling: No. Ex equipment is only required for the region defined as a hazardous area to AS/NZS 60079.10.1 – see ruling to AS/NZS 60079.10.1.

However:

- *AS/NZS 60079.10.1 clause 1 identifies that larger distances might need to be applied for other ignition sources. In such cases, larger distances could account for flammable gas and vapour with concentrations much less than those concentration typically used for the classification of hazardous areas and also for leak conditions that exceed the conditions used as the basis for the classification of hazardous areas*
- *Risk assessment may also be used to assign a required Equipment Protection Level to areas which would otherwise be considered non-hazardous. Refer to the risk assessment provisions and associated appendix for Equipment Protection Levels in AS/NZS 60079.14 for further information"*

The requirement to manage **hazardous areas** therefore applies to any space where a potentially explosive atmosphere may occur, whether occupied or not. **Hazardous atmospheres** are those atmospheres which are occupied by personnel and the reduced threshold for concentrations of flammable substances in air reflects the need to protect personnel from the potential risk of explosion. A good example is a large gravity sewer. While it may be classified as a non-hazardous area, it could still contain a hazardous atmosphere when personnel are entering the space for inspection and maintenance.

Water agencies encounter situations where hazardous atmospheres might exist in two common scenarios:

- Where staff or contractors enter a wet well, maintenance structure or gravity main to carry out repair, maintenance, or inspection activities.

- Where staff or contractors work in or adjacent to an area of a treatment plant which may contain a flammable atmosphere, for example an inlet works or a digester.

For these scenarios, water agencies have the same responsibility and duty of care that any PCBU has to its employees or contractors.

In the case of a wastewater treatment plant, where access to the plant is generally secure and members of the public are under the supervision of trained staff, the risk of an accidental or unmitigated exposure to a hazardous atmosphere is low.

In the case of linear infrastructure, where assets do not have permanent staffing available and in some cases are unsecured against trespass, it is possible that a member of the public could become exposed to a hazardous atmosphere, for example at a malfunctioning inlet cowl, a leaking maintenance hole or an open pumping station wet well. This might constitute an exposure of a visitor to a water agency's "workplace atmosphere", namely an atmosphere over which a water agency has control as a PCBU. It is important that this risk is considered in the design of future assets and in refurbishment of existing assets, based on internal or external engineering judgement and legal advice in some cases. It is also important to consider toxicity. An area could be underneath the required thresholds for a hazardous atmosphere but exceptionally harmful when considering exposure to toxic chemicals and substances.

This guideline is intended to provide information and advice for the management of **hazardous areas**. Some of this information could have some overlap with management of hazardous atmospheres. By being mindful of their obligations for the management of both hazardous areas and hazardous atmospheres, water agencies (acting as a PCBU) can comply with their duty of care to their staff, contractors and the community they serve.

1.3 Industry engagement

As part of the development of this guideline, a working group of water agencies was engaged in an industry survey. This industry survey asked questions about:

- Flammable atmospheres in the water agency’s asset base
- Management of these atmospheres in the water agency’s assets
- Areas of further interest or desires for further knowledge
- Current monitoring practices.

Following this survey, key stakeholders from each of the participating water agencies were interviewed. Survey results and knowledge gaps were discussed.

The strong desire of the working group was for information on monitoring and instrumentation. The driver behind this was a desire to better understand the formation of flammable atmospheres within a sewer network (otherwise known as linear infrastructure) context. There was much less interest in wastewater treatment plant applications indicated on the survey and follow up interviews revealed this was because there was generally an organisational history in classification of hazardous areas in these areas which was working well.

Following on from this data capture, the next preference was to understand how to use this data to provide an input to the hazardous area classification. The broad consensus was that the classification of the area was the difficult point for many water agencies. Where the classification was resolved, the following steps in the process of hazardous area engineering (design, installation and maintenance) were well understood, either in house or through the use of external expertise.

For this reason, this guideline focussed its effort on providing guidance to the industry in hazardous area classification, with a particular focus on developing a tool for use in a sewer network application.

1.4 Structure

This guideline is structured in the following way:

- Chapter 1 introduces the guideline, its intent, some legislative background and a discussion of issues not discussed by the guideline as they are covered elsewhere.
- Chapter 2 discusses flammable atmospheres which could be present in the wastewater system and their likely sources, providing some examples of common LFL events.
- Chapter 3 provides guidance and recommendations on monitoring instruments and sampling campaigns.
- Chapter 4 discusses how this guideline interacts with current Australian standards and provides guidance and interpretation for the water industry.
- Chapter 5 provides a framework for generating a classification for wastewater conveyance linear infrastructure.
- Chapter 6 provides guidance and advice on common wastewater treatment processes and a suggested minimum classification or suggested classification logic for use in detailed zoning exercises.
- Chapter 7 provides commentary on zoning extents for linear infrastructure and wastewater treatment plants and the importance of well-designed ventilation.
- Chapter 8 discusses mitigation measures and emergency responses to a flammable atmosphere, including guidance on implementation.
- Chapter 9 provides selected case studies for reference, using the guidelines to classify them.
- Chapter 10 provides zoning diagrams for some common cases in network applications.

1.5 Use of the guideline

This guideline is intended to inform the water industry by providing reference information for hazardous area professionals, water agencies and design engineers about the factors which may influence the likelihood of hazardous areas in wastewater networks and wastewater treatment plants.

Although the advice provided in this guideline is intended to inform future works in both network and treatment environments, there are many existing assets in use nationally which are not designed according to the concepts and recommendations outlined herein. This represents a challenge for water agencies, as there are many assets of concern present in their networks which have not previously been classified. For example, there are currently pumping stations, zoned as non-hazardous, which have flammable atmospheres regularly exceeding 100% of the LFL. These assets are in highly developed urban areas, where an ignition or explosion could present a risk to the community.

This guideline recommends that all future greenfield work and brownfield upgrade, repair or rehabilitation work considers hazardous areas. This work is additional to current practice at many agencies and will therefore have a cost impact. However, as more monitoring data is collected by water agencies, this data can be used as a reference in greenfield constructions and the costs associated with the additional work will most likely decrease over time. This guideline encourages data sharing between agencies in the same state, or agencies with similar asset profiles, to create a wealth of sample data which can be used to inform planning and decision making.

1.5.1 High probability locations

Water agencies are encouraged to prioritise the investigation of potentially explosive atmospheres in their asset base for the following two types of existing assets:

- Previously un-classified assets which have some or all of the features of concern listed below.
- Assets which have been previously classified (either formally or informally) as non-hazardous which have some or all of the features of concern listed below.

This guideline identifies features of concern, which indicate an increased probability of a potentially explosive atmosphere, as those assets which have the following characteristics:

- Be in a predominantly industrial area or convey predominantly industrial influent.
- Be the subject of odour complaints, especially where these complaints are of a nature **other than** “rotten egg” or “sulphur” smells, for example “solvent” or “chemical” odour.
- Have observed histories of oily sheen, chemical or unusual scum on the wastewater surface.
- Have frequent confined space entries where greater atmospheric control is needed due to the 5% LFL limit being breached.

- Have a monitoring history which demonstrates the need to change the zoning of the asset.
- Have unsecured access to the sewerage system such as road dump points (for caravans/ motorhomes).
- Have upstream conditions suitable for the generation of methane gas.

Due to the volume of assets across Australia's wastewater network which have not been previously classified, it can be difficult for water agencies to prioritise which assets should be considered first. This prioritisation of which existing assets to investigate for potential classification is best achieved through a risk assessment approach.

Where existing classifications are being investigated, this investigation should ensure that any monitoring data collected after the classification was undertaken has been taken into consideration and that all risk factors have been appropriately considered.

1.6 Areas not considered

To provide relevant and concise commentary, there are some areas which have a relationship with the management of potentially explosive atmospheres which are not covered by this guideline. They are discussed below.

1.6.1 Toxicity

One aspect which may occur simultaneously with an explosive atmosphere is a toxic or harmful atmosphere. The working group noted an incident where several workers who were preparing for entry into a sewage pumping station wet well were exposed to a toxic environment and were subsequently hospitalised. No explosion occurred. The hospitalisation occurred due to the fumes of solvents, which had been discharged into the sewer, escaping into the atmosphere. There will be cases whereby the threshold value decided upon by a water agency for control or management of an explosive atmosphere will be insufficient to control harmful exposure to toxic or poisonous substances present in the atmosphere. This is particularly relevant in illegal discharges associated with illicit drug manufacture.

Exposure standards are published by the federal safe work authority, Safe Work Australia[11]. These are generally incorporated into law by the various state-based safety bodies, with any state-based changes being considered prior to adoption. One key example of a compound found in trace amounts in most gravity sewers in the country is gaseous hydrogen sulphide (H_2S). Due to the large amount of H_2S required to meet the LFL, it is unlikely to be a contaminant of concern with regards to its explosivity risk. However, with Workplace Exposure Standards (WES) mandating an 8-hour time weighted average of 10 ppmv[12], H_2S may become a contaminant of concern for the design of any ventilation system. It should therefore not be assumed that control of explosive atmospheres is sufficient to control toxicity

[11] **Workplace exposure standards for airborne contaminants (2019) – note most of these limits are under review and may change.**

[12] **At time of writing, Safe Work Australia has nominated a reduction in this limit to 1ppmv.**

risks; these risks should be assessed independently for their impact on wastewater infrastructure design.

In line with the above, this guideline does not provide advice regarding procedures of safe work and the control of atmospheres. An example of this is entry into a gravity sewer for cleaning or de-silting, whereby gas monitoring and ventilation are required as part of legal minimum requirements for confined space entry, as per AS 2865:2009. In this case, procedures of safe work and the control of atmospheres is left to the individual agency to determine in accordance with their local legislative environment.

1.6.2 Chemical compatibility

An area which is also not covered in this guideline is explosions or auto-ignition caused by chemical incompatibility and reaction.

There are many instances where chemicals coming into contact with each other can cause explosive reaction (such as flash vaporisation) or explosive compound formation and subsequent detonation. Two such examples of this are sodium hypochlorite and acids (flash vaporising and forming steam/chlorine gas), and mixture in air of sodium hypochlorite and ammonia (forming a UV sensitive high explosive, nitrogen trichloride). A further example is caustic soda and aluminium (producing hydrogen gas). These reactions and reaction products can be significant risks, causing injury or asset damage from either an explosion or toxic atmosphere.

Storage and the use of chemicals should be checked by safety-in-design procedures prior to implementation. Other than the storage of flammable liquids and gases and potential flammable atmosphere generation, chemical incompatibility or other aspects noted above are not covered in this guideline. Water agencies are however encouraged to consider these issues during normal safety-in-design protocols in the design of such facilities. With robust safety-in-design procedures the risk of flammable atmosphere generation is low in a treatment plant environment. Although possible in a wastewater network environment, mixtures of this nature are generally not encountered in these settings due to the diluting effect of the wastewater.

1.6.3 Dust hazards

As part of standard hazardous area classification and as per the definition of a hazardous area, the risk of a combustion due to dust generation should also be considered. In the conveyance of wastewater, combustible dusts are seldom encountered. In a wastewater treatment plant environment, there are a few areas where the potential for a hazardous area due to combustible dusts might need to be defined. Examples of possible combustible dust hazardous areas include:

- Powdered polymer preparation areas.
- Some chemical areas, such as granular calcium hypochlorite.

- Activated carbon installations, such as those in use for odour control systems (note that powdered activated carbon or granular activated carbon systems, such as those found in drinking water treatment, may also fall under this category).
- Sludge silos, where sludge has dried, and combustible dusts might form a cloud if dislodged from silo surfaces.
- Sludge drying or pyrolysis/gasification/incineration processes, where heat is being applied to thermally destroy contaminants or reduce sludge volumes, and where off-gas and ash require careful management.

These areas require special consideration and are often resolved in conjunction with a supplier, or with specific reference to the actual installation. Due to the variances in factors for combustible dusts it is difficult to discuss combustible dust hazardous areas in detail or make any general recommendations. This guideline therefore does not apply to these areas. AS/NZS 60079.10.2 applies to the classification of hazardous areas associated with combustible dust hazards.

1.6.4 Sources of ignition

There are many potential sources of ignition of a flammable atmosphere that can occur during normal or abnormal operation. These include, but are not limited to:

- Mechanical spark caused by installed equipment which is not inherently safe for the atmosphere in which it is used.
- High ambient or process temperatures.
- Mechanical spark caused by temporary equipment which is not inherently safe for the atmosphere in which it is used.
- Reactions such as the thermite reaction, which are created by striking an aluminium object with a rusted iron (iron oxide) object.
- Pyrophoric sparks, which can occur when flammable gases and vapours and oxidised (rusted) iron react to create iron sulphide. Iron sulphide, when exposed to oxygen, rapidly releases large amounts of heat.
- Electrostatic charge.
- Ultrasonic and radar signals from instrumentation.
- High strength electromagnetic fields from nearby radio frequency transmitters, which can lead to sparks within a hazardous area depending on a number of factors. For detailed information refer to AS/NZS 60079.14 and CLC/TR 50427 – Assessment of inadvertent ignition of flammable atmospheres by radio-frequency radiation – Guide. Radio frequency power below 6W for Group IIA gases or vapours, or 3.5W for Group IIB gases and vapours is accepted without further assessment.
- Work activities in and around the asset, such as:
    - Welding, including plastic welding
    - Grinding

    - Drilling
    - "Hot" cutting
    - The use of certain manual tools.
- Smoking around assets.
- Nearby combustion engine driven equipment such as lawnmowers or vehicles.
- Improper electrical installations or electrical failures, including degradation over time (for example due to long-term exposure to H_2S).
- Bushfire embers, or nearby fire, where a Bushfire Attack Level (BAL) is present.

It should be noted that there can be other external factors that can lead to sources of ignition, such as embers in the air in bushfire affected areas or in campgrounds where fires are allowed, which the zoning of an area and the subsequent equipment protections put in place will have no ability to impact.

The source of ignition does not impact the hazardous area assessment, as the assessment is based on the likelihood of a hazardous area occurring and not the likelihood of that atmosphere igniting. The zoning of a hazardous area and the required equipment to be placed inside the zone as well as other administrative procedures is intended to protect against the likelihood of a flammable atmosphere igniting.

1.6.5 Prescription of hazardous areas

This guideline does not provide prescriptive, detailed design level advice for classification of hazardous areas. Although there are some reference zoning diagrams which can be used and adapted by water agencies, this guideline cannot replace the need for detailed design involvement by a qualified, competent design professional. The diagrams are intended as examples to assist hazardous area professionals and cannot be used in replacement of an assessment.

2. FLAMMABLE ATMOSPHERES IN THE SEWERAGE SYSTEM

2.1 Contaminants of concern

2.1.1 Methane and hydrogen sulphide

2.1.1.1 Natural sources

Traditionally, analysis of explosive atmospheres in wastewater assets has covered the two major gaseous by-products of the natural organic material present in raw sewage; the first of these is hydrogen sulphide (H_2S). When sulphide has developed in a sewer, often due to long retention times and the impact of biomass in the pipework (particularly sulphate reducing bacteria (SRB) in the biofilm under full pipe conditions), some of the dissolved sulphide can be present in the form of H_2S. Molecular H_2S can then be released from the liquid phase into the gas phase. The relationship between different sulphide species in sewerage is described by Equation 1 below and a conceptual view is provided in Figure 2-1. The figure is a visual representation of the fate of sulphur in a sewer pipe.

Equation 1: $S^{2} + 2H^{+} \leftrightarrow H + HS \leftrightarrow H_2S$

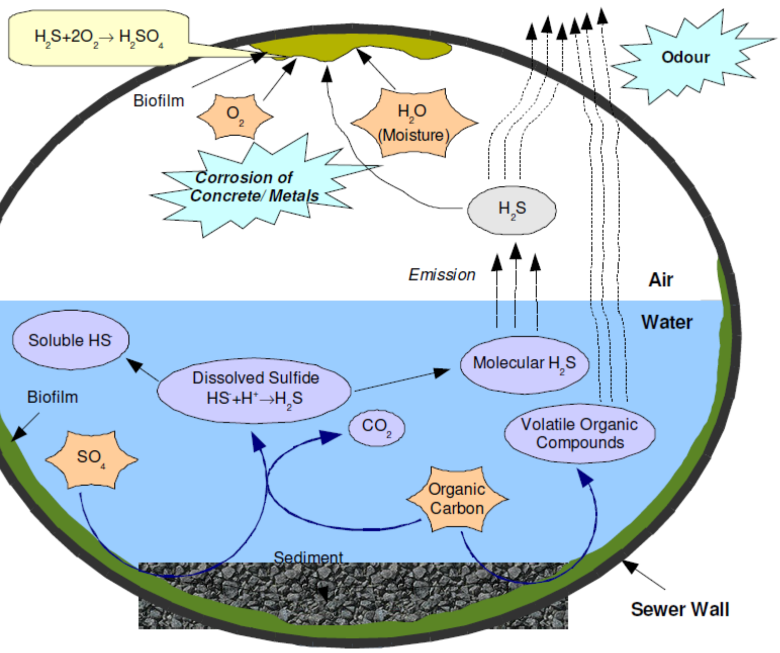

Figure 2-1: This figure shows the pathway by which sulphuric acid is created in wastewater networks (adapted from Capati et al, 2008)[13]

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[13] **Capati B., Corrie, S., Sikder S., Hollingsworth A., 2008, H_2S Modelling – a step ahead to minimum odour and corrosion, MWH Australasian Water & Sewer System Modelling Seminar**

H_2S has a LFL of 4% by volume, corresponding to 40,000 parts per million by volume (ppmv). These concentrations are exceptionally rare in practice, with more common concentrations in the range of 1 to 1,000 ppmv depending on the hydraulic characteristics of the system. H_2S rarely becomes a contaminant of concern in the formation of explosive atmospheres in wastewater systems, primarily due to the sulphur content of the wastewater being insufficient to generate the large concentrations required for explosive atmospheres, but also due to the long hydraulic residence times (HRTs) and other conditions required to generate sufficient H_2S. It remains a primary concern for water agencies due to its health and safety impacts, its potential to form sulphuric acid by thiobacillus and corrode the internal wall of steel or cement lined pipelines and its odour emissions.

In competition with the SRBs for the hydrogen released by the organic matter in wastewater are methanogenic bacteria (MB). Gaseous methane production is positively correlated with, among other things, increasing HRT of wastewater in the sewerage system, as methane and sulphide are the final products of bacterial metabolism. A diagrammatic representation of the process by which the chemical oxygen demand (COD) in wastewater is biodegraded is presented in Figure 2-2[14].

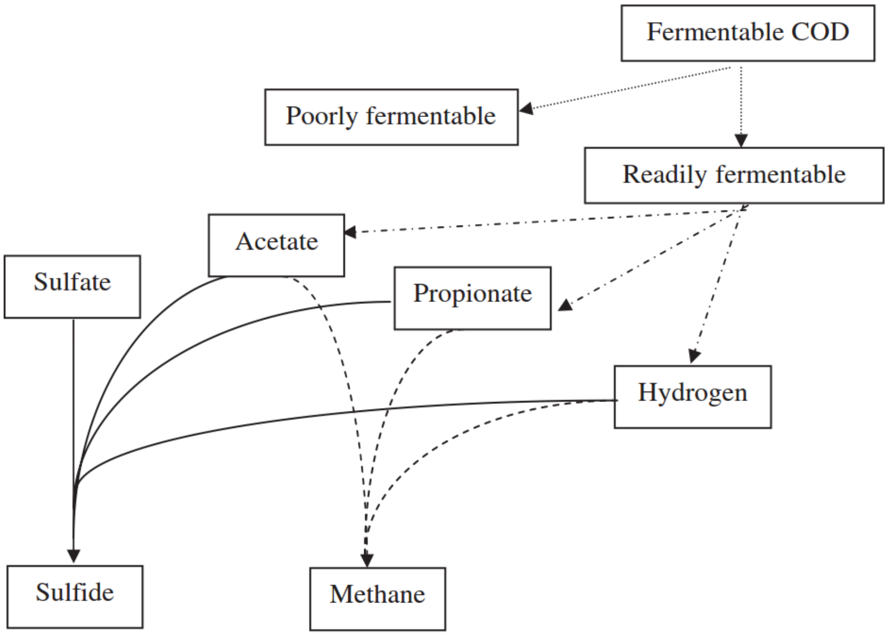

Figure 2-2: Generation of methane and sulphide in sewerage systems[15]. Solid lines indicate most common development pathways, dotted lines indicate less common pathways

Methane has a LFL of 4.4% by volume in air and is a contaminant of concern in the formation of explosive atmospheres in wastewater treatment facilities. It is of particular concern in sludge storage and processing, as well as (in certain instances) in the sewerage network for example in structures with very high HRT. Methane is lighter than air and therefore the gas will tend to rise and exit the structure from any leakage points or vent shafts. The weight of

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[14]Guisasola, A., de Haas, D., Keller, J. and Yuan, Z. (2008). Methane formation in sewer systems. Water Research, 42(6-7), pp.1421–1430

[15] ibid

the substance is such that buoyancy induced movement may even dominate a ventilated space.

It is still common practice for hazardous area assessments of wastewater infrastructure to focus primarily on hydrogen sulphide[16] and methane. The engineering basis of this has historically been that "normal operation" of the sewerage system is predominantly the transport of municipal wastewater, with minor volumes of industrial wastewater not contributing substantially due to the controls in place by the organisation's trade waste policy. If this is the case, the chemical reactions previously discussed lead primarily to these two contaminants of concern. In certain cases, such as an anaerobic sludge digester, this largely holds true. In the experience of the working group however, other compounds which are encountered in wastewater networks such as volatile organic compounds (VOCs) can have a significantly greater effect.

Whilst H_2S is often considered problematic from a corrosion and odour point of view in full pipe conditions with HRTs of around 4 – 12 hours within linear assets, methane becomes more prevalent in longer HRTs in the order of 12 hours or more. These cases tend to be where the sewer begins to act as an anaerobic digester. The methane generation reactions can occur more quickly in cases where:

- The Chemical Oxygen Demand (COD) is higher than normal.
- The temperature is higher than normal.
- The pH is lower than normal.
- The pipe size is less than DN200.

And can occur slower where:

- The COD is lower than normal.
- The temperature is lower than normal.
- The pH is higher than normal.
- The pipe size is greater than DN300.
- There is chemical dosing (either continuous or intermittent) to mitigate H_2S or methane generation.

Methane tends to form more readily in sewer sediments, meaning it can be found in flat sewers that accumulate debris. Methane levels around the LFL have been detected in many sewers in Australia and across the USA[17], some with identified causes as being biological activity from upstream full-pipe conditions while others being from biological activity in sediment.

With H_2S, a large portion of the substance remains within the wastewater (at regular pH and turbulence conditions) even when a full pipe breaks to gravity. This allows H_2S to be an issue

[16] The LFL for H_2S is 40,000 ppm (4%). It is very rare for this level to occur in wastewater systems which are normally sulphur limited. The biological processes that generate H_2S are similar to those that generate methane, and it is more common for methane to reach the LFL well before H_2S does.

[17] More information on methane generation and measurement can be found in Liu, Y., Bing-Jie, N., Sharma, K.R., Yuan, Z., 2015, Methane emissions from sewers, Sci. Total Env., 40-51, 524-525

at further locations downstream. With methane, however, the majority of it will be liberated once a full pipe breaks to gravity. This is due to H_2S having a solubility approximately 160 times that of methane. This means that, unlike H_2S, methane is often (but not always) only an issue at the end of the full pipe in which it is generated, be that a gravity main, maintenance hole, pumping station or inlet works.

2.1.1.2 Other sources of methane

Natural gas pipelines (either main carriers or reticulation pipes) can sometimes run near water or wastewater assets, as well as within wastewater treatment assets to service boilers, hot water systems or co-generation engines. Natural gas contains predominantly methane and is given an odour by the addition of mercaptan at the processing plant. Ruptures of natural gas pipelines leading to ingress of natural gas into wastewater assets are abnormal, however they have been known to occur.

In addition to gas pipelines, sewer mains traversing geographical features such as coal pockets or within proximity to landfills have been known to result in gas migrating into the underground pipe headspace. Such an instance resulted in the Abbeystead explosion in 1984, which caused multiple fatalities at a valve house.

2.1.2 Hydrocarbons

Hydrocarbons are a group of chemicals which contain combinations of hydrogen and carbon. Although methane is a hydrocarbon, when referring to hydrocarbons common industry practice is to refer to these substances being introduced into the sewerage system either via trade waste discharge or other sources. This is distinct from methane, which can occur naturally in wastewater systems through fermentation and the influence of MB. Hydrocarbons are used in all facets of modern life, particularly in the form of fuels such as natural gas, petrol and diesel. A feature of natural gas and petrol is their combustibility at standard room temperature and pressure; this highly exothermic oxidation-reduction reaction produces carbon dioxide and water. Hydrocarbons generally do not dissolve in water, meaning they can persist in the sewerage system for long periods of time and have a high risk of flammable vapour formation as they settle on the surface layer of the wastewater. This leads to an increased risk of explosion.

Petrol has a LFL of 1.4%, diesel fuel has a LFL of 0.6% and natural gas has a similar LFL to that of methane, 4.4%. The specific physical and chemical properties of the hydrocarbon also affect the likelihood of a explosive atmosphere; diesel, with its higher auto-ignition temperature and flash point, is less likely to cause an explosive atmosphere than petrol[18].

Some hydrocarbons of common use are mixtures of different hydrocarbons. Often the mixture as a whole, such as petrol, has different physical attributes, like vapour pressure and LFL, than its constituent parts. A sewer, particularly a shallow gravity sewer, can provide a large surface area for the mixture of hydrocarbons to evaporate. The evaporation process can act somewhat like a distillation system whereby one part of a mixture is separated first,

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[18] **Diesel is considered a combustible rather than a flammable liquid. Refer to Supplement 1 of AS/NZS 60079.10.1:2022 CB7.1.(b)**

followed by another and so on. This is generally the case where there are large areas for evaporation that are not prone to washout, such as in shallow gravity sewers or sewer pumping stations that do not have capacity to remove floating materials.

When conducting explosive atmosphere assessments on hydrocarbons care should be taken as to whether the hydrocarbon should be treated as a mixture or as the components of the mixture, depending on the evaporative conditions present.

A broader description of volatile organic compounds (VOCs) (of which hydrocarbons are a subset) is provided below.

2.1.3 Volatile Organic Compounds

Volatile organic compounds (VOCs) can be generalised as organic compounds that have a high vapor pressure and low water solubility. VOCs are typically industrial solvents such as trichloroethylene, fuel oxygenates such as methyl tert-butyl ether (MTBE), or by-products produced by chlorination in water treatment such as chloroform. They are often components of petroleum fuels, hydraulic fluids, paint thinners, and dry-cleaning agents. VOCs are common ground-water contaminants in remediation sites where heavy industry has historically been present.

VOCs can contribute significantly, or solely be responsible for, an explosive atmosphere formation within a wastewater network or treatment plant. A selection of VOCs is presented below with Table 2-1 providing more information, including LFLs and flash points[19].

2.1.3.1 Organic solvents

These chemicals are commonly used as surface preparation in certain coating or painting processes and as cleaning products in industrial processes. Some examples include:

- Methyl-ethyl-ketone (MEK)
- Methylamine
- Acetone
- Toluene
- Chlorinated hydrocarbons, which although not generally flammable, may breakdown with other products in the sewerage system to produce flammable atmospheres.

2.1.3.2 Organic industrial chemicals / precursor chemicals

These chemicals are present in manufacturing processes, for example in the production of PVC or PE, or in cosmetics or creams. Some examples include:

- Benzene
- Phenol
- Ethylene

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[19] **The flash point is the lowest temperature at which the vapours of the substance will ignite.**

- Styrene
- Butadiene.

2.1.3.3 Chemicals used in drug and pharmaceutical manufacture

These chemicals are used in pharmaceutical manufacture, and in the manufacturing of some illicit drugs. Some examples include:

- Methylamine
- Ethanol
- Ethyl ether
- Isopropanol
- Methanol (particularly in wastewater treatment where it is undiluted)
- Petroleum ether
- Phenol and 3- / 4-methylphenol
- Acetophenone.

2.1.3.4 Industrial products

These are paints, thinners and other products used both by residential and commercial customers. Some examples include:

- Formaldehyde (varnishes)
- Xylene (paints)
- Alcohols (cleaning agents)
- Acetic acid (cleaning agents).

2.2 Likely sources

Apart from methane and hydrogen sulphide, which occur via natural pathways (methane migration is also an issue, as noted above), other compounds which are at high risk of generating flammable atmospheres can come from a variety of sources, for example:

- Trade waste discharge by licensed dischargers, either declared and regular, declared and irregular or undeclared and irregular.
- Illegal dumping of material by members of the public or organisations.
- Illegal manufacturing processes, such as from undeclared organisations or the manufacture of illegal drugs.
- Infiltration of the stormwater system into the wastewater system, either through cross connection or through combined sewerage systems for transport of both stormwater and wastewater.

- At the release point of rising mains at discharge manholes or gravity sections where a drop in pressure is accompanied by a drop in methane solubility causing a rapid release of entrained gas.
- Migration of explosive gasses / vapours from underground sources such as coal fields, gas fields (especially those generated by fracking) and landfills into underground pipes and other assets.

In wastewater treatment plants, there are several likely sources of generation, release, or accumulation of these substances:

- In areas where sludge is treated or stored, strongly correlated with Solids Residence Time (SRT).
- In inlet works, which receive the combined effluent of a network and thus have a similar risk profile to that of a network asset.
- At the release point of rising mains at inlet works where a drop in pressure is accompanied by a drop in methane solubility causing a rapid release.
- In primary treatment areas, where an inlet works has not effectively removed contaminants.
- Chemical areas, which can store flammable chemicals such as methanol for use in wastewater treatment processes.

Table 2-1: Selected chemicals that can be found in the sewerage system, their LFL and some potential sources. Note this list is not exhaustive

Substance	LFL	Flash Point (°C)	Potential sources	Additional comments
Acetic acid	4%	39	Fungicide, household cleaner, industrial chemicals, food manufacture, hospitals	Carboxylic acids are flammable at high solution concentration; however, these are generally only likely found close to the discharge source.
Acetone	2%	-18	Solvent, fibreglass and plastics manufacture, pharmaceuticals, limited household products	Ketones are polar solvents, and this have solubility in water. However, these can form flammable atmospheres above sewage depending on specific ketone and mass transfer conditions
Acetophenone	1.1%	77	Solvents, drug manufacture, plastics manufacture, cosmetics, food manufacture	Insoluble ketone which can form floating liquid layer and flammable atmosphere.
Alcohols			Dependent on the substance	Primary, secondary and tertiary alcohols are polar

Substance	LFL	Flash Point (°C)	Potential sources	Additional comments
				solvents and thus soluble in water (variable depending on specific compound). Flammable atmospheres can be formed at high solution concentration; however, these are generally only likely found close to the discharge source.
Benzene	1.2%	-11	Petrol additive, solvent, plastics manufacture, printing industry, painting products	Barely soluble, simplest aromatic hydrocarbon which can form floating liquid layer and flammable atmosphere.
Ethanol	3.1%	12	Brewery waste, hospitals and other areas using ethanol for sterilisation, pharmaceuticals, plastics manufacture, cosmetics, solvent in other processes	Primary alcohol (see above), care should be taken downstream of facilities which produce or use alcohols. Commonly used for biocide qualities.
Ethyl ether	1.7%	-45	Plastics manufacture, pharmaceuticals, gunpowder solvent, cosmetics and beauty, petrol additive, paint products	Extremely flammable / volatile compound which rapidly forms flammable atmospheres.
Formaldehyde	7%	83	Disinfection, morgues and hospitals,	Flammable atmospheres are / can be formed at high solution concentration; however, these are generally only likely found close to the discharge source.
Isopropanol	2%	12	Solvents, electronics manufacture, coating manufacture, pharmaceutical, cosmetics, food manufacture	Miscible in water, however, can form flammable atmospheres depending upon concentration.
Methane	4.4%	-188	Naturally occurring in sewers	Known to leach into stormwater / sewage infrastructure when gas permeable pipes are used across coal / hydrocarbon bearing rock / ground. Ref: Abbeystead Disaster

Substance	LFL	Flash Point (°C)	Potential sources	Additional comments
Methanol	5.5%	9	Base chemical for acetic acid, formalin. Additive to natural gases, solvent, production of other chemicals such as chloromethane	Refer primary alcohols
Methylamine	4.2%	1.1	Chemical manufacture, tanning and dyeing processes, plastic manufacture, photography, solvent	Highly soluble in water, but at high concentrations liquid and vapour is extremely flammable
Methyl-ethyl-ketone (MEK)	1.5%	-9	Illegal drug manufacture, paint and similar products, fibreglass, and plastic manufacture	Soluble, but can form extremely flammable vapour clouds in right mass transfer conditions.
Natural Gas	4%	-188	Leakage of low/high pressure gas mains, buried natural gas deposits, LFL mix dependent	Mix of alkanes, alkenes and aromatic hydrocarbons
Petrol	1.4%	-43	Illegal dumping, accidental discharge, traces from sump wash out e.g., automotive industry, stormwater wash out at petrol stations	Petrol is a combination of compounds including benzene, toluene, xylene, ethyl benzene and others, each with varying volatilities. This causes changes of the flammable properties as it is passed down the sewer network, with insoluble volatile compounds being transferred large distances. Where possible use petrol components rather than generic "petrol" LFL
Petroleum ether	1.1%	-18	Solvents, laboratories, paints and coatings, pharmaceuticals	Insoluble, highly flammable liquid / vapour which will form flammable floating layer on water.
Phenol	1.3%	79	Plastics manufacture, pharmaceuticals, explosives	Highly soluble in water, and unlikely to be present is sufficient quantities to form a flammable atmosphere unless a large illegal dump occurs.

Substance	LFL	Flash Point (°C)	Potential sources	Additional comments
Styrene	1%	31	Plastics manufacture	Barely soluble, flammable compound that will form flammable floating liquid layer on water & corresponding flammable atmosphere.
Toluene	1%	4	Petrol additive, solvent, industrial paint products, plastics manufacture, chemical manufacture, beverage production	Sparingly soluble, flammable compound that will form flammable floating liquid layer on water & corresponding flammable atmosphere.
Xylene	0.9% to 1%	32	Automotive industry, paints, solvents, lubricants, printing, plastics manufacture, leather and tanning	Mixture of di-methyl benzene isomers – insoluble, highly flammable compound that will form flammable floating liquid layer on water & corresponding flammable atmosphere.

2.3 Difficulty in measurement

The different sources of flammable substances listed above have varying challenges in quantification and measurement, described and summarised in Table 2-2 below. As there is a strong relationship between HRT (and other factors such as COD, temperature, pH and surface area to volume ratios) and the presence of methane in a sewer system, this allows a degree of predictability as to where methane will occur. Additionally, there are models which can predict the generation of methane in a sewer system; this makes sampling campaigns relatively easy to target and short in duration. The review of land use and geological features near an asset will provide information on the risk of underground methane migration, which again makes sampling campaigns relatively easy to target and short in duration.

Table 2-2: Likely source and sampling characteristics, comparing the difficulty of various aspects of the sampling process for different categories of wastewater assets

	High hydraulic retention time catchments	Industrial catchments, combined systems	Cross connections, illegal dumping or drugs	Wastewater Treatment Plants
Sample Location Assessment	Easy	Easy/Moderate	Hard	Easy
Sampling Duration	Short	Moderate	Long	Short/Moderate

Sampling Difficulty	Easy	Moderate	Hard	Moderate

Explosive or flammable atmospheres are also likely to occur where the wastewater system has a large volume of industrial discharge relative to its residential connection (or where the industrial discharge is small in volume but from high risk sources) or is a combined catchment (that is where sewers convey both wastewater and stormwater). This is readily observable by the experience of many members of the working group (and international water authorities in the case of combined systems), who report increased issues in these areas. Due to this relationship, selecting sampling locations for a monitoring campaign is more straightforward although identifying an exact sample point can sometimes prove challenging. Discharge of contaminants of concern by trade waste customers may not always have malicious intent, as most licence to discharge agreements are limited to simple criteria such as flow, pH, temperature, COD, Biochemical Oxygen Demand (BOD) or solids. Some of these agreements prohibit the discharge of flammable liquids. However, very few of these agreements prohibit discharge based on the flammability of the atmosphere. For example, an industrial process may have fully defined their day-to-day discharge for the water agency but failed to consider their seasonal backwash with heavier concentrations of chemicals which may lead to an explosive atmosphere. This can make determining what to sample moderately difficult, as the typical discharges of the businesses connected to the network may not be wholly reflective of the contaminants of concern present over long periods of time. For this reason, sampling durations must be longer to capture seasonal processes.

In the case of illegal drugs or illegal dumping, members of the public are disposing of material which they are unwilling (in the case of the public) or unable (in the case of those manufacturing drugs) to dispose of through the proper channels. Certain factors may affect these discharges, such as a restriction of movement leading to increased residential discharge of residential quantities of paints, or illegal drug production rotating around a certain residential area. These kinds of discharges are difficult to predict without prolonged and constant monitoring and could be the source of a large variety of compounds.

In a treatment plant environment, process units are generally operated in a steady state fashion with closely monitored inputs and outputs. This allows easier location and duration selection, as the plant staff or design engineers will be familiar with the cycles of the plant's operation. However, it can still be difficult to identify contaminants of concern, particularly in pre-treatment and primary treatment modules which are highly reliant upon the feed network or those which are not operated in a steady state manner, which may include inlet works or septage/tanker receival facilities.

2.4 Examples of explosive atmospheres in wastewater and associated assets

Water agency experiences in Australia and internationally present numerous examples which demonstrate the occurrence and impact of flammable atmospheres being generated in wastewater networks. The events listed below can be attributed to specific causes, however, there are other events which have occurred which are yet to have their root cause identified. Some instructive examples are listed below.

2.4.1 Fuel dumps

A water agency in Australia encountered a situation where waste fuel was dumped into the wastewater system via a pumping station located in a marina. The fuel subsequently worked its way through the entire wastewater network and receiving works preliminary treatment facility. The discharge was noticed when the treatment plant operator observed the organic layer on the secondary treatment process, together with a strong odour. The network transited by the fuel was considered non-hazardous. The incident caused a major review of all network assets: some of which were reclassified as Zone 1 or Zone 2 environments.

Another water agency had two customers complain of a hydrocarbon smell, resulting in a call out. It was found that a pumping station in the network had a flammable atmosphere, as verified by a broad spectrum LFL monitor. The source was identified to be mostly petrol. Hazardous area certified fans were brought in to ventilate, with the pumping station discharged to a holding tank at a treatment plant. The contaminated sewage was gradually introduced into the plant to avoid upset of biological process. The police and fire brigade were called, alerted and on standby to mitigate potential impact on the public.

2.4.2 Illegal drug manufacturing

A water authority in Australia encountered a high concentration of VOCs while monitoring for other contaminants in their network and managed to isolate the discharge source to a certain location. After analysis of the contaminants, it was concluded that the source was a mobile drug lab, moving around a local area and operating out of different locations. The data recorded by the water agencies’ collection gas detection equipment (calibrated against isobutylene) over 9 days is shown in Figure 2-3, with the background levels reflective of a domestic catchment (0 to 10 ppm) for the first 3 days. The discharges of volatiles (shown by the 13 peaks) immediately reach the sensor maximum at 15,000 ppm and are thought to coincide with batch production of illicit drugs. These discharges not only cause a toxicity risk, but also a significant explosion risk. Given the recorded values, technology used, and calibration compound it is probable that these events exceeded 100% of the LFL. This water agency has since been working with relevant stakeholders to locate and mitigate these risks.

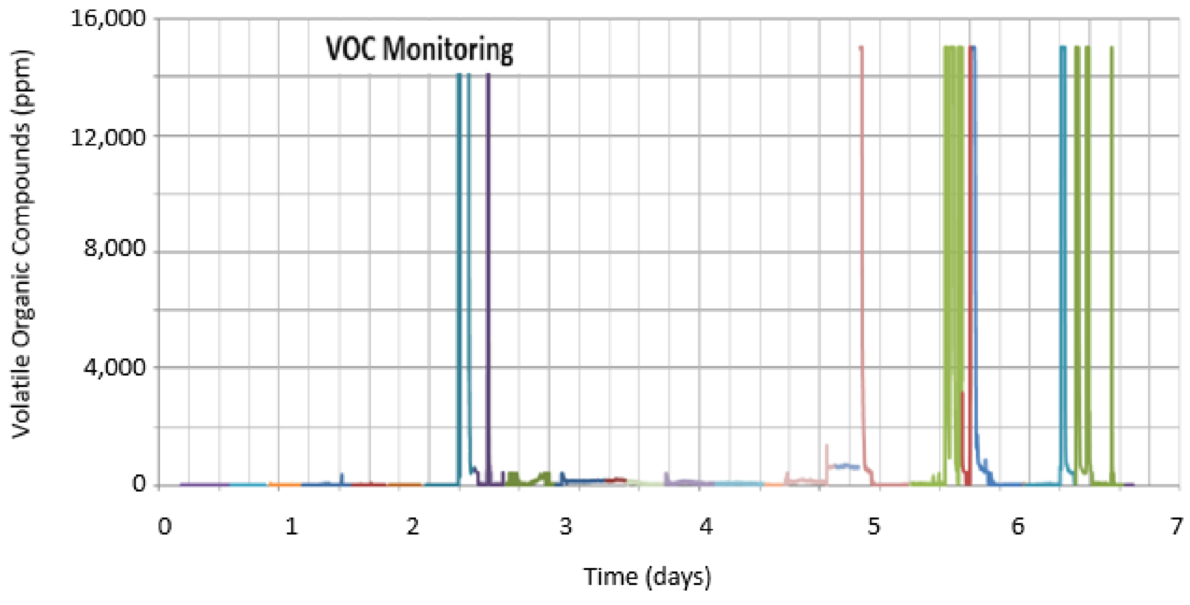

Figure 2-3: Example of VOC monitoring. The graph shows the concentration of VOCs in ppm as measured at a pump station. Different colours are different monitoring campaigns. Intermittent, extremely high values correspond to the dump of chemicals.

2.4.3 Industrial catchment pumping station

A water agency in Australia owns and operates a pumping station in a heavily industrial catchment, with very little domestic flow contribution. Monitoring data for this pumping station reveals 64 days from a total of four years where the percentage LFL of the atmosphere was above 20%. Full data is shown in Table 2-3.

Table 2-3: Industrial pumping station - days above percentage LFL. This data is cumulative, meaning that a day with a value of over 100% is also a day over every previous value in the table. Total number of days with a peak over 20% is therefore 64.

LFL (%)	Number of days with a peak value above value nominated
20	64
30	59
40	54
50	39
60	22
70	18
80	17
90	13
100	8

2.4.4 Inverted siphon

A water agency in Australia operates an inverted siphon asset. Methane data was collected over a one-month period. The methane levels measured in two of the connecting maintenance holes had a 90th percentile value of 17% and 13.4% of the LFL respectively. Operators complained of odours, with access into the infrastructure limited for safety reasons. Currently, no further mitigation is in place. With these measurements, the LFL is not high enough to be considered a hazardous area; however, this could change should accumulation of sediment reduce the head space or augment the methanogenic bacteria in the siphon.

2.4.5 Sewer running alongside gas line

A major sewer in Taiwan ran parallel to a propylene gas line. It is thought that propylene gas leaked into the sewer. A drainage culvert was allowed to be built over the pipeline and after some years, the drainage channel exposed the four-inch pipeline to air and moisture, causing it to corrode and eventually rupture. A spark within the sewer is believed to have caused the detonation of the atmosphere within the sewer which caused rupture of the gas pipe and further detonations. 32 people were killed and over 300 people were seriously injured.[20]

2.4.6 Inlet works

A large wastewater treatment facility in Queensland has a number of industrial sub-catchments including a large military base. After a discussion with designers and a targeted sampling program, several of the plant areas had to have their classification amended from non-hazardous to a zoned hazardous area, even when considering ventilation. The nature of the sub-catchments meant that there was a steady stream of flammable volatiles entering the facility which are generally controlled below 5% LFL by mechanical ventilation by the gas treatment facility, which is fitted with duty/standby fans.

Figure 2-4 below shows how rapidly (within 90 minutes) the bulk headspace reaches 30% of LFL in a fan failure event. In this scenario, the flammable vapour concentration was still rising and would have likely reached 100% of the LFL had the fan not been brought back online. After the fan fails, the graph begins to rise, approaching a maximum value of 30% of the LFL within the air space of the structure. With the reintroduction of mechanical ventilation as the standby fan is brought online, there is an immediate sharp reduction in the concentration of flammable substances in the atmosphere.

Note that even with duty/standby fan redundancy, the mechanical ventilation still had a failure event leading to a potentially explosive atmosphere being developed.

[20] **https://www.bbc.com/news/world-asia-30527598**

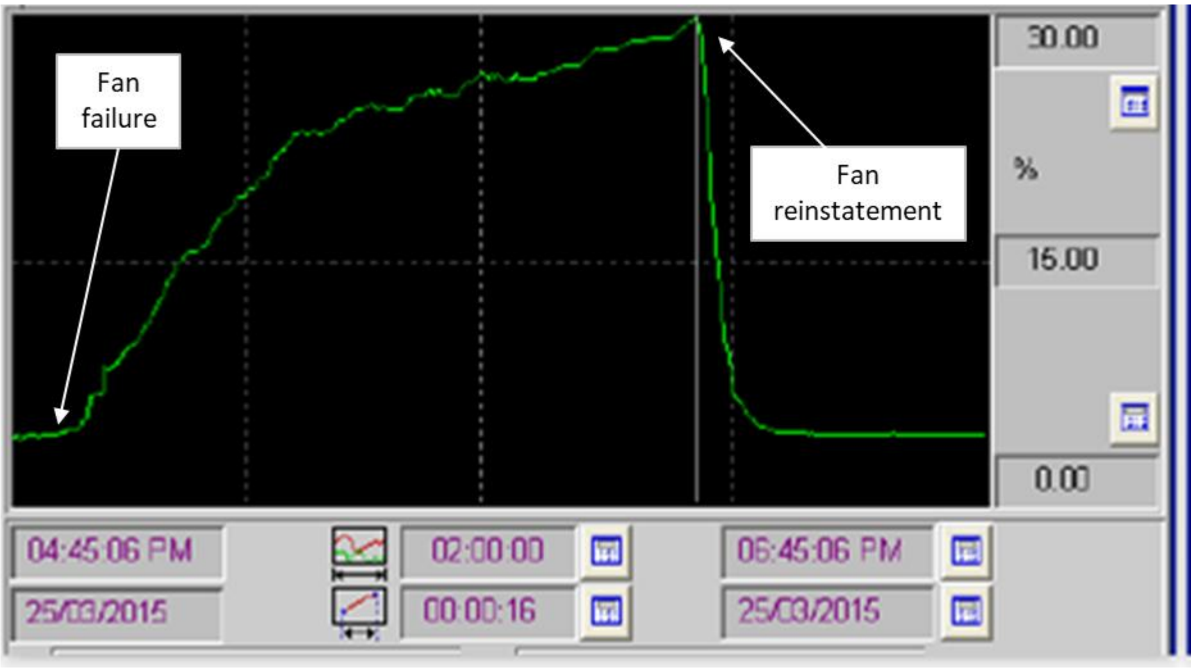

Figure 2-4: Percentage of LFL as recorded at a secondary screens pumping station after an extraction fan failure event, and subsequent re-start.

2.4.7 Sludge infrastructure explosions

Four workers were killed in a blast located at a biosolids facility within a water recycling centre in December 2020. The facility was located in the United Kingdom. A fifth person was critically injured. The blast occurred during maintenance work on a conveyor feeding a biosolids silo. The investigation into the event is still (at the time of writing) ongoing. Figure 2-5 is an image of the silo in the aftermath of the blast.

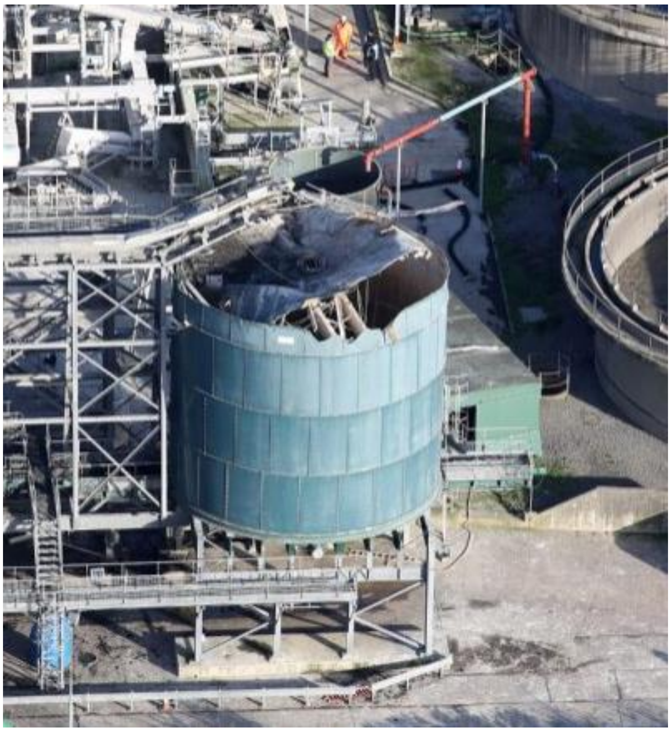

Figure 2-5: Ruptured silo at the facility showing the force of the explosion

2.4.8 Storage of flammable materials

In 2006 two workers were killed, and one seriously injured at a wastewater treatment plant in the USA. Workers were removing a steel canopy from the roof of a closed methanol storage tank. The workers were using a cutting torch that likely ignited methanol vapours from the tank and caused an explosion. The explosion led to the release of the total contents of the tank (approximately 11,000 litres of methanol).

3. MONITORING OF EXPLOSIVE ATMOSPHERES

To ascertain the likelihood of an explosive atmosphere forming, or the frequency or extent of this formation, there are a number of sampling and analysis techniques available. This section discusses some of those techniques used successfully for wastewater atmospheric monitoring applications.

Updated in 2016, AS/NZS 60079.29.2 provides a comprehensive discussion of the selection, installation, safe use and maintenance of flammable atmosphere detection equipment. Performance requirements for detection equipment are discussed in AS/NZS 60079.29.1 and in AS/NZS 60079.29.4. These standards are recommended for those water agencies that require additional information on this topic. The intent of this section is to provide a general guide to instrument and measurement technique selection, such that equipment would be suitable for use in most wastewater monitoring applications.

Monitoring effectiveness is dependent upon several factors, including whether continuous or spot sampling is required, whether the compounds need to be specifically quantified, or whether a specific compound (or group of compounds) is present in the gas phase that may constitute a hazard.

It is important to consider that instruments, even those with very similar specifications, can vary significantly in response time, calibration gas selection and sensitivity. When selecting an instrument for monitoring, discussion with the supplier of the purpose of the monitoring is recommended to ensure that the supplied equipment is fit for the intended use.

3.1 Purpose

The monitoring of atmospheres for compounds that could form explosive mixtures with air is generally undertaken for one or more of the following purposes:

1. Detect the presence of a flammable atmosphere for shutdown of equipment to prevent or reduce the risk of ignition, or to isolate electrical equipment not rated for hazardous areas.
2. Ascertain the likelihood, extent and duration of flammable atmospheres being present to inform decision making for classification of specific assets.
3. Determine the specific type (or lack thereof) of flammable compound(s) present or identify specific contaminants of concern so that further action can be taken, for example provide information to emergency responders, or reduction of contamination through modified trade waste agreements.

The type of instrument and the testing used should be selected depending upon the intent and purpose of the monitoring.

3.2 Instrumentation

This section describes the main form of detectors available, their advantages and disadvantages and situations where they are suited. The information is current as of the date of publication of this guideline; over time, this may be subject to change.

Each of these detector technologies can be configured to be stand-alone such that local collection of data is possible. Sampling assemblies can also be designed and constructed to output one or more analogue signals for use with a remote telemetry unit (RTU), or to provide a single output covering all assets through technologies such as Modbus over Ethernet or Profibus. Collaboration with the supplier of the equipment can provide a solution which suits the budget and the need of the water agency.

Table 3-1 below provides a high-level summary of commonly used sampling technologies currently used by the working group to monitor hazardous areas. Further detail can be found in Appendix C. It is important to note that all online solutions require regular calibration and maintenance; this includes calibrating every month to every 6 months depending on the installation and the device manufacturer's requirements, with potential for additional calibrations in case of sensor poisoning. Poisoning occurs when the sensor is damaged or compromised by a contaminant, with a common one being humidity. For hire systems without automatic moisture management, it is often required to empty condensate collection traps, which remove moisture upstream of the sampling point for best accuracy and sensor life. The interval between emptying of traps can range from daily to weekly depending on the installation. Other maintenance may also be required, such as refilling of gas cylinders or cleaning of sampling points. This should be discussed with any vendor prior to hire or purchase of equipment.

Table 3-1: High level overview of different sampling technologies

Technology	Type of monitoring	Results	Suggested use:	Key challenges:
Pellistor/ catalytic oxidising	Continuous, logged	Online, 10 – 60 s	Monitoring of broad spectrum of contaminants	Can be poisoned by H_2S and other common compounds, requiring regular calibration
IR absorption	Continuous, logged	Online, 10 – 20 s	Monitoring of most hydrocarbons	Some compounds such as unsaturated VOCs are not detected well, requiring prior knowledge of contaminants
PID/FID	Continuous, logged	Online, < 5 s	Monitoring wide range of low concentration VOCs	Can become overwhelmed by high concentrations. If methane monitoring is needed a hydrogen cylinder is required
GC-MS	Spot sample, as continuous GC-MS is prohibitive in	Discrete, 24 – 48 hours	Detailed and accurate breakdown of all contaminants in sample against search library	Sample transportation, discrete samples provide only a snapshot, expensive if many samples are required

Technology	Type of monitoring	Results	Suggested use:	Key challenges:
	cost and practicality			

3.3 Limitations and accuracy

It is important to understand the limitations of each technology summarised above. For instance, monitoring for methane emissions would rule out the use of a Photoionisation Detector (PID), a measurement technology described in more detail in Appendix C.

Unless a specialist lab is used with a GC-MS or similar technology, the accuracy of all the field instrument assemblies is reliant upon the following:

1. the correct selection of equipment
2. correct calibration and calibration gas
3. understanding the effects of humidity on the sensor
4. understanding the cross-sensitivities and sensitivities of the gas being detected
5. air movement at the sensor head
6. particulate contamination or blockage at the sensor head filter
7. many other factors which are not only technology dependant but also manufacturer and maintenance dependant.

One of the major factors in determining the accuracy and relevance of any monitoring is the choice of measurement location. In an ideal situation, any contaminant of concern is well mixed within the entirety of the air volume of an asset. In practice, with infrastructure such as pipework and access platforms providing an impediment to the movement of air, there will be differing levels of contaminant at different points in the air space. This is also dependent on the contaminant. For example, petrol is heavier than air and is non-soluble, such that it will sit on a liquid surface and emit vapour. This means that the highest concentration is most likely to be present close to the wastewater surface. It is therefore important to consider both the air movement in the space as well as the contaminants of concern when selecting a sampling location.

Some samplers, or instrument providers, are used to working in or providing equipment for ambient conditions or working conditions. Any sampler, or instrument provider, should be informed of the expected location as well as some basic information such as:

- Will the monitor be installed outside of the atmosphere under investigation? This may require a suitable sample pump to bring atmosphere to the instrument.
- Will the location be under negative pressure (only valid for when the sensor is remote from the location)? The sampling pump may need to draw against a negative pressure.
- How far away is the atmosphere being sampled from the instrument? The sampling tube will need to be purged before measurements are considered accurate. There may be a delay between when the atmospheric conditions change and the instrument registers

this. The length of the delay will be influenced by the volume of the sample line and the flow rate of the sample pump.

- Will there be power supply available to the instrument? Some instruments are battery operated but can suffer from short battery life. Alternative power supplies may be required.
- Will the location contain a high level of humidity? – This can poison the sensor or damage a sample pump.

It must be stressed that sampling campaigns and selecting equipment must be done in conjunction with a suitably qualified specialist or, if the knowledge is contained in-house, with the equipment manufacturer.

3.4 Sampling campaigns

A sampling campaign should be designed around establishing the risk of a flammable atmosphere occurring in an asset. It should therefore be of sufficient duration and breadth to ensure that a representative dataset has been collected.

Generally, assets can be split into two categories: those operating in steady state (where the quality and quantity of the inputs and outputs can be controlled and are relatively predictable) and those which have inputs that are unpredictable in nature.

Predictable or steady state processes can be considered, for example, as assets at a wastewater treatment facility downstream of primary treatment, or, notwithstanding certain exceptions, in a sludge treatment facility. In such processes technical knowledge of the process and its operation, associated standards and the use of industry standard safety techniques (such as hazard operability studies) can provide suitable hazardous area zoning. This can then be demonstrated or confirmed by relatively short sampling regimes.

Unpredictable processes such as those which are not steady state and where the inputs are outside of the control of the asset owner are more complex and require longer sampling regimes. These generally include network assets and preliminary and primary treatment assets.

In an ideal situation, the duration of sampling should cover all predictable normal and abnormal operating conditions if the risks associated with the contaminants of concern cannot be reasonably identified with high certainty. This includes temperature effects as biological activity is often higher in summer months.

Another factor is the asset condition at the time of sampling. Asset age can influence the results of any sampling, for example through the build-up of sludge or scum layers, the blockage of sludge or scum withdrawal systems and perishing of seals, etc. The age of the asset and the likelihood of future deterioration should be considered when analysing the results of any sampling campaign.

It should be noted that the gaseous areas within chemical storage tanks, where the stored chemical is known, do not require sampling. Correct hazardous area zoning can be determined by simply knowing the tank contents and the storage variables in conjunction with the use of existing standards.

3.4.1 Methodologies

Sampling should not be utilised on its own for establishing zonal classification of equipment if the extent and duration of sampling does not cover the main likelihood factors as outlined in Section 5 or Section 6 of this document. It can, however, be used as an excellent tool to identify contaminants of concern (and thereby suitable mitigation measures), durations of events and likely responsible sources.

If an asset is proposed and not currently constructed and in use (rendering a sampling program impossible) feed infrastructure should be considered for a sampling program. If feed infrastructure is also not currently constructed, alternative similar locations should be considered for a sampling program. Where an existing asset is due for replacement, the existing asset can be sampled (for example, the upgrade of an undersized pumping station). Where any sampling is impossible or the campaign would yield results which are not relevant to the asset under consideration, the use of results from similar assets in a water agency's network can be considered.

It should be noted that, if the asset is being modified, replaced or if the upstream processes are predicted to change, those factors should be considered in interpreting the data collected. The addition of an incoming long rising main, for example, to an existing pumping station from a new industrial catchment would increase the likelihood of both methane formation in the atmosphere as well as flammable industrial discharge.

3.4.1.1 Selection of assets to sample

Linear assets

Selection of linear assets for sampling campaigns can be done in many ways. Some suggestions as to methods of selection are below:

- By selecting high likelihood locations, as outlined in Section 1.5.1.
- By doing desktop analysis such as that outlined in Section 5 and selecting the higher likelihood locations from this process. Desktop analysis is also best for newly sewered areas, where there is no upstream or downstream area which can be sensibly sampled.
- For new assets in an existing network, by sampling upstream or downstream locations.

Care should be taken when selecting sampling locations in linear assets, as the likelihood of a flammable atmosphere being produced is dependent upon many local factors. For example, consider several pumping stations in series. The inflow to each pumping station in the series is the discharge from the preceding pumping station with the addition of local inflows. This case has several scenarios:

1. One pumping station is monitored and recorded as having an atmospheric LFL measurement above the threshold value. This measurement in a single pumping station does not necessarily dictate that all or any of the others will have a flammable atmosphere and the local network inflow could be the cause. When diluted by other inflows, downstream pumping stations could be non-hazardous.
2. The last pumping station in the chain is monitored and recorded as having an atmospheric LFL measurement above the threshold value. This may be the only one in

the chain to need a hazardous rating, as it is the first point at which the combination of flammables from the previous pumping stations reaches a level of concern.

3. The pumping station at the beginning of the chain is in a high-risk catchment, susceptible to “dumping” or significant trade waste due to a high commercial/industrial discharger base or in an area with a history of unidentified illegal dumps, causing the entire downstream chain to have an increased likelihood of forming flammable atmospheres. In this example, re-direction of flows to limit the risk of hazardous areas forming downstream or addressing the discharges directly could be more economical than other forms of mitigation.

In a large network, the selection of assets to sample such as pumping stations or trunk sewers) should be made on the basis of the features detailed in Section 5. In order to trace the source or prevalence of a substance, an initial sampling of several pumping stations and/or sewers is recommended. This could then lead to further sampling being required if flammable atmospheres are identified.

Treatment plants

On a treatment plant facility, every asset should be considered in a hazardous area assessment. Sampling is only required in those non-steady state processes that are not “standard”, do not have classification information from previous projects or other plants available as a reference, or where the zoning cannot be selected with a high degree of certainty. As an example, anaerobic digestors, combined heat and power (CHP) engines, secondary digestors, flares, raw sludge processing and storage are all predictable, with zoning achievable without sampling. Yet sludge or wastewater import facilities, inlet works and primary treatment processes are unpredictable in that the asset owner has little to no control over what is received. Such processes should generally be sampled as part of a hazardous area assessment, or at least have the risk ascertained using the methodology described in Section 5

For most processes in use in Australia, there are generally a sufficient number of similar installations to make an assessment based on data from a similar site. For sites with novel technologies, international experience can usually be relied upon. In practice, it is exceptionally rare to use a process at full scale which has never been used before. In these cases, a conservative classification should be undertaken based on modelling or process calculations.

3.4.1.2 Gas sampling locations within an asset

The gas sampling location for any asset should be selected to reflect the true headspace concentrations. Best practice is shown in Table 3-2 below for a number of common assets containing sewage, sludge or biosolids.

Note that for sludge dryers and downstream processes there is a significant dust explosion risk. Where it is likely that an atmosphere can become explosive due to dust accumulation, specific guidance should be sought as to how this should be sampled.

Table 3-2: Best practice sampling locations for various wastewater assets

Asset type	Covered or uncovered	Passive or Mechanical ventilation	Sample location(s) to be included	Reasoning
Tanks, vessels, preliminary & primary treatment processes, wet wells, pumping stations	Both	Passive only	Within tank, just above liquid level	Surface measurements for non-soluble hydrocarbons will be higher than the bulk gas levels due to a concentration gradient forming i.e., the emissions from the liquid layer will mean that there is higher concentration of contaminant at the surface. Covered tanks are at greater risk of forming flammable atmospheres due to lack of wind and limited air volume, slowing dispersion.
	Covered	Mechanical	Within tank, just above liquid level	Surface measurements for non-soluble hydrocarbons will be higher than the bulk gas levels due to a concentration gradient forming i.e., the emissions from the liquid layer will mean that there is higher concentration of contaminant at the surface.
			In extraction duct	Measurement of bulk gas concentration to atmosphere or gas treatment. This applies for soluble contaminants or lighter than air gases, as these would be well mixed in the bulk gas phase.
Gravity main/storm sewer/MH	N/A	Passive	Within sewer headspace, above liquid level, at key points down the sewer (such as confluence of sub-mains)	Due to air movement down the sewer driven by surface tension will generally cause good mixing and achieve maximum gas phase concentrations – unless the headspace is unusually high (> 1 m) - bulk gas detection is sufficient.

Asset type	Covered or uncovered	Passive or Mechanical ventilation	Sample location(s) to be included	Reasoning
		Mechanical	Within sewer headspace, above liquid level, at key points down the sewer (such as confluence of sub-mains)	Due to air movement down the sewer driven by surface tension will generally cause good mixing and achieve maximum gas phase concentrations – unless the headspace is unusually high (> 1 m) - bulk gas detection is sufficient.
			At extraction fan inlet	Measurement of bulk gas concentration to atmosphere or gas treatment. This applies for soluble contaminants or lighter than air gases, as these would be well mixed in the bulk gas phase.
Buildings containing sewage and/or sludge processes	Enclosed Building	Passive	At low and high points within building – located close to equipment of concern, and away from grilles or other air passage devices.	Upper and lower level sample points to account for varying gas/vapour densities of varying substances. Sample point should be close to the equipment or process of concern, but away from fresh air sources that could dilute the sample and prevent true readings.
		Mechanical	Upper and lower points as per passive ventilation	As per passive ventilation.

Asset type	Covered or uncovered	Passive or Mechanical ventilation	Sample location(s) to be included	Reasoning
			In extraction duct (in several key locations depending upon building size)	Measurement of general bulk gas concentration from building. For large buildings with varying use, several points in the ductwork system should be selected to establish if there are any local flammable gas risk areas. Measurement of bulk gas concentration locally in duct system and to atmosphere/gas treatment.

3.4.1.3 Type and duration of sampling needed

Once the assets to be included in the sampling program are selected, the duration of sampling should be such that it includes all or most of the high risk normal and abnormal modes of operation. It is generally difficult to predict these periods in network assets, as well as pre-treatment, primary treatment processes and associated facilities. The duration of sampling should be based on an understanding of either the processes involved (at a treatment plant) or on the unique catchment features which dictate the composition and quantity of flows (at a network location). This understanding is a combination of asset owner experience, operator feedback and internal or external engineering advice. Some examples of the factors which can influence the duration of monitoring campaigns for different types of catchments are presented below.

In industrial discharge areas, knowledge of the industry and practices helps in understanding changes in discharges depending upon shift, shutdowns and other factors. For example, flammable liquids may only be used infrequently during seasonal shutdowns, or only when processing a particular type of product.

In residential areas there may be a large transient population due to vacation areas or seasonal workers. For example, in periods of low flow, hazardous areas may form because of lack of dilution of trade vs domestic waste, or longer HRTs causing methane generation.

In residential areas with high vacancy, for example, due to mining turndowns a higher risk of illicit drug manufacture and associated discharges may be present due to the lack of population. This might also apply in areas with high rates of drug related crime.

In the absence of any guiding factors to determine a monitoring period, the following is suggested as a minimum program per identified asset:

1. An initial 14 days of continuous sampling, with either a combined PID/pellistor-type monitor or FID/pellistor-type monitor.

   Continuous monitoring for at least this period of time is critical in identifying problem discharges, and to determine baseline levels and any flammable levels of concern. Figure 3-1 below gives a clear example. A domestic network with no licenced discharges was reported by operators to have a “solvent” odour early in the morning daily. In one instance a personal detector was set off. 7 days of monitoring via PID clearly demonstrated a discharge into the network at the same time each day, with the rapid increase/decrease of concentration reflective of a sudden dump of flammable liquid close to the asset being sampled. This is shown in Figure 3-1.

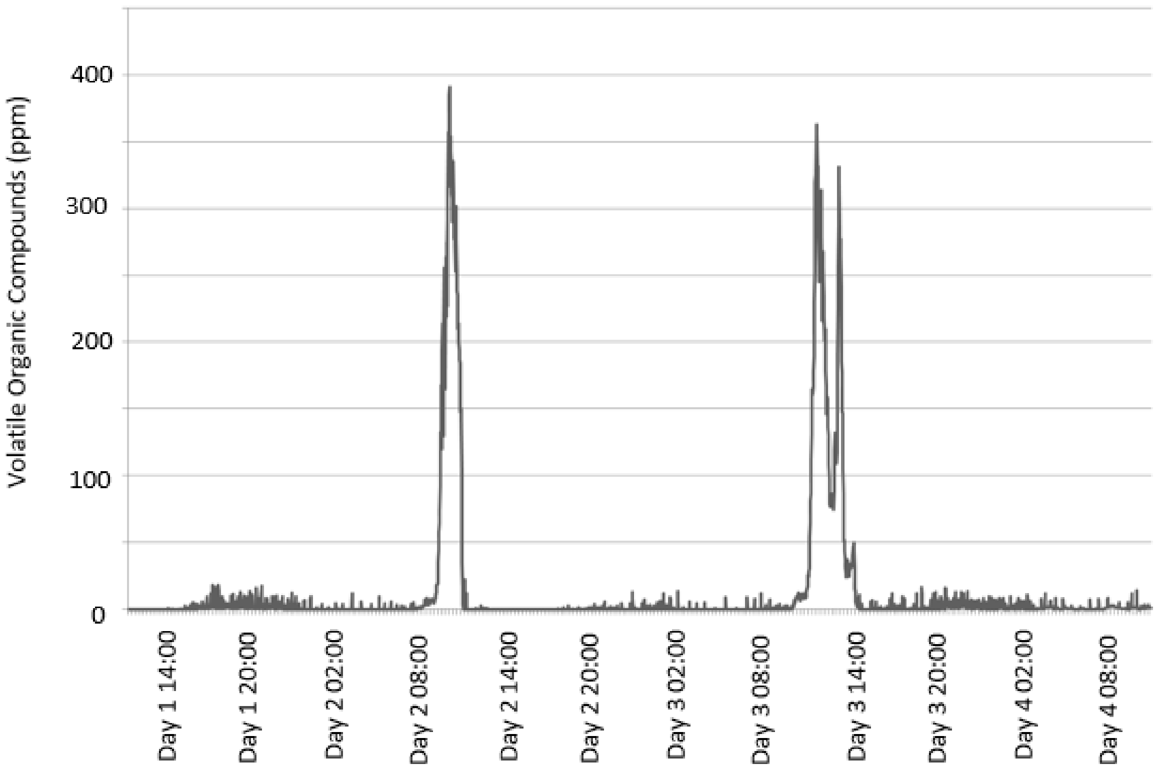

Figure 3-1: Example of sporadic industrial VOC concentrations in pumping station air due to industrial discharges into a sewerage network

Investigation into the relatively small catchment yielded the cause – a photographer disposing of waste developer fluid each morning. Spot sampling clearly would be unlikely to pick up such an event, thus the requirement for continuous logging. In addition, spot sampling at the peak could in certain cases prove to be a WHS hazard.

2. After the first few days of continuous logging, the data should be reviewed to establish concentrations (ppmv or %LFL) of concern and any pattern. If no events occur, then the sampling period should be run to its conclusion, regularly checking the dataset for any events of concern. If any such events are established, one of the following is required:

    a. If distinct discharges are evident, spot sample the gas at the peaks and undertake lab analysis to establish the compounds present. This can be costly, but worthwhile if further action can be taken to prevent the discharges or if the type of compound needs to be identified to aid in selecting mitigation technologies.

    b. If there are multiple high concentration events from multiple discharge events the recorded data is usually sufficient to inform the hazardous area assessment and enable appropriate zoning[21] and required modifications for compliance as appropriate.

    If no pattern is established after the first 14 days of sampling, continue sampling until a pattern is established or for 28 days, whichever occurs first.

[21] **Multiple peaks during the sample period would generally indicate a zoned area**

3. If the sampling yields conclusive data in line with the other factors identified, then further sampling is not required unless the asset use is changed in any way that changes the risk profile (such as a new rising main discharge being added to a maintenance hole).

Although a pellistor-type instrument is referred to above, an IR instrument can also be used, as long as the user has considered the potential compounds present.

3.4.2 Limitations on use and interpretation of data

There are a number of factors which can affect the validity of data from even the most comprehensive of sampling programs. Prior to the use of any data, the person charged with interpreting the data should understand how, when and where it was taken. Initial testing should always be continuous – spot sampling alone can rarely be used to determine likelihood. By establishing the pattern of discharge, the peak can then be sampled to identify the contaminants of concern at their worst.

Sampling must consider the intended use of the future or refurbished asset. One of the most common mistakes is measurement from an open structure, which is then used to inform the hazardous area selection in an upgrade which encloses that structure for health and safety, odour or other purposes. In such a circumstance a temporary cover should be constructed to simulate the build-up of gasses that will occur in the upcoming modification. Sampling should also consider the weather and flow conditions and the effect of these on the baseline measurement. Any asset which has wastewater flow as a variable will have dilution effects at high storm flows, but also may experience a “spike” in concentration at the start of the storm event due to flushing. This is especially pronounced in a combined system. However, sampling after high flow and storm events will generally not be representative of the normal flow regime of the asset. As a rule of thumb, after the first flush from storm events is captured, sampling should be paused until 10 days have passed. At this point, any high flows have usually returned to normal. In addition, some assets may have two normal conditions, for example, if a regional town is a popular tourist destination with significant additional flows between December and April. This means that there is a “peak season” baseline, and an “off-peak” baseline condition.

It is important to note that a sampling campaign may not adequately capture known peaks. Many peaks can be seasonal; that is, every three to four months or even long term, with only a few events per year. By knowing the contributing catchment well enough such that a campaign can be targeted towards suspected peak times (scheduled shutdowns of industrial emitters, off-peak seasons etc.), or by using multiple sampling campaigns at different times of the year, these peaks can be better captured. If doubt exists, assets should have their likelihood of forming explosive atmospheres checked using the methods in Section 5 of this document.

3.4.2.1 Data confidence

As long as the principles herein are followed, the more data available the better the outcome of the sampling campaign. It is important to ensure that the sampling campaign is fit for purpose. For example, classifying a rising main discharge point solely from data provided by PID would be improper selection of equipment, given the instrument cannot detect methane.

There have been instances where an initial sampling program has shown high VOC concentrations and associated flammable vapours in the atmosphere. Asset owners can sometimes request additional sampling in the hope that this sampling will provide enough data to ignore the initial dataset, thus overruling the first set of samples taken. In such an instance the additional data does not overrule the likelihood demonstrated by the previous sampling; it only shows that the high levels do not occur frequently or on a regular basis. A second set of data showing low levels does not allow for a non-hazardous classification, unless the first set of sampling is proven to be in error or effective mitigation measures (such as discharge enforcement) have been undertaken.

3.4.2.2 Likelihood assessment input

Once sufficient sampling data has been collected, it can then be used as an input into the likelihood assessment process.

In some cases, the sampling data can be conclusive enough that a suitable classification can be derived immediately following the conclusion of an initial 28 day campaign. However, some datasets are not as conclusive and require further assessment.

A dataset allowing immediate classification would show regular events above the threshold value of LFL in the atmosphere, with GC-MS analysis showing a compound such as petrol (octane and other isomers) being consistently present. Such a combination would be a “worst case” scenario, as petrol quickly forms a surface layer on water spreading out into a very thin film and evaporating. In this situation, at a location near to the liquid surface, it is likely that an explosive atmosphere will exist. In such an instance mitigation measures such as ventilation (mechanical or passive) are insufficient to allow a non-hazardous rating to be used. The enclosed headspace and potentially surrounding assets would require a Zone 1 or 2 classification depending upon frequency, duration and other factors such as pressure. Refer to subsequent sections of this guideline for further guidance.

4. INTERACTION WITH STANDARDS AND GUIDELINES

After understanding the types of contaminants and their likely sources and discussing how to identify and monitor these contaminants, a strategy can then be formulated for classification of wastewater networks and treatment plants. To provide agreement and compatibility with standard industry practice, a thorough review of national and international hazardous area standards was undertaken.

4.1 Relevant standards and guidelines

As part of the development of this guideline, a selection of guidelines and standards specifically addressing hazardous areas were reviewed, as well as other material for reference or background. These are discussed briefly below.

4.1.1 Australian standards and guidelines

4.1.1.1 Standards

As part of the work of this guideline, the following key Australian standards were reviewed:

- AS/NZS 60079.10.1 (both 2009 and 2022 versions)
- AS/NZS 60079.13
- AS/NZS 60079.14

The foundation of area classification for flammable gases and vapour in Australia is AS/NZS 60079.10.1: *Classification of areas - Explosive gas atmospheres*. This standard, adopted from International Electrotechnical Commission (IEC) 60079-10-1, contains methodologies by which areas can be classified. This is based on either one of the simplified methods or one of the ‘source of release’ methods accepted by the standard (or a combination of the two), with definitions available which define the discharge frequency of sources. There are also methods to ascertain availability of ventilation, appropriate safety factors for ventilation and the effect of ventilation on zoning. A detailed supplement provides reference cases for use, with some specifically targeted at the water industry for areas of release at wastewater treatment plants such as valves, compressors, gas meters, filters and regulators in gas lines as well as areas around sludge digestion tanks. The examples note that the classifications are based on plants with inlet screens and clarifiers open to atmosphere; where they are enclosed (for example for odour control) further consideration will be necessary.

AS/NZS 60079.13 covers rooms which are protected by pressurisation “p” or ventilation “v”. It specifies the requirements for ventilation or pressurisation equipment when it is contained in a hazardous area, as well as stipulating requirements for the design, control and documentation of areas served with pressurisation or ventilation. With some rare exceptions such as underground treatment plants with hazardous areas, wastewater applications rarely have ventilation equipment within a zoned area, with only the internal ductwork being classified as a hazardous area. The standard also provides guidance on some general requirements for ventilation. which inform recommendations outlined in Section 5.

AS/NZS 60079.14 is a standard for the design, installation and initial inspection of electrical equipment in hazardous areas (EEHA). It is a comprehensive resource for electrical designers to use in selecting equipment which is designed and constructed for use in hazardous areas. It also provides minimum requirements for documentation of classifications. It is the regulatory link between AS/NZS 3000 and various other 60079 series standards, such as AS/NZS 60079.13 and the AS/NZS 60079.29 series. As such, knowledge of the standard is critical for any hazardous area professional undertaking design work. AS/NZS 60079.14 refers readers to AS/NZS 60079.10.1 for classification of hazardous areas, the core focus of this guideline. For this reason, reference to AS/NZS 60079.14 in the guideline text is limited. It is however referenced by the guideline in one specific case discussed in Section 5, where an increased equipment protection level (EPL) is assigned to equipment in an area deemed non-hazardous.

4.1.1.2 Australian utility guidelines

The following Australian water utility guidance documents were reviewed in developing this guideline:

- SA Water, TS 0376 *Classification and Design for Electrical Equipment in Hazardous Areas*
- Sydney Water, *Technical Guidance Note TG502: Classification and management of flammable gas hazardous areas*
- Water Corporation, *HA-ST-02 - HA Classification Standard*
- Mackay Regional Council, *83501246-P-003 1 Mackay Sewerage Network Hazardous Zoning Final Report*

SA Water's guidance note provides specific guidance on design preferences but goes further by providing a baseline set of classifications for wastewater treatment plant assets, an overall philosophy for the classifying of wastewater networks, and specific commentary on the use of international standards as well as the details of AS/NZS 60079.10.1. It also covers detail design advice for hazardous areas and preferred parameters for dispersion modelling. Intended as a baseline from which design professionals can provide consistent zoning across their asset base, this guidance note has both prescriptive elements and recommendations.

Both the Sydney Water and Water Corporation standards provide specific guidance on preferences regarding the design process including competence of personnel, but do not provide classification methodologies or minimum zoning advice. Both documents refer to the advice provided in AS/NZS 60079.10.1 for classification of assets.

As part of an exercise for Mackay Regional Council, in 2013 MWH (now Stantec) assisted Mackay Regional Council in creating a hazardous area classification system. This covered a review of available international standards and the formation of a system of classification with or without available monitoring data. A decision tree which could be used to classify areas was provided for use.

4.1.2 International standards and guidelines

The following international standards and guidelines were reviewed:

- IEC 60079-10-1: 2020, the latest version of the international code for the classification of hazardous areas where flammable gases exist
- (UK) United Utilities Code of Practice (COP) 1, named *Installations in Potentially Explosive Atmospheres* both i7 dated February 2013 and i9 dated March 2021
- (UK) Thames Water SPD E04, named *Zoning of Hazardous Areas*, dated May 2009
- (UK) Scottish Water Section 204, named *Guidance for the Assessment and Zoning of Hazardous Areas*, dated April 2006
- (UK) HSE Executive Dangerous Substance and Explosive Substances Regulation (DSEAR), a collection of WHS legislation from the UK providing guidance on hazardous areas introduced in December 2002
- (USA) National Fire Protection Association (NFPA) 820, named *Standard for Fire Protection in Wastewater Treatment and Collection Facilities*, both the 2020 and the 2012 edition
- (DE) DIN EN 1127-1:2019-10, named *Explosion prevention and protection - Part 1: Basic concepts and methodology*; German version EN 1127-1:2019
- (INT) EI15, named *Area classification for installations handling flammable fluids*, dated June 2015

Due to the global harmonisation of the IEC codes, many countries around the world (EU countries such as Germany, as well as countries such as Japan and China) use standards which are closely modelled on IEC 60079-10-1, as Australia does. For this reason, this standard was reviewed.

The DSEAR regulations in the UK provide a regulatory framework in which the various UK water authority standards operate. The requirements are summarised in *Approved Code of Practice L138*, which sets out requirements for hazardous areas as well as requirements for explosive dusts and toxic compounds. The fundamental basis of the regulations is a risk-based approach to the control of dangerous atmospheres, the responsibility of which lies with the "employer" or "duty holder" (similar to Australia's PCBU). This includes requirements and guidance on design, storage, control and safe maintenance in affected areas.

Each of the guidelines from the UK water authorities (United Utilities, Thames Water and Scottish Water) provide guidance on the approach to be used with hazardous areas in wastewater environments. The i7 revision of COP1, and the current revision of SPD E04, are prescriptive in nature although there is a discussion about risk assessment and its application in SPD E04. For network assets, they describe different installation configurations and assign a zone rating based on availability of ventilation and the number of petrol stations and major petrol tanker routes in the asset's service catchment. For treatment plant assets, they provide comprehensive guidance on design, operation and maintenance of assets in hazardous areas and assign zoning classifications to common process units.

i9 of COP1 and Scottish Water’s Section 204 guidelines share a risk-based approach to classification, ventilation and other mitigation factors to assign a classification rating to both network and treatment plant assets. i9 of COP1 removes the prescriptive approach of earlier revisions and provides a framework for risk assessment, with some specifications regarding hazardous area installations and input data to use. Section 204 provides a tightly defined and comprehensive assessment methodology for assigning hazardous area zoning, along with prescriptive commentary on various unit processes as well as various inputs for further risk assessment.

In the aftermath of the Abbeystead explosion (where methane gas migrated into a water pumping station and exploded, killing 16 people) many UK water authorities introduced guidelines tightly prescribing zone ratings for network and treatment plant applications. After the DSEAR guidelines came into effect in the early 2000s this approach began to shift towards the risk-based framework outlined by regulation, with inputs such as petrol stations in a catchment, degree of ventilation or methane production potential. This shift is clearly evident in the changing requirements of COP1, with Scottish Water's Section 204 providing a hybrid between pre- and post-DSEAR strategies for dealing with risk.

A highly prescriptive approach is evidenced by NFPA 820, which provides the exact zone rating for various network installations and unit processes for wastewater treatment plants. This is accompanied by a reduction in changed zoning requirements at the two different ventilation rates of six Air Changes per Hour (ACH) and 12 ACH, as well as mandatory minimum fire protection infrastructure such as alarms, interlocks and local fire-fighting equipment. This provides a straightforward classification but is not flexible. Over two versions, separated by eight years, this approach has not changed; rather, the number of installation cases has increased to provide more examples for design practitioners.

EN 1127-1 is a European Union guideline to the risk assessment process in regard to the management of explosions and explosive atmospheres, in accordance with the European standard for risk assessment and reduction in machinery (EN 120100:2010). The document specifies methods for the identification and assessment of hazardous situations leading to explosion and the design and construction measures appropriate for the required safety of equipment and machinery. Although its focus is on product design, it provides a generalised risk assessment framework which can apply to any system. The standard calls up the use of the EN 60079-10-1 for the classification of hazardous areas yet does not classify hazardous areas itself. By providing a generalised framework for risk classification, the standard provides a strong reference for risk assessments in the water industry, covering not only classification but other factors such as secondary guards, ventilation etc.

EI15 is a model code of practice, targeted primarily at the onshore oil and gas industry. It covers in depth ventilation and the control of contaminants of concern commonly found in oil and gas installations. It uses a method of classification similar to that of AS/NZS 60079.10.1: a point source method, with additional information on the use of a risk-based approach to determining point source sizing. There is also a direct example method, which provides common oil and gas installations and their zoning, which is not relevant to the water industry. The risk-based approach estimates a hole size for a secondary source of release, based on frequency of exposure of workers, probability of ignition and release frequency. The standard has guidelines for zoning around vents and stacks, based on air flow rate, pressure and stack size, which may be of use to the water industry. In addition, the ventilation guidelines described by the standard provide an alternative method of calculating ventilation when compared with AS/NZS 60079.10.1.

4.2 Guidance on use and interpretation of standards

Based on a review of national and international standards, as well as the experience of the working group, there are different approaches to the classification of explosive atmospheres in wastewater conveyance and treatment assets. This difference can be substantial and can lead to disagreements among hazardous area design professionals and water agencies.

This guideline proposes the following interpretations of common areas of divergence among the standards. The intent is to provide an agreed set of common principles which can be universally applied across the Australian water industry.

4.2.1 Prescriptive vs likelihood-based approach

Apart from suggested classifications for wastewater treatment plant unit process applications, this guideline does not recommend a prescriptive approach to the classification of assets in wastewater conveyance and treatment infrastructure. Prescriptive approaches to classification may provide significantly different effectiveness of outcome for the same asset in different contexts, and therefore cannot be relied upon to be universally applicable. For example, when ventilating at a rate nominated in NFPA 820 to achieve a zone rating, it is not possible to know if the rate of ventilation is sufficient to control the contaminants of concern for that installation. A prescriptive approach may also be overly cautious for the majority of installations of a certain asset type.

It is important to note that AS 60079.10.1 provides reference classifications which can be used by water agencies as a basis for their own hazardous area classification. These are not prescribed by the standard and are referred to in the hazardous area industry as ‘classification by use of examples’. These reference classifications should, if necessary, be altered to suit the unique requirements of the installation.

This guideline favours a likelihood-based approach to classification. The likelihood approach assesses the various factors which are likely to influence the formation of a potentially explosive atmosphere and is based on the unique attributes of the asset in consideration. Hazardous area classification according to AS 60079.10.1 does not consider the consequence of any potential explosion or ignition. The common understanding of a “risk based approach” in both water industry practice and general industry practice is a process which looks at both the likelihood and the consequence of an event occurring. In this sense, AS 60079.10.1 and this guideline do not allow for a risk based approach to classification (as they both focus on likelihood, rather than consequence). However this guideline does allow a graded approach to assigning a likelihood based on Australian industry experience. Section 5 describes an approach whereby increased or lesser likelihood of explosive atmosphere is assessed.

4.2.2 Abnormal vs. catastrophic operating conditions

4.2.2.1 Catastrophic conditions

Baseline Australian industry for the classification of hazardous areas is based on AS/NZS 60079.10.1-2022. The standard states the following in Clause 1 c) as being a case where its guidance is not intended to apply:

> "*Catastrophic failures or rare malfunctions which are beyond the concept of normality dealt with in this standard (see 3.7.3 and 4.5)*"

Clause 3.7.3 defines a rare malfunction as a malfunction which may only occur in rare instances. Two further notes read:

> "*Note 1 to entry: Rare malfunctions in the context of this standard include failure of separate and independent process controls, that may be automated or manual, that could trigger a chain of events that would lead to major release of flammable substances*
>
> *Note 2 to entry: Rare malfunctions could also include unanticipated conditions that are not covered by the plant design such as unexpected corrosion that results in a release. Where releases due to corrosion or similar conditions may or could reasonably be expected as part of the plant operations then this is not considered a rare malfunction*"

Further examples of rare malfunctions are also included in Supplement 1 of AS 60079.10.1:2022, Clause C3.7.3.

Clause 4.5 of this supplement provides further advice on catastrophic failures:

> "*Reasonably unexpected catastrophic failures need not be accounted for in the hazardous area classification, for example, major accidents such as the rupture of a process vessel, or large scale failures of equipment or piping such as total breakdown of a flange or seal*"

To provide further guidance on this for the water industry, this guideline recommends that the below events be considered examples of catastrophic failures:

- The impact due to a lightning strike which is beyond the control measures identified in AS 1768.
- A flood of magnitude greater than that which can be reasonably foreseen. A structure may have a life span of 50 years; in this case, the 2% (and in some cases, the 1%) annual exceedance probability (AEP) flood event can be reasonably expected, including consideration of potential changes to historical weather patterns. A process plant may have a 20-year design life; in this case, the 5% (and in some cases, the 2%) AEP flood event can be reasonably foreseen.
- Cyclone or El Niño, outside of certain areas of the country where these can be reasonably foreseen.
- Earthquake, of a magnitude and/or in a location where the risk cannot be reasonably foreseen.

- Terrorism and intent to cause harm such as sabotage. While petty maliciousness such as vandalism or purposeful carelessness can be expected in certain installations, terrorism and intent to harm cannot be predicted. There are however certain instances where this should be considered; this is discussed in Section 5.

4.2.2.2 Abnormal conditions

Clause 3.7.1 of AS 60079.10.1: 2022 defines normal operation as the "situation when the equipment is operating within its designed parameters", with two explanatory notes as below:

> "*Note 1 to entry: Failures (such as the breakdown of pump seals, flange gaskets or spillages) caused by accidents which involve repair or shutdown are not considered to be a part of normal operation*
>
> *Note 2 to entry: Normal operation includes start-up and shut down conditions and routine maintenance, but excludes initial start-up as part of commissioning*"

For a wastewater treatment plant, where there exists a relatively controlled, steady state process with defined and understood load cases, normal, abnormal or catastrophic conditions are more clearly defined. In a network environment, this becomes more difficult.

In the machine design industry, there are many usage cases which are well defined. These include intended use, obvious misuse, deliberate misuse and foreseeable misuse.[22] However, what should be included in each use case and therefore what should or should not be considered for a hazardous area has not historically been well defined in the classification of wastewater assets. Furthermore, the open and accessible nature of the sewerage system introduces a complexity to the classification process that many other process industries (such as oil, gas or aviation) do not have. For this reason, most hazardous area standards use descriptors and examples for abnormal conditions that are not well suited to the wastewater industry.

To provide a unified national basis for hazardous area classification, this guideline outlines aspects of abnormal operation and foreseeable misuse considered necessary as a minimum for consideration in the classification of both network and treatment plant applications. These are based on review of the literature and the experience of the working group. This list is below, and is further discussed in Section 5:

- Power failure and start-up on power return
- Asset failure
- Varying load cases
- Blockage or leakage
- Flood, with the selection of an appropriate AEP for design

[22] **https://secutify.com/en/foreseeable-misuse/**

- Foreseeable misuse. By its nature, the contents of the sewage system are not within the full control of the asset owner[23]. As such, material which is not standard municipal or industrial (pre-treated) wastewater occasionally enters the sewerage system. This is a key influencer of likelihood for a wastewater network. Some key examples include:
    - Illegal dumping of large quantities of material in high risk areas such as drug labs.
    - Minor discharges of non-standard wastewater from residential houses.
    - Undeclared discharges from trade waste dischargers.
    - Stormwater ingress carrying material such as brake fluids, oils, fuels, etc.
    - Events which could occur due to insufficient operator training.
    - Events which could occur due to a lack of concentration or carelessness.
    - Other, similar failures which could occur due to human error.
    - Vandalism and trespass by members of the public.

Some of the above cases will only provide a small amount of flammable substances to the sewer. The foreseeable misuse cases should be assessed against the catchment as a whole to determine the overall likelihood of the event occurring in such a manner that leads to an explosive gas atmosphere occurring within the sewer.

4.2.3 Control of atmospheric concentration of substances

In accordance with clause 3.3.1. of AS/NZS 60079.10.1, a hazardous area is defined as:

> "*an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such that special precautions for the construction, installation and use of equipment are required*"

In AS/NZS 60079.10.1, the implicit intent is that the concentration of flammable vapours in the atmosphere should be managed or controlled such that 100% of the LFL is not reached. This is further discussed in AS/NZS 60079.13 Clause 7.1.3.1[24], which states:

> "*The required artificial ventilation flow rate and arrangement shall be determined such that it is sufficient to control the internal source of release or achieve the required dilution for the anticipated release conditions. This shall be determined in accordance with AS/NZS 60079.10.1. …*
>
> *The area to be protected shall be managed to reduce the concentration of the gas or vapour to less than 25% of the lower flammable limit*"

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[23] **Australian industry experience has shown that these events occur nationally, in both regional and major metropolitan areas. They are therefore a foreseeable misuse of the sewerage system. Due to their higher risks, their inclusion is critical to an understanding of hazardous areas in wastewater conveyance environments.**

[24] **The standard considers concentrations above the UFL as hazardous. This is because any upset could lead to a drop in explosive substances in the air, bringing the concentration in air to the explosive range. Standard industry practice is also to allow a safety factor on the value above which an area is considered hazardous, meaning that the atmosphere is controlled to a concentration of a maximum (for example) of 25% of the LFL. This is not explicitly stated in the standard.**

This implicit assumption is made explicit in the international literature. From DSEAR 6.233:

> "*Ventilation for plant and machinery is normally considered adequate if it limits the average concentration of any dangerous substance that might potentially be present to no more than 25% of the LEL. However, an increase up to a maximum 50% LEL can be acceptable where additional safeguards are provided to prevent the formation of a hazardous explosive atmosphere*"

The guidance provided by the UK DSEAR is further reinforced by the recent ruling on AS/NZS 60079.10.1:2022 by MS-011 for WSAA. This states:

> *"Situations where the concentrations are unlikely to exceed 25% LEL would typically result in a classification of non-hazardous"*

This strongly implies that a value of 25% of the LFL is a threshold value, above which classification of the area should change.

On this basis, this guideline is concerned with vapour concentrations in atmospheres which can breach this control point. This guideline calls this value the threshold value.

4.2.4 Ventilation

As per AS/NZS 60079.10.1:2022, the degree of ventilation available influences the zoning of a space. For this reason, both natural and forced ventilation are fundamental tools in the control of hazardous areas. A discussion of the design of ventilation systems for mitigation of hazardous atmospheres is provided in Section 5.5.3.

There are cases in the application of the standard where the presence of ventilation can allow the use of non-hazardous equipment by reducing the volume of the zone to a negligible extent. This approach has been used successfully industry wide. However, one aspect which can fail to be considered in hazardous area assessments is the effect of the abnormal operating condition (defined in 4.2.2.2). Three key clauses from the international literature, reproduced below, provide a summary of this intent:

> **SPD E04 A 2.2.3:** *"Failure of mechanical ventilation shall be considered and duty/standby extract fans may be prudent to improve the overall availability. This is particularly important when mechanical ventilation is being used as a means of controlling continuous and primary grades of release."*
>
> **DSEAR Schedule 1 of Regulation 6(8):** *"Ensuring that equipment and protective systems meet the following requirements –*
>
> *(a) where power failure can give rise to the spread of additional risk, equipment and protective systems must be able to be maintained in a safe state of operation independently of the rest of the plant in the event of power failure"*
>
> **EI15, 2.5:** *"The drawings and/or notes should indicate where the classification depends on the correct operation of a dedicated ventilation arrangement. It should consider and indicate the effect of failure of such an arrangement."*

In cases where the absence of ventilation can contribute to a flammable atmosphere, this failure state should be considered as part of the classification exercise. Duty/standby ventilation may not be sufficient to provide this as there are various reasons why standby equipment may not be immediately available, such as operator unavailability, failure of automatic change over, power failure, etc. AS/NZS 60079.13 specifies that any equipment which must operate in case of ventilation failure must be rated for the latent (without ventilation) hazardous area. This has an implication for vent shafts providing passive ventilation for sewerage networks. These vent shafts should always be assumed to have poor availability, and in some cases micro-climatic conditions dictate that they cannot be relied upon at all. Refer to Appendix D for more information.

The second aspect is that if the flammable liquid is insoluble, such that it forms a surface film, a concentration gradient will form. The concentration at the liquid film surface is then determined by the saturated vapour concentration. The concentration is lower as the distance from the liquid surface increases (much more rapidly for mechanical ventilation than passive), however there will always be a period of time and location just above the liquid surface where the LFL boundary is transited. In the instance of such a liquid being present the provision of mechanical ventilation does not prevent a flammable atmosphere from occurring; rather, it limits its spread to the bulk gas. This precludes the use of a non-hazardous classification rating as any spark which reaches the liquid surface at that time would cause an ignition/explosive event, regardless of controls.

For these reasons, ventilation or availability of ventilation does not mean that the area served is always non-hazardous, regardless of other factors.

4.2.5 Equipment protection level and classification

A hazardous area classification is first undertaken without assessing the consequence of any potential explosion or ignition. The likelihood of the ignition is determined (by use of one or more methods outlined in AS/NZS 60079.10.1 or otherwise) and a zone is established. This zone is then used to assign an EPL for electrical equipment operating within the hazardous zone, as per Table 1 of AS/NZS 60079.14. However, there may be situations where a water agency wishes to increase or decrease the default EPL of the equipment within the zone. This is summarised well in Clause 5.3 of AS/NZS 60079.14, and further discussed in AS/NZS 60079.10.1 Supplement 1 Clause I.2:

> *“Subsequent to the completion of the area classification, a risk assessment may be carried out to assess whether the consequences of ignition of an explosive atmosphere require the use of equipment of a higher EPL or may justify the use of equipment with a lower EPL than normally required.”*

An example of this is where a water agency has assessed an asset as non-hazardous due to the likelihood of a potentially explosive atmosphere being low, yet considers the asset critical or high risk. In this case, where the potentially explosive atmosphere may be present for a period of time less than that required to classify the area, there may be a desire to specify an EPL for the equipment in the area such that it does not become a source of ignition. This can be done by selecting an EPL for any equipment in the non-hazardous area.

It is important to note that in order to maintain the EPL of the equipment, the equipment must be designed, installed and commissioned in accordance with AS/NZS 60079.14 (and in case of ventilation, AS/NZS 60079.13) and the manufacturer’s instructions. It must also be maintained in accordance with AS/NZS 60079.17. An EPL is not maintained without the prescribed equipment maintenance.

4.3 Network specific interactions

4.3.1 Pumping station zoning

In Supplement 1 of AS 60079.10.1:2022, Clause E.2.1 refers to wastewater treatment plants and wastewater pumping stations in the following way:

> "*This section provides examples of area classification for areas associated with biogas recovery, sewage treatment plants and sewage pumping plants. It is concerned with methane occurrences from the biological digestion of wastes*"

This implies that the primary contaminant of concern in wastewater infrastructure is biogas or methane, which might not be the case; the primary contaminant of concern may be methane, or it may be externally introduced substances.

Clause E.2.6 of Supplement 1 of AS/NZS 60079.10.1:2022 refers specifically to sewage pump stations as follows:

> "*Generally, sewage pumping plants are non-hazardous (NH). However, where a pumping plant has a record of flammable liquids being passed through it, areas where the concentration of flammable vapour is likely to exceed the LFL should be classified in accordance with the relevant clauses of this Standard.*
>
> *Biogas may be evolved within these installations, but the concentrations may be low enough to prevent the formation of significant flammable concentrations. It is recommended that the classification is maintained as NH by the use of gas monitoring and the provision of ventilation. Each installation should be evaluated on a case-by-case basis.*"

It is important to note that the international literature places a greater emphasis on external substances being introduced to the sewerage system. Many of the examples presented are from the US or UK, which have a longer urban history and therefore contain many active installations of combined sewerage/stormwater infrastructure. Perhaps due to the increased risk of chemical spills in these systems, there is a much stronger emphasis on hazardous area classification for network infrastructure in these countries with a particular focus on non-methane substances.

With reference to clause E.2.1 as outlined above, this guideline does not recommend that hazardous area assessments of either sewage pumping stations or other conveyance infrastructure focus purely on the presence of methane. Australian industry experience has shown that there are other contaminants of concern which may be present in the municipal sewerage system, and in some instances these are the driver of the asset's classification. For further information, see Section 2.

With reference to E.2.6, as outlined above, it is true that many pumping stations nationally should be and are classified as non-hazardous. This is particularly true of areas with primarily municipal wastewater flows and short upstream retention times. It is not, however, always the case. Furthermore, there are recent examples of classification professionals and water agencies citing this clause as justification to enable sewage pumping station construction to occur without any hazardous area classification. Without investigation, it is difficult to establish if the site has or could have a history of dumping of flammable liquids (or flammable atmospheres). It is therefore prudent to allow for a hazardous area assessment when adding new linear assets such as maintenance holes, vent shafts or pumping stations to a network, or when building new unit processes at treatment plants. For brownfield locations, high likelihood locations should be identified and assessed.

4.3.2 Classification mechanism

A wastewater network of anything larger than a size encompassing a few homes is difficult to classify according to a source of release method. The large number of entry points for liquid wastewater makes it difficult to predict the exact quantities of any contaminant of concern present without long term monitoring at key locations. The risk of illegal or malicious activity is also difficult to quantitatively ascertain. For this reason, international examples of network classification have provided pre-set designs which have been developed in-house by water agencies for their own common installation examples such as:

- Wet well and valve chamber (open between)
- Wet well and valve chamber (sealed between)
- Dry well and wet well
- Pump house/structure
- Sewer mains
- Odour control units (OCUs).

This guideline provides a method which can support water agencies and hazardous area professionals in understanding the risks associated with their asset of focus. It is intended to apply using two mechanisms in the body, and in Supplement 1, of AS 60079.10.1:2022. The first is as a simplified method, described in 5.4 in AS 60079.10.1:2022 as follows:

> "*Where it is not practicable to make required assessments from individual sources of release, a simplified method may be used, for example in basic projects, where the equipment or locations are not yet defined, or calculations for all sources of release may be too onerous. Simplified methods shall identify sources for each of the zone types, zone 0, 1 and 2 that are suitably conservative to allow for potential sources of release without individual detail. The judgement is best made by reference to a set of criteria based on industry experience and appropriate to the particular plant.*"

This guideline looks at a range of factors which are likely sources of release in a linear infrastructure environment. By assessing the likelihood of significant contribution to each factor, it provides a conservative assessment on a possible zonal classification. In this way, the guideline is a form of simplified hazardous area classification for wastewater network assets. This is further discussed in Section 5.

Furthermore, the likelihoods in the classification are generated by using a reference asset, created from the industry experience. For example, a reference pump station with high trade waste contribution and high methane generation risks is generally a zoned area. For this reason, the framework provided could also be described as area classification by way of example, similar to Annex E of Supplement 1 of AS 60079.10.1:2022.

4.4 Treatment plant specific interactions

As opposed to a network environment, in a treatment plant environment (with the exception of pre-treatment modules and other areas which have the characteristics of a network asset), the source of release method outlined by AS/NZS 60079.10.1 is an appropriate and practical method by which to classify treatment plant assets.

In addition to the source of release method, Annex E.2 of Supplement 1 of AS60079.10.1:2022 provides industry proven examples of hazardous area classification for various sewage treatment processes. Although use of the examples is not mandatory, they represent common industry practices. For consistency, where Annex E.2 has identified an example classification, this guideline defers to that example. Furthermore, this guideline will suggest some example classifications for use, noting that they are suggestions only. A properly undertaken hazardous area classification by an experienced hazardous area professional, taking into account potential sources and contaminants as outlined in this guideline, can overrule these examples where the evidence suggests that they are unsuitable. These are provided in Section 6.

4.5 Current state of knowledge

The development of this guideline has been conducted based on the current state of knowledge from the experience of the working group and other guidelines and standards, both locally and internationally. Changes in key standards may warrant a review of these guidelines.

5. METHOD OF CLASSIFICATION FOR LINEAR INFRASTRUCTURE

5.1 Overview

AS/NZS 60079.10.1 provides alternatives to the method of area classification being:

1. Source of release method
2. Simplified method
3. Combination of source of release and simplified methods.

The source of release method requires a thorough understanding of the types of flammable materials and their release rates. These can generally be determined by thorough monitoring or a high level of knowledge of a specific situation. The level of monitoring in linear infrastructure required to be able to inform the source of release method is often difficult for most water agencies. A simplified method for linear infrastructure is provided in this guideline for those occasions when monitoring conducted is insufficient.

This guideline provides a likelihood based classification methodology as a useful tool to inform hazardous area classification by qualified hazardous area professionals. An overview of its framework is presented in Figure 5-1.

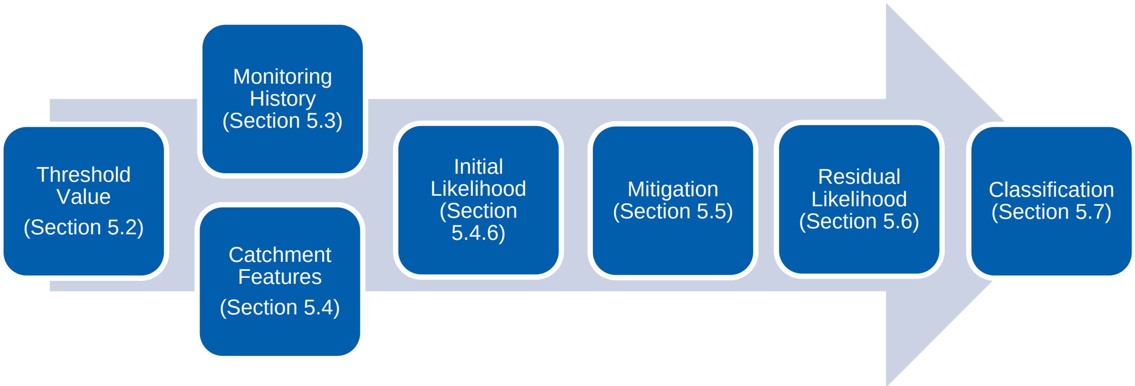

Figure 5-1: Overview of the linear infrastructure classification method

The process is a guided assessment of the likelihood of a flammable atmosphere occurring, with areas for consideration and tools to make informed decisions about likelihoods. The steps are as follows, with each step discussed in detail in following sections:

1. Assess available monitoring data
    a. If there is sufficient available monitoring data, use a ‘Source of release’ method defined in AS/NZS 60079.10.1.
    b. If there are gaps in this data, or the data is not considered representative enough for assessment, follow the remaining steps of the framework.

2. Assess the catchment features
    a. Consider the following information and make informed judgements about their impact on the likelihood of an atmosphere containing flammable contaminants above the threshold value:
        i. Hydraulic features
        ii. Catchment composition, such as stormwater infiltration and trade waste contribution to overall flow
        iii. Security features of the asset and how likely the asset is to be maliciously targeted, for example by illegal dumping
        iv. Abnormal operation, such as reports of hydrocarbon sheen or odour, or flow events which can influence trade waste discharge
    b. At the end of this process, collate risks from each category to provide an overall likelihood as provided in Table 5-6 below.
    c. Assess mitigation measures (if any):
        i. Assess the effectiveness of monitoring in providing advanced warning of risk in the asset or system.
        ii. Assess the effectiveness of ventilation in removing contaminants of concern from the asset or system.
    d. Re-assess the likelihood based on the benefits associated with the mitigation measures.
        i. Assess the consequences of an explosion occurring to influence the classification.
    e. Classify the area based on the residual likelihood. Refer to Table 5-12 in section 5.5.4 for the relationship between risk assessed and threshold values.

5.2 Threshold value for network installations

As discussed in Section 4.2.3, to begin the process by which linear infrastructure can be zoned, a threshold value must be set. A threshold of 25% of the LFL for the vapour concentration of the most significant substance is recommended. This is supported by AS/NZS 60079.13 as well as the UK DSEAR guideline (clause 6.219). Further justification for the use of a value substantially below 100% of the LFL is as follows:

- Measurements of the kind described in Section 3 are from a single point. This point may not be reflective of the overall hazard, particularly if ventilation is low. Depending on asset geometry, pockets of higher concentrations may exist within a structure. Although measurement should occur from a conservative location, this is not always possible. As such it is possible that the measured value is insufficiently conservative.
- Early indication of an event leading to high concentrations of flammable substances in the space. If such an event is occurring, advance notice should provide the opportunity to take action well before the concentration reaches 100% of the LFL. This is especially true

of events which may begin slowly and become stronger over time, such as a plant malfunction at a high strength trade waste customer's premises.

- Time is required to respond to an event with a potentially explosive atmosphere. Emergency services could need notification, assets may need to be shut down, bypasses may need to be placed into service, back-up power may be required, etc. All these activities require planning time which is less available should higher threshold values be used. This applies where the flammable or potentially flammable atmosphere could have an impact on public safety and is possibly not applicable where an area is already hazardous-area rated.

Table 5-1 outlines how the threshold value should be applied. A gas or vapour concentration of 25% of the LFL is the limit at which concentrations are concerningly high for normal or reasonably foreseeable abnormal operation and a hazardous area classification should be considered. At a level above 40%, emergency services need to be notified. If gas or vapour concentrations are exceeding this level in normal or reasonably foreseeable abnormal operation, a hazardous area classification is essential. An event of this nature is sufficient evidence to deem the area hazardous, unless there is a strong justification for the area to remain non-hazardous, for example a major flood outside the design life of the asset destroying all protection equipment.

Table 5-1: Threshold gaseous concentrations, suggested responses and associated commentary

Gas/vapour conc. (%LFL)	Responses	Comments
> 5%	Initiate stop work order and evacuate space if occupied If regularly exceeding this value, consider a monitoring campaign and hazardous area classification Evaluate any installed equipment, and consider its risk of spark e.g. consider removal of inherently sparking relays	Possibly a hazardous atmosphere, however it may not be a hazardous area Temporary or permanent mitigation measures such as ventilation for access should aim to control gas concentrations at or below this level
> 25%	Concentrations are unacceptably high for normal operations with no hazardous zoning Hazardous area classification should be considered unless outside normal/reasonably foreseeable abnormal conditions Monitoring campaign necessary to understand and better classify space	Existing mitigation measures (including ventilation) already in place are insufficient If no mitigation measures are in place, these should be evaluated and implemented Further consideration of the source of release and further control measures should be undertaken.

Gas/vapour conc. (%LFL)	Responses	Comments
	Shutdown of all systems and items of equipment that are not rated for hazardous areas	
> 40%	Notify fire brigade or local authorities as per State/Territory requirements Hazardous area should be assigned unless outside normal/reasonably foreseeable abnormal conditions Shutdown of all systems and items of equipment that are not rated for hazardous areas	Safety factors are compromised Automatic shutdown applies to parts of an installation protected by gas detection or ventilation Unless outside of normal and reasonably foreseeable abnormal parameters, mitigation measures are essential

Hazardous area classifications in other industries often refer to 50% of the LFL being a threshold at which the concentrations of flammable vapours should lead to hazardous area classification. This guideline aligns the fire brigade emergency response limit of 40% (as described by members of the working group) with the unacceptable threshold at the more conservative value of 40%.

It is important to emphasise that a single event leading to high concentrations of flammable gases may not require a zoning classification, should the cause be some event not practicably accounted for. However, a monitoring campaign and detailed hazardous area classification are essential to fully understand the likelihood of future events.

It is important to emphasise that this threshold value is for hazardous, that is, flammable or explosive areas. It does not apply to hazardous atmospheres. Toxic substances, for example, are not considered during a hazardous area classification or assessment. H_2S is a compound typically found in wastewater systems. Exposure to H_2S concentrations of 1,000 ppm is lethal, whereas the LFL is 40,000 ppm (4%). This is highly dependent on the specific contaminant of concern. A separate assessment should be made for hazardous atmospheres.

5.3 Monitoring history

Prior to any qualitative assessment, data collection from any sampling should be assessed. Based on the guidance provided in Section 3, assess:

- If the data is of sufficient monitoring duration to represent the asset's baseline or normal operating condition.
- If the data demonstrates abnormal operating conditions such that a judgement can be made confidently about these conditions.
- If the quality of the data is sufficient for it to be trustworthy.

If all the above is true, discontinue the process outlined in this section and use one or more source of release methods either outlined in or in accordance with AS/NZS 60079.10.1.

If one or more of the statements is false, continue with the process. Use the data collected to inform decisions made in subsequent likelihood analysis.

Example: A water agency is classifying a pumping station in a high probability location: an industrial catchment which receives primarily industrial effluent. The 28 day monitoring shows that peaks in flammable gases in the atmosphere are occurring, however there is no data to provide an indication of what compounds are causing the events. The simplified method is used in conjunction with the data to assess the likelihood of a flammable atmosphere based on potential contaminants, rather than the exact contaminants.

Example: A water agency is classifying a gravity sewer main. A spot sample analysed with GC-MS shows that there are some species of VOC which could cause explosive atmospheres. The simplified method is used in conjunction with the known contaminants of concern, as the peaks of the contaminants are not known because the data was not continuous.

5.4 Catchment features

It is recognised that an asset within a wastewater network exists within a catchment, servicing a specific number of commercial and residential connections. When classifying an asset, a sensible boundary must be developed so that the classification exercise can be focussed. This could prove to be difficult, especially in large and complex networks. This guideline recommends focussing on a critical point (such as a maintenance hole or a pumping station) and applying the rating from this asset backwards to the entry points, until such time that data is available to distinguish which connections present the most risks and sub-classifying these as separate assets.

The source of the cause of a flammable atmosphere occurring should be considered. If methane from biological activity within a rising main is a concern, the majority of high methane environments will be at the rising main discharge maintenance hole and the area sharing a downstream headspace. However, any locations downstream that do not share (or are not connected to) the headspace where methane will likely occur are unlikely to also be affected.

If the cause of a flammable atmosphere occurring is from VOCs that float on a surface, this can affect multiple downstream assets such as maintenance holes. If a pumping station has a continuous or intermittent mechanism to remove floating materials, such as through a vortex, swirl or snorkel, downstream pumping stations may also be affected.

It is recommended that each asset is assessed individually and, as part of that assessment, the upstream assets are analysed for any catchment features that would have a knock-on effect. This requires a sound knowledge of the local catchment and the various contributors (both registered and illegal) to the flows through the asset.

5.4.1 Hydraulic features

The type of asset in the linear infrastructure can lead to differences in methane generation risks. Methane generation predominantly occurs either in slime layers on sewers or in accumulated sediment, under anaerobic conditions. Gravity systems with shallow slopes or areas which can accumulate sediment such as inverted siphons are prone to sediment accumulation and have a higher risk of methane generation. Mains that have no, or small, gas-liquid interface, such as rising or undulating mains, are at greater risk of turning anaerobic than gravity mains and are therefore at higher risk.

By design, the sewerage network conveys a large range of flows. Often, infrastructure is installed with future capacity available such that future flows can be conveyed within engineering tolerances. This provides a strong benefit, in that capital expenditure in the present can create a piece of infrastructure which is suitable for use in the future. The weakness of this approach is that it leads to longer hydraulic residence times (HRTs) of sewage in the system, which can then lead to methane generation and therefore increased likelihood of a hazardous atmosphere forming.

In this assessment, the main with the largest retention time just upstream of the asset of interest should be considered, not the sum of all mains or areas upstream. This is because the methane generated in the longest retention time main will then be liberated on release. This assumes that all upstream pumping stations are at a minimum passively ventilated. For sealed networks, further work will need to be done to understand accumulations of gas.

Assess the risk of methane generation using Table 5-2. Note that there is additional risk associated with rising or undulating mains compared to gravity mains leading to an increased likelihood of high concentrations.

Table 5-2: Hydraulic residence time likelihoods. Rising mains, which convey sewage under pressure, have a higher likelihood than gravity mains of releasing significant methane concentrations in the atmosphere at their discharge point.

Gravity main infrastructure (maintenance holes, wet wells, gravity vent shafts)		Rising main infrastructure (pipelines, air release valves, discharge maintenance holes, receiving wet wells)	
Residence Time	**Likelihood**	**Residence Time**	**Likelihood**
0 – 12 h	Low	0 – 6 h	Low
12 – 24 h	Medium	6 – 12 h	Medium
24 h +	High	12 h +	High

Note 1: If the asset has an upstream rising main retention time of >12 h on average, a minimum rating of Zone 2 should be used to reflect the high likelihood of methane present during low flow periods unless there are alternate mitigation measures to inhibit methane biomass activity such as chemical dosing.

The likelihood of methane generation is further influenced by the following[25]:

[25] **Liu, Y, Ni, B-J, Sharma, KR & Yuan, Z 2015, 'Methane emission from sewers', Science of The Total Environment, vol. 524-525, pp. 40–51.**

- Surface area to volume ratio of pipelines; for example, short length and large diameter pipelines have a lower risk compared to long length and small diameter pipelines with the same retention time.
- Slope of pipework in gravity systems; the shallower the system slope the greater risk of sedimentation and methane build-up.
- Velocity of pipework; the greater the velocity the greater opportunity for sediment to be pushed further downstream.
- COD; the greater the COD the faster methane generation will occur.
- pH; above a sustained pH of approximately 8.5 – 9.0 methanogens will not produce methane.
- Temperature; the greater the temperature, the faster methane generation will occur.
- Turbulence; the greater the turbulence, the greater methane will be released to the headspace.
- Transient populations. For areas such as holiday destinations or towns with seasonal industry, the flow will be low during significant periods of time leading to higher retention times in sewers.

5.4.2 Catchment composition

One of the primary features to consider in classifying a linear asset is the catchment composition. The amount and type of trade waste, as well as the susceptibility to stormwater flows carrying contaminants from pavement and other surfaces into the sewerage system are discussed below.

5.4.2.1 Proportion of trade waste connections

The experience of the working group has found that assets which convey primarily commercial and industrial wastewater are more likely to develop an explosive atmosphere. Although many water agencies carefully monitor the discharge of trade waste customers, these customers' wastewater is not as predictable as that discharged by a municipal connection. Their own process upsets, foreseeable misuse or improper waste management can affect the wastewater system, even if much of the time their waste is predictable as per their trade waste agreement.

It is difficult to assign a boundary in terms of flow contribution from trade waste customers as it is highly dependent on the contaminants of concern being discharged. A single discharge from a certain type of emitter can significantly affect the catchment. Table 5-3 below provides a mechanism to determine the likelihood of trade waste producing an explosive atmosphere based on the proportion of trade waste flow and the quality of the trade waste. When talking about 'quality', this table describes a low, medium and high 'quality' in terms of its likelihood to contain substances that lead to an explosive environment. The use of this table is only a heuristic method as to how to account for the strength and quantity of trade waste in a catchment. Where concerns about a particular trade waste exist, lower proportions of trade waste may also be considered to produce a medium or high likelihood of explosive atmosphere development. In addition, control of the trade waste discharge should inform the use of the table. For example, strong source monitoring and treatment may reduce the likelihood of a high strength emitter discharging concerning quantities of flammable vapour. Conversely, no source control can mean that lower likelihood emissions are more significant.

Table 5-3: Likelihood classification based on catchment composition and type of discharge

	Likelihood of trade waste to produce an explosive atmosphere		
Percentage of flow from sources [Note 2]	Low likelihood trade waste quality	Medium likelihood trade waste quality	High likelihood trade waste quality [Note 1]
< 10% of flow from trade waste sources	Low	Low	Medium
10 – 25% of flow from trade waste sources	Low	Medium	High
25%+ of flow from trade waste sources	Low	High	High

Note 1: If any emitter is from a high likelihood source without source control such as a trade waste agreement, consider the likelihood of trade waste forming an explosive atmosphere high, regardless of flow contribution

Note 2: Flow is at the critical time and is therefore instantaneous flow

Please note that the system flow used to ascertain the likelihood of a trade waste discharge creating an explosive atmosphere is the flow at the most critical time. This means that this flow is an instantaneous flow, not an average flow. Some examples of most critical time, based on actual examples from the working group, are:

- An asset experiences a large dumping of wastewater from a trade waste source between 2 – 4 AM daily. At this time the trade waste discharge is >10% of incoming flows, and is therefore the most critical time.
- An asset in an industrial area experiences a large spike in trade waste discharge on a Friday afternoon (2 – 4 PM) weekly, as the local businesses wash out and empty sumps in anticipation of the weekend. At this time domestic flows are minimal therefore this is the most critical time.
- An asset experiences a major spike in flow from a major trade waste emitter, corresponding to cleaning and descaling processes at their plant one day every quarter. This day each quarter is the most critical time for trade waste.

If the proportion and quality of trade waste is unknown, it is recommended to assume a medium trade waste risk until such time as more information is available.

Trade waste quality classification

To assist in understanding the impact of trade waste on the likelihood of producing an explosive atmosphere, this guideline provides a list of common commercial and industrial businesses, their likely contaminants of concern and a classification of the risk of these contaminants creating an explosive atmosphere. Water agencies can assign their own risk profile to certain discharges or select from the table provided. The likelihood of an explosive atmosphere being formed by a trade waste emitter may vary from that mentioned in the table in Appendix A, depending on how well individual businesses manage their waste processes.

5.4.2.2 Stormwater infiltration

Certain assets are more likely to be affected by stormwater infiltration than others. The stormwater system is area of concern in heavily industrial areas, as run off from industrial spaces can carry with it various contaminants which can cause hazardous atmospheres to develop. Assess the likelihood of this infiltration. A guide is provided in Table 5-4 below. Low industry refers to areas where there are primarily residential dwellings and porous surfaces. High industry refers to areas of cities or towns where manufacturing, transport and handling of materials takes place, for example a business park or precinct with large, open and impervious areas.

Table 5-4: Likelihood of stormwater infiltration, relating the urbanisation of an area to the likelihood of contaminants of concern being present in stormwater discharge

Rate of measured or suspected infiltration	Catchment potentially contributing stormwater to asset		
	Low industry	**Medium industry**	**High industry**
No infiltration	Low	Low	Low
Low infiltration	Low	Low	Medium
Medium infiltration	Low	Low	High
High infiltration	Low	Medium	High
Combined system	Medium	High	High

5.4.2.3 Local ground conditions

As sewerage network infrastructure is generally buried under the ground, sometimes at great depths, there are various underground features which may affect the possibility of an explosive atmosphere being formed within the asset. Nearby infrastructure can play a significant role in affecting the atmosphere of a network asset. Some examples are:

- Buried or above ground natural gas delivery infrastructure, such as mains or reticulation pipes. Leaks from these can enter the sewerage system causing an explosive atmosphere. This is documented as occurring at several locations nationally over the previous 10 years.
- Nearby fracking or gas fields, which have the potential to cause gas migration, which then enters the sewerage system.
- Buried infrastructure such as landfills. Where landfills are poorly lined or sealed, the methane generated by the decay of buried organic material can migrate through the surrounding earth. This gas can bubble to the surface, or enter nearby infrastructure.

In addition to these man-made sources of risk, some examples of risk associated with naturally occurring underground features are:

- Contaminated groundwaters which may contain contaminants which influence the wastewater system.

- Buried deposits of gas, which can migrate into nearby sewerage infrastructure.

Assess the likelihood of the ground conditions contributing to an explosive atmosphere in the asset. If constructing a greenfield asset, consider if the location can be selected to reduce risk. The gas permeability of the local earth should also be considered; permeable sands are of higher risk than well-compacted soils.

If a permeable asset, such as a pipeline, is upstream of the asset in question and within an area of higher geological risk, then further sampling is recommended to determine if there is an impact on the asset.

5.4.3 Security

Having established the likelihood of an explosive atmosphere associated with HRT and catchment composition, the location and operational considerations of the asset are evaluated for their contributions to the likelihood of the development of explosive atmospheres.

5.4.3.1 Location

Location can influence the likelihood of an explosive atmosphere being present within the asset. It can influence this by:

- Being in such a place as to be difficult to access for illegal dumping purposes.
- Being in a remote location, such that vandals are less likely to target it.

Assess the asset's location, and if constructing a greenfield asset, consider if the location can be selected to reduce risk.

5.4.3.2 Security of site

The security of the site can play a significant part in preventing foreseeable misuse. As discussed in Section 5.4.3.1, some sites are secure by virtue of their location being difficult or inconvenient to access. In this section, security is intended to discuss the barriers which may stop people or vehicles from entering. Some items for consideration for the security of the site are:

- Is the asset in a fenced compound? Is this fence sufficiently robust to stop people from entering? This can serve to prevent foreseeable misuse, reducing the likelihood of an explosive atmosphere being caused.
- Does the asset have an open lid? Can the lid be opened easily by a member of the public? For example, a lockable lid or a heavy-duty cast-iron lid are not easily opened without multiple people and tools, making misuse much less likely and leading to a low security risk.
- Is the asset monitored, for example by CCTV or patrolling security? Monitoring of this nature is more likely to discourage illegal activity and reduce the likelihood of explosive atmospheres being caused.

Consider the security of the asset and adjust the likelihood based on how secure the asset is.

5.4.4 Abnormal operation

Having assessed the hydraulic features, the catchment composition and the security features associated with the asset, abnormal operating conditions and their effect on the potential for hazardous atmosphere should be considered. As discussed in Section 4.2.2.2, abnormal operating conditions form an important part of the hazardous area assessment. Assess the effect of the below factors on the overall likelihood of the asset forming an explosive atmosphere.

5.4.4.1 Power failure

Consider the effect of power failure on the asset being considered. Loss of power in the network could mean:

- Loss of flow, leading to high residence times and methanogenesis in rising mains or accumulation of waste streams causing build-up of flammable atmosphere.
- Loss of ventilation for control of gas concentrations in the atmosphere.
- Loss of monitoring for equipment controlling gas concentrations in the atmosphere.

Assess the effect of power failure on the asset. This check primarily applies to pumping stations (both wet and dry/wet configurations) and odour control units (OCUs).

- Will power failure lead to an increased likelihood of explosive atmosphere in the asset?
- How often is power failure occurring at the asset, and for how long? Refer to actual historical data.
- How long until loss of power increases the likelihood of explosive atmosphere?
- Are there processes in place such as back up generators, alternative power supplies and/or maintenance crew manual interventions such that power can be restored sooner than the time frame which will lead to an increased likelihood of explosive atmosphere? Refer to actual historical power failures and their time to re-energisation. If no data exists, consider that power cannot be restored in time.

If power failure can affect the explosivity of the atmosphere and if power cannot be restored in time to prevent this effect, take this into consideration during the assessment.

When undertaking an assessment, the user should consider the most critical upstream source (as discussed in Section 5.4.1) and its potential for methane generation, as well as process specifics such as whether mechanical or passive ventilation is present. There are a number of factors which need to be considered, which will vary from asset to asset. A “fault tree” analysis or other safety in design type assessment is recommended to assess the full impact of power failure on an asset.

5.4.4.2 Plant/equipment failure

Plant/equipment failure in a network can cause:

- Loss of flow, leading to high residence times and methanogenesis in rising mains or accumulation of waste streams causing build-up of flammable atmosphere.
- Loss of ventilation for control of explosive atmospheres.
- Loss of monitoring for control of equipment managing explosive atmospheres.

Assess the effect of plant/equipment failure. This check primarily applies to pumping stations (both wet and dry/wet configurations), air valves and their pits and OCUs.

- Will failure lead to an increased likelihood of explosive atmosphere?
- How often is failure occurring, and for how long? Refer to actual historical data.
- How long must the plant/equipment be offline until the likelihood of explosive atmosphere increases?
- What is the time to the asset being placed back in service? Refer to actual historical data and experience. It is common practice that installed standby infrastructure can be left for long periods of time, especially for particularly bespoke assets such as specialist fans requiring custom parts. If this data is not available, refer to Table 5-10 for an indication of the asset's susceptibility to plant failure.

If plant/equipment failure can affect the explosivity of the atmosphere and if the plant/equipment cannot have its service restored in time to prevent this, take this into consideration during the assessment.

5.4.4.3 Varying load cases

Differing loads on the sewerage system can have an effect on assets. For example, wet weather flow can lower methane production in discharge maintenance holes (DMHs) through the decrease of HRT. Wet weather flows can also contribute to sewer chokes, which may restrict movement of air in the system. It is recognised that connections to the sewerage system mean that these loads change over time. The forecast load to be used in the assessment should reflect the frequency that a hazardous assessment is reviewed. For example, if it is intended that the hazardous area assessment is reviewed every 4 years, the forecast load should consider expected variations across the next 4 years. In this assessment, the following should be considered:

- Will lowest dry weather flow affect the formation of an explosive atmospheres? If so, how frequently does this occur?
- Will peak dry weather flow affect the formation of an explosive atmospheres? If so, how frequently does this occur?
- Will wet weather flow affect the formation of an explosive atmospheres? If so, how frequently does this occur?
- Will peak wet weather flow affect the formation of an explosive atmospheres? If so, how frequently does this occur?
- Will these flows change significantly in the review period?

For example, a trade waste discharger with a known problematic wastewater stream discharges this stream in the middle of the night for their own process reasons. At this time the wastewater forms a significant portion of flows in the local sewerage system, leading to increased possibility of a hazardous atmosphere occurring.

If changing flow to the asset causes a change of atmosphere, consider this in the assessment.

5.4.4.4 Blockage or leakage

Blockages (sometimes referred to as chokes) can increase the likelihood of an explosive atmosphere occurring by:

- Restricting headspace and reducing volume, therefore creating an increased likelihood of an explosive atmosphere forming in the downstream air space.
- Higher pressure discharge in air movement pathways such as vent shafts leading to a greater likelihood of explosive atmospheres outside the asset.
- Reduced liquid flows in pipelines, increasing HRT and (for rising mains) increasing pipeline pressures meaning the possibility of more methane being released.

Leakage of pipework can increase the likelihood of an explosive atmosphere by:

- Releasing flammable gases into unintended spaces.
- Allowing migration of explosive atmospheres into the sewerage system, such as that found from a nearby leaking gas main or in-ground methane deposits.
- Insufficient control of an atmosphere such as leaking OCU ductwork).

Assess the risk of blockage or leakage in pipework. Check the following:

- Will blockage or leakage lead to an increased likelihood of explosive atmosphere?
- How often is blockage or leakage occurring? Refer to actual historical data.
- How long is it taking for blockages or leaks to be repaired? Refer to actual historical data.
- How long can a blockage or leak be in place until the likelihood of explosive atmosphere increases?

If blockage or leakage in the asset increases the possibility of a change of atmosphere, consider this in the assessment.

5.4.4.5 Flood risk

The effect of a design flood should be considered on the hazardous atmosphere. Floods can:

- Reduce air spaces, leading to higher concentrations of flammable gases in the reduced volume if the source is an immiscible liquid such as petrol.
- Disturb sediments, potentially releasing discharges.
- Carry contaminated stormwater.
- Degrade the quality of trade waste discharges.

There may also be cases where flooding decreases the likelihood of hazardous atmospheres occurring through infiltration diluting wastewater, leading to lower COD, temperature and retention times in sewers.

Consider the effect of a design flood in line with or of greater magnitude than the asset life. Common industry practice is to consider the 1% AEP for in ground structures; for mechanical equipment, with its lower design life, it is generally either the 5% or 2% AEP flood. If flooding increases the likelihood of explosive atmospheres, take this into account in the assessment.

5.4.4.6 Foreseeable misuse

An important abnormal condition is that of foreseeable misuse of the sewerage system. Because of the open and unmonitored nature of the system, it is open to misuse in both malicious and unintentional ways. Some examples of unintentional activities which can contribute to increased likelihood of explosive atmosphere include:

- Undeclared discharges from trade waste dischargers, for example from businesses whose process knowledge is low.
- Minor discharges of a domestic nature. Although generally not a problem in isolation, an event such as a government mandated lockdown can lead to more prevalent discharging and contribute to hazardous atmospheres.
- Operator error, for example leaving valves in incorrect positions, wrong control sequences initiated, carelessness, insufficient training.
- Accidental discharge such as spills from tankers which make their way into the sewerage system.

Some examples of malicious intent would include:

- Businesses knowingly discharging trade waste not covered in quantity or concentration by their discharge agreements.
- Purposeful dump of illegal material, for example a tanker emptying at pumping station
- Illegal material manufacture, such as drugs or unlicensed industry
- Vandalism

Consider the possibility of these events in leading to an explosive atmosphere, and assess the following for the asset:

- Is the current trade waste monitoring system robust enough to ensure that undeclared discharges are found and corrective action taken, deterring improper use? If not, how will these potential discharges affect the potential for explosive atmospheres in the asset?
- Is the asset secure enough to prevent vandals from entering and illegal dumping?
- Are there combined systems or known areas of cross connection which may mean that an accidental discharge such as a fuel spill enters the system?
- Is there sufficient training and supervision to ensure that operator errors are minimised?
- Is there good community outreach to prevent illegal dumping by residential customers?

5.4.5 Baseline zonal classification

In the absence of good quality monitoring data, the catchment features should be assessed individually. The likelihood for each area can be summarised in Table 5-5 below by circling whether the likelihood is high, medium or low for each area. Each 'High' rating is given a score of 3, with each 'Medium' rating a score of 2 and 'Low' ratings a score of 1. Then the number of ratings circled should be summed and multiplied against the score for that rating type. The sum of this will provide an overall score. Each area is weighted to accommodate the fact that in practice some areas will have more of a bearing on the likelihood of an explosive atmosphere being formed in the asset.

After each area has been scored, this score is divided by three and multiplied by the weighting of the category. After this, the score for each area is calculated. By adding all the scores, a value out of 100 can be given.

Table 5-5: Catchment feature summary, listing each of the areas for consideration in the simplified method and their weight

Section	Area	Likelihood of gas concentrations exceeding the threshold value			Weight	Score
5.4.1	Hydraulic features Note 1	High (3)	Medium (2)	Low (1)	40%	
5.4.2	Catchment composition				40%	
5.4.2.1	Proportion of trade waste connections Note 2	High (3)	Medium (2)	Low (1)	30%	
5.4.2.2	Stormwater infiltration	High (3)	Medium (2)	Low (1)	5%	
5.4.2.3	Local ground conditions Note 3	High (3)	Medium (2)	Low (1)	5%	
5.4.3	Security				10%	
5.4.3.1	Location	High (3)	Medium (2)	Low (1)	5%	
5.4.3.2	Security of site	High (3)	Medium (2)	Low (1)	5%	
5.4.4	Abnormal operation				10%	
5.4.4.1	Power failure	High (3)	Medium (2)	Low (1)	1.7%	
5.4.4.2	Plant/equipment failure	High (3)	Medium (2)	Low (1)	1.7%	
5.4.4.3	Varying load cases	High (3)	Medium (2)	Low (1)	1.7%	

Section	Area	Likelihood of gas concentrations exceeding the threshold value			Weight	Score
5.4.4.4	Blockage or leakage	High (3)	Medium (2)	Low (1)	1.7%	
5.4.4.5	Flood	High (3)	Medium (2)	Low (1)	1.7%	
5.4.4.6	Foreseeable misuse	High (3)	Medium (2)	Low (1)	1.7%	
	Total Score				100%	
	Initial zonal rating					

Note 1 – If the asset has a rising main retention time of >12 h on average, a minimum rating of Zone 2 should be used to reflect the high likelihood of methane present during low flow periods unless otherwise controlled for instance through chemical dosing.

Note 2 – If there is a confirmed history of flammable immiscible liquids being discharged into the asset or confirmed odours of a sickly sweet, solvent or non-sewage nature, then the minimum classification should be Zone 2 and a sampling campaign should be undertaken.

Note 3 - If a permeable asset, such as a pipeline, is upstream of the asset in question and within an area of higher geological risk, then further sampling is recommended to determine if there is an impact on the asset.

The sum of scores can then be evaluated against Table 5-6 below to determine an overall likelihood rating that can be used in lieu of monitoring data, as a precursor or pre-screening tool to assess the need to collect monitoring data or as a supplemental tool in the classification process.

Table 5-6: Catchment features likelihood score

Total Score	Initial zonal rating (subject to sampling)
<55%	Non-Hazardous
<70%	Zone 2
<90%	Zone 1
>90%	Zone 0

An example of catchment feature risk is provided in Table 5-7.

Table 5-7: Example of filled in catchment features assessment

Section	Area	Likelihood of atmosphere exceeding the chosen threshold value			Weight	Score
5.4.1	Hydraulic features	High (3)	Medium (2)	Low (1)	40%	26.7%
5.4.2	Catchment composition				40%	
5.4.2.1	Proportion of trade waste connections	High (3)	Medium (2)	Low (1)	30%	10%
5.4.2.2	Stormwater infiltration	High (3)	Medium (2)	Low (1)	5%	5%
5.4.2.3	Local ground conditions	High (3)	Medium (2)	Low (1)	5%	3.3%
5.4.3	Security				10%	
5.4.3.1	Location	High (3)	Medium (2)	Low (1)	5%	3.3%
5.4.3.3	Security of site	High (3)	Medium (2)	Low (1)	5%	1.7%
5.4.4	Abnormal operation				10%	
5.4.4.1	Power failure	High (3)	Medium (2)	Low (1)	1.7%	0.57%
5.4.4.2	Plant/equipment failure	High (3)	Medium (2)	Low (1)	1.7%	0.57%
5.4.4.3	Varying load cases	High (3)	Medium (2)	Low (1)	1.7%	0.57%
5.4.4.4	Blockage or leakage	High (3)	Medium (2)	Low (1)	1.7%	0.57%
5.4.4.5	Flood	High (3)	Medium (2)	Low (1)	1.7%	0.57%
5.4.4.6	Foreseeable misuse	High (3)	Medium (2)	Low (1)	1.7%	1.1%
	Total					53.95%
	Initial zonal rating (from Table 5-6)				Non-Hazardous	

The water agency can choose to modify the provided weightings that are applied to each of the above catchment features to take into account local issues that may influence the formation of explosive atmospheres. If weightings are modified, the scoring should also be reviewed by the water agency to consider the impact of changing these weightings.

5.5 Mitigation Measures

After having considered the hazards within the catchment either through monitoring or through an evaluation of the catchment features, an initial zonal rating is assigned to the asset. This section investigates mitigation measures that may influence the initial zonal rating; these mitigation measures could include aspects over and above what is covered in this guideline. Examples of hazard mitigation measures include:

- Selection and installation of equipment to be commensurate with the nature of the hazard. This includes the use of standards such as AS/NZS 60079.14 for electrical equipment.
- Management of hot works or external sparking factors such as combustion engines.
- Emergency response plans. See Section 7.
- Safety management system to manage risks of exposure to hazardous atmospheres.
- Confined space procedures in accordance with relevant state code of practice and Australian standards for entry into atmospheres which may be considered hazardous.

Mitigation measures must be reasonable, effective and operational to enable the hazards to be considered as adequately mitigated.

5.5.1 Monitoring and source control

5.5.1.1 Monitoring

The presence of an online monitor in the asset can provide an early warning ahead of an incident. A suitably calibrated instrument, providing a time history of contaminant concentration in the air space of the asset, can indicate if a potentially explosive atmosphere is substantial in magnitude or different enough from historical trends to warrant investigation. Depending on the asset, an emergency mode could be activated in case of high concentration in the space. For example, if a concentration of contaminant approaching the threshold value is detected, then ventilation could be increased automatically. Alternatively, if a high concentration of flammable contaminants is detected at a pumping station, the pumps could be called to stop and an alarm raised. Other examples could include:

- Alarming operators to investigate, isolate and pump down the asset.
- Alarming operators to co-ordinate an emergency response.
- Interlocking to assets such as pumps, fans etc. to provide another kind of engineering control.

If the asset being assessed has monitoring which is suitable for the environment and is linked to a method of responding more quickly to the potential of an explosive atmosphere developing, this likelihood can be significantly reduced. An indication of this changing benefit effectiveness is provided in Table 5-8 below, noting that this will not apply in every circumstance.

Table 5-8: Benefit of monitoring on mitigation of hazardous atmosphere, linking the alarm threshold of the monitoring to the time to respond to potential hazard

Monitoring alarm threshold, concentration in atmosphere	Time to respond to potential explosive atmosphere
26 – 40% of LFL	Low
15 – 26% of LFL	Moderate
5 – 14% of LFL	High

For a linear asset, the monitoring of flammable concentrations in the asset headspace can be a cost-effective way to assist the prevention of an explosive atmosphere if an action is automated to reduce the concentration based on the measurements. Consistent, long term monitoring can also inform decisions about the classification of an asset when it is due for its next inspection period.

It is important to consider that monitoring is not itself a mitigation of any potential explosive atmosphere. In this way, monitoring by itself does not affect the classification of an area.

5.5.1.2 Source control

Monitoring is of major benefit for use in source control. In certain assets, hazardous areas will be the result of a frequent trade waste license breacher, or from a customer who does not know that their waste is producing flammable atmospheres. In this case, monitoring provides exceptional utility in understanding patterns of flow and concentration of these substances such that breach of license or undeclared discharge can be identified and prevented at the source. This process can be time consuming, however, and can produce mixed results.

The effectiveness of any source control being relied upon needs to be validated through monitoring.

Future source control cannot be relied upon as a mitigation. If source control is successful in the future, as deemed by monitoring, future consideration of the asset (such as a change of flow due to increased population) can consider the impact of this success on the contaminant profile and thus the possibility of a flammable atmosphere being formed.

5.5.2 Isolation and bypass

In the event of an explosive atmosphere being discovered, the risk can be somewhat mitigated if there is both liquid and gas phase isolation and some way of bypassing the asset; in case of any event, the asset can be isolated in both liquid and gas phases and safely bypassed such that the threat is contained. The water agency can then contain the atmosphere to a single location. This does not affect the likelihood yet does affect the consequence.

While theoretically possible, this type of mitigation measure is considered impractical in most linear assets throughout Australia and is therefore not considered further for linear assets.

5.5.3 Ventilation

A common control for the mitigation of explosive atmospheres is ventilation. Ventilation is then further modified by its availability: good, fair or poor.

This section discusses ventilation best practice, international examples of suggested ventilation rates and specifies a method for determining the availability of ventilation and if the ventilation is good, fair or poor.

5.5.3.1 Cost/benefit considerations with ventilation

As per AS 60079.13 Table 7.1.6, if an area is classified as hazardous without ventilation, any equipment in the area which is required to be online during a failure of ventilation must have an EPL in line with the zonal requirements without ventilation. The ventilation system itself must always have the EPL of the baseline zone. This means that there is a cost/benefit consideration to the use of artificial ventilation in controlling flammable vapours. For example, consider a pumping station classified as a Zone 2 hazardous area with an EPL of Gc. The use of ventilation in the wet well could provide the opportunity to use non-hazardous equipment. However, the asset owner would have to consider loss of ventilation and will most likely find that all of the assets in the wet well (actuated valve, instrumentation, pumps etc.) are required to be operational even when ventilation has failed. In this case, these items must all have an EPL of Gc. If this is the case, the ventilation does not provide a benefit. Another example is a primary sedimentation tank (PST) classified as a Zone 2 hazardous area. The tank's equipment could be isolated in case of power failure and therefore the ventilation system would enable the installation of non-hazardous equipment. This can be more cost effective than the additional design, construction and maintenance requirements associated with EPL Gc equipment.

In practice, most wastewater assets require constant availability, regardless of ventilation status. However, many wastewater assets also have a need to be ventilated for reasons unrelated to explosive atmospheres such as odour and corrosion control. It could be cost effective to integrate the additional requirements of AS/NZS 60079.13 into this ventilation system during installation and use it to provide the possible benefit of reduced equipment protection. This is especially relevant for installations in brownfield areas which are being re-classified as hazardous areas.

5.5.3.2 Ventilation best practice

To provide recommendations regarding ventilation, it is firstly important to define ventilation best practice. Some key aspects of ventilation best practice are discussed below. Ventilation is used to control the formation of potentially explosive atmospheres in the asset by the introduction of (in most applications) clean air and the removal of contaminated air. For further information on ventilation requirements in hazardous areas, refer to AS/NZS 60079.10.1 and AS/NZS 60079.13.

Concentration gradient and local vs. bulk ventilation

Vapours which are discharged by immiscible flammable substances, as well as vapours which are discharged by flammable substances which have mixed with wastewater, will enter the headspace of an asset through different pathways. Immiscible liquids will remain on the wastewater surface, creating an oily sheen or rainbow coloured effect which can be visible. These liquids will spread over the wastewater surface, creating a layer which will begin to directly discharge (or evaporate) into the space. As this evaporation occurs, there will remain a portion of the atmosphere immediately adjacent to the liquid surface where the air will be saturated with the flammable vapour. For flammable vapours such as petrol, this saturation concentration can be higher than the LFL. It is important to note that even at exceptionally high rates of ventilation, it is very difficult if not impossible to avoid a concentration in the air space of at least 100% of the LFL at some location in the space. From this point, vapour is diffused through the bulk gas phase and the concentration in the atmosphere begins to increase at all points in the space. This leads to a concentration gradient, where the local concentration close to the wastewater surface can be significantly higher than a point distant from that surface.

Soluble liquids, which will dissolve in wastewater, are transferred from the liquid phase more slowly and are driven by the partial pressure of that substance above the liquid surface. This is defined by Henry's Law. In this case, the evaporation of the liquid substance into the vapour phase will generally be better mixed than an immiscible liquid in that the liquid in contact with the vapour contains a smaller concentration of the substance. Ventilation of the bulk gas phase is generally sufficient to manage the concentration of these substances. However, there will remain some difference between the concentration at the liquid surface and the uppermost part of the head space. This is particularly true when the substance, in the vapour phase, is significantly lighter or heavier than air.

There are broadly two methods which can be used to ensure that the concentrations of flammable vapours in the bulk gas phase remain below the LFL. The first is an approach where air is extracted from the entirety of the air space. This relies upon the contaminant being adequately mixed into the bulk gas phase and extracted from the atmosphere; in this case, impediments to mixing of the flammable vapours with the bulk air stream can cause localised pockets of high concentration. Some of these impeding factors are discussed below. To overcome this limitation and maintain this approach, usually more air is extracted and relieved to ensure that there is sufficient turbulence everywhere in the space to mix the flammable vapours into the bulk air stream.

The second ventilation extraction strategy uses multiple points of extraction. An example of this is a wood working shop, where each booth or work area has high velocity local extraction adjacent to the work area which is creating the contamination. Extraction points should be chosen to avoid localised concentrations; this could mean selecting an extraction point close to the liquid surface (while keeping it high enough that it will not be submerged during peak flow times), or for larger assets, multiple extraction points close to the water surface. In the case of an item of plant or equipment, the extraction point should be close to the source of release to minimise the diffusion of the local flammable atmosphere into the bulk air space. This will minimise the formation of local pockets of high concentration. In smaller spaces or where contaminants are of a nature where diffusion to the bulk gas phase is more likely, ventilation of the bulk phase can be sufficient to control the formation of an explosive atmosphere.

Relief or make up pathways

Although often neglected in ventilation design, the mechanism by which air is brought into or removed from a space which is being ventilated is an important ventilation consideration. If air is being supplied by the ventilation system, the air which then leaves the process unit is called relief air. If air is being extracted by the ventilation system, the air that first enters the process unit is called make up air. The general rule is that positive pressure should be applied where an asset is located inside a hazardous area and negative pressure should be applied where the enclosed space is the source of the hazard. In the wastewater industry it is often the enclosed space that is the source of the hazard, and for this reason positive pressure systems are rare.

Relief air or make up air is generally sourced from a dedicated item of equipment. In network applications, this is generally an inlet cowl or an air inlet. In wastewater treatment plant assets, this may be via a barometric air damper for a low-pressure application or flame arrested relief valve for a digester. It is important that the equipment contains a low pressure drop, such that air is encouraged to enter or exit through the intended pathway and not through uncontrolled leakage points such as gaps in covers. The location of introduction of this ‘make-up’ or relief air is important, as it affects the path that air travels through the air space of an asset until it arrives at the extraction point (or vice versa). Best practice is to have multiple air relief or make-up air openings, such that the air is not swept from a single point to the extraction point. Locations for relief valves should also be positioned to avoid short-circuiting, where the relief or make up point is too close to the extraction point and path of the air does not sweep through adequately. Best practice in ventilation design for covered assets also includes an allowance in the ventilation rate and extraction pressure to allow sufficient negative pressure under the covers; this is further discussed in the Appendices. Sufficient points of low-pressure drop should be available such that fresh air is being reliably used to control the atmosphere in the space, rather than borrowed air from upstream of the extraction point.

Turbulence

Where evaporation is based heavily on the partial pressure of the vapour above the surface, the turbulence of the wastewater is a significant factor in the quantity of flammable vapour which is emitted to the bulk gas phase. This is especially true for soluble liquids yet also applies to immiscible liquids. A quiescent surface, such as the water level of a maintenance hole with submerged inlets and outlet, will not lead to an increase in emissions. The worst-case scenario is an asset with an exceptionally turbulent wastewater surface. This is readily evident in treatment plants, for example, where a rising main fitted with a bellmouth discharging above the water line produces a free discharge and creates significant turbulence.

A primary cause of surface turbulence in wastewater applications is the hydraulics of asset operation. Waterfalls, where wastewater falls from one height to another, free discharges or steep inclines all agitate the wastewater surface and can increase the release of any flammable substances.

Submerged inlets and outlets and low wastewater velocities, long radius bends and the minimisation of baffles are common best practice approaches used to ensure that wastewater surfaces are quiescent.

Impeding factors

Blockages to the movement of air can be a factor in increased local concentrations of flammable vapour in a space. In an open environment such as open process units at wastewater treatment plants, physical blockages such as walls or roofs can prevent horizontal air movement and decrease the effective ventilation of an installation. In a covered and ventilated space, blockages such as pipework, walls, stopboards or access platforms can cause a blockage between the area obstructed and the extraction point. The physical geometry of the asset itself can also cause this impedance. For example, a pumping station with an annular emergency storage tank which surrounds a wet well has very poor air movement between the tank and the wet well.

Best practice ventilation designs for open plant areas ensure that wind can access the structure from the most commonly occurring wind direction at the site, and with structures positioned away from key wind corridors to allow maximal natural ventilation. In the case of an enclosed structure, it may not always be possible to keep any internal structures or pipework minimal. In this case, additional extraction points are provided which allow for ventilation of areas impeded by the structures.

Contaminant features

The contaminant features can strongly influence the optimum ventilation strategy for an asset. For example, methane is lighter than air, meaning it will float and can often be released from gaps in covers of structures. Heavier than air contaminants will tend to accumulate near the wastewater surface. The striation in concentration gradients can alter quickly in dynamic systems, such as those where the water level significantly changes.

Ventilation rate based on control of contaminants

AS/NZS 60079.10.1 provides methods of calculating ventilation based on a known rate of release of hazardous material. If monitoring data is available to provide enough information to quantify the flammable material and the quantity of its release such that the methods of a recognised standard can be used, it is recommended that the ventilation requirement for the asset be calculated using one of the following recognised standards:

- AS/NZS 60079.10.1
- EI15
- Dispersion modelling software tools such as Computational Fluid Dynamics (CFD)
- Institution of Gas Engineers and Managers (IGEM)/SR/25, however this method should only be used where the contaminants of concern are exclusively biogas, methane or natural gas, which is unlikely.

Water agencies should balance the initial costs of additional design work in the form of dispersion modelling/CFD against the construction and operation costs of larger ventilation infrastructure and the impact of this to the community, for example through increased noise disturbance. This should only be done when there is high confidence in the data available.

Dispersion or discharge modelling using CFD is a tool which is growing in popularity as the costs of usage are reduced over time. There are commercially available packages tailored specifically towards hazardous areas as well as standard CFD packages which can be used. CFD can provide strong evidence of the effectiveness, or lack thereof, of ventilation on hazardous areas, and when used correctly is one of the best available tools to understand the impacts of ventilation. As well as providing a benefit in terms of assessing ventilation efficiency, it is important to note that CFD, when done properly, is one of the most accurate tools when assessing the build-up of flammable vapours in atmosphere. This can provide confidence in life safety aspects of ventilation design such as in assessing evacuation times of personnel. This is particularly true in complex structures with enclosed spaces.

United Utilities CoP 1 recommends IGEM25 and Chartered Institution of Building Services Engineers (CIBSE) B. CIBSE B has been reviewed and was deemed unsuitable for ventilation of linear assets. This is best used for habitable spaces such as buildings and is primarily concerned with odour and CO_2 build up to assess breathability of air in those spaces. IGEM25 is included but with a caveat which limits its applications to a very small set of cases.

Where information regarding the contaminants present is insufficient, other methods must be used. This could be a headspace air change rate as discussed below.

Ventilation rate based upon headspace air change rate

In the absence of monitoring data there is no alternative but to rely upon a heuristic approach to ventilation. These are air change rates, expressed in Air Changes per Hour (ACH), which when applied to the air volume of the space can provide a ventilation rate in cubic metres per hour.

For raw sewage applications, such as those found in network applications or inlet works 6 – 15 ACH is common in the water industry. These ventilation rates are often to ensure odours do not escape from the covered asset and are **not** designed to reduce the contaminants within the headspace of that asset below a certain concentration.

Many international guidelines specify ventilation rates for hazardous area control, although often no engineering basis is presented for review.

Using a specified air change rate can lead to either over or under design, as it does not address the requirements of the specific contaminant of concern. However, without knowledge of the specific contaminants of concern present in the asset these heuristics are the only tools available. A range of international examples are discussed below.

5.5.3.3 International recommendations

Like AS/NZS 60079.10.1, EI15 does not provide any ventilation rates for use. Rather, it states that ventilation should contain the contaminant of concern in the space to 25% LFL. It also recommends localised ventilation close to the source of release, rather than space ventilation, to minimise the area. Although useful for a treatment plant environment, for the purposes of ventilation of network infrastructure it is difficult to apply without good monitoring data.

In the review of the international standards and guidelines, prescribed figures are used by certain water agencies to provide an indication of sufficient ventilation. Examples include:

- NFPA820, containing two ventilation level recommendations which reduce the classification of the area with no guidance as to their recommended use:
  - 12 ACH
  - 6 ACH.
- SPD E04, containing three recommended levels with guidance as to their usage:
  - 1 ACPH rate for digester air spaces and enclosed plant rooms to allow reduced zoning
  - 3 ACPH for enclosed plant rooms allowing further reduced zoning, wet wells and a lower limit for odour control
  - 6 ACPH as an upper limit on odour control.
- COP1 i7 contains recommended levels with guidance as to their usage. The newer edition (i9) changes this to a recommendation to use a suitable standard such as IGEM25 (from the natural gas industry), Quadvent (a UK government developed tool for calculating gas release volumes for hazardous areas) or CIBSE B (a building services industry ventilation code, somewhat equivalent to AS 1668.2). The i7 version recommended levels are:
  - 5 ACPH for enclosed plant rooms
  - A range of prescribed equations for different installation cases covering both network and treatment plant applications.

5.5.3.4 Degree of ventilation

If a sampling campaign has provided the concentrations of flammable vapours in the atmosphere, use these values to calculate the required ventilation rate as per the guidance in AS/NZS 60079.10.1.

Without knowing the contaminant of concern, it is not possible to accurately assess whether the degree of ventilation is high, medium or low. Therefore, some assumptions have to be made in order to provide an indication that the ventilation is sufficient.

When the contaminant of concern is unknown, this guideline recommends assuming that the liquid surface of the asset being investigated is covered in petrol. This will provide a conservative estimate of the required ventilation rate which will be well in excess of the requirement for most wastewater installations. Having assumed this, a number of methods can be used to provide an estimate of the emissions from this liquid surface. These include but are not limited to:

- AS/NZS 60079.10.1 release methods, such as those found in Section B.7.3
- CFD analysis of the asset.

Ventilation can be classified as 'High dilution' if the ventilation rate is able to control the concentration of flammable vapour in the atmosphere (inclusive of any turbulence or blockage) to less than 5% of the LFL. Ventilation can be classified as 'Medium dilution' if the ventilation rate does not meet the selected LFL threshold value at the worst case conditions inclusive of any turbulence or blockage conditions, however keeps the LFL below 25%.

All other cases should be considered as having a 'low dilution' ventilation rate.

Guidance on the use of AS/NZS 60079.10.1 Section B.7.3 in network applications

Equation B.7, covered in Section B.7.3. is provided below for commentary[26]:

$$Q_g = \frac{18.15 \times 10^{-8} u_w^{0.78} A_p p_v}{M^{0.333}} \times \frac{T_a}{T} \left(\frac{m^3}{s}\right)$$

Where M is the molar mass of gas or vapour (kg/kmol), u_w is the wind-speed at the pool surface (m/s), A_p is the area of the pool (m^2), p_v is the vapour pressure of the pool at temperature T (Pa), T is the temperature of the fluid, liquid or gas (K) and T_a is the ambient temperature (K).

This equation models the evaporation of a thin liquid pool of at least 10 mm in depth. Assuming that the contaminant being modelled is at the wastewater temperature, evaporating and not boiling and is at a relatively low vapour pressure, this equation can be used to model the evaporation of an immiscible liquid on the liquid surface within a wastewater asset. This is merely an approximation, used in the absence of sampling data or of more sophisticated modelling, and should be used carefully.

For network applications, some typical input data is below:

Variable	Range of values	Comments
u_w (m/s)	0.5 – 1.5 for natural ventilation	There will be some induced movement of air through the drag effect in the sewer, even where the temperature difference is low. A greater upstream slope will give a higher velocity in a gravity system. It is uncommon for velocities of 1.5 m/s to be experienced at the wastewater surface
	Based on extraction rate for mechanical ventilation	Some iteration can be required to match the evaporation rate to the air flow rate creating the velocity. Assume full wet surface area of asset and extraction rate to obtain velocity

[26] **This equation has comments associated with its use in AS/NZS 60079.10.1:2022 Supplement 1. Please refer to Clause CB.7.3: The exact calculation of release rates from evaporative pools and spills on either land or water is extremely complex and depends on a wide range of factors. These factors include the temperature and heat input available from the surface or body onto which the liquid is spilled and the nature of that surface, including roughness. The equation presented in the Standard is empirical and does not account for these and other factors. It is therefore suggested for application to pools exceeding 1 c m deep. While this will not be representative of many spills, the calculation is still very simplified, even for deeper pools. The calculation presented is simplified for initial determination of an evaporation release and further analysis could be necessary.**

Variable	Range of values	Comments
A_p (m^2)	Use full wet surface area of asset	Although some wastewater may contact the edges of walls, equipment or the like, this is assumed to be negligible in comparison to the surface area of wastewater in the asset
T (K)	285.15 – 303.15	Wastewater temperatures of 12 – 30°C are common. 12°C is the winter design case in colder climates, 30°C upper limit of summer design case in temperate climates
T_a (K)	291.15 – 303.15	Ambient sewer temperatures are generally slightly higher than liquid temperatures. A range of 16 to 30°C is common. Lower temperatures correspond to cooler climates, higher temperatures to warmer climates.

In addition to this baseline ventilation rate, the effect of turbulence should be considered. In the absence of a detailed CFD study investigating this, some broad multiplying factors are provided in Table 5-9. Note that there will remain cases where even these factors will be insufficient to control explosive atmosphere formation in a space.

Table 5-9: Multiplying factors to account for the effect of turbulence and/or blockages on the baseline liquid pool evaporation rate.

Multiplying factor	Description
1.5	Mostly quiescent surface, some minor blockages, for example emergency storage tanks
2	Moderately turbulent/impeded surfaces such as a large pump station with low velocity draw down pumps and drop tee
3	Highly turbulent surfaces such as a small pump station with no drop tee, internal baffles and blockages
4	Extremely turbulent surfaces such as a mixed pump station, frequently active discharge maintenance hole, structure with many internal baffle walls

Natural ventilation

Natural ventilation for wastewater applications is generally low in dilution. It is also generally of poor availability. For this reason, in many cases natural ventilation cannot be relied upon to control the formation of a flammable atmosphere in a network asset and it is recommended that natural ventilation is not considered in the absence of data regarding an asset. A more detailed look at natural ventilation for a typical reference asset is contained in Appendix D, as well as in section C.5 of AS/NZS 60079.10.1:2022.

Should there be a desire from the water agency to rely upon natural ventilation for the control of a flammable atmosphere in an asset, a detailed understanding of the vent shaft operation by a hazardous area professional would be required. This would take into account microclimactic features such as wind speed, ambient temperatures, the operation of the asset (for example time between filling and drawing), internal liquid and air space temperatures, potential blockages and the contaminants of concern in the asset.

5.5.3.5 Availability of ventilation for mechanical ventilation

Clause C.3.7.1 of AS/NZS 60079.10.1 describes the availability of ventilation as follows:

> "*good: ventilation is present virtually continuously*
>
> *fair: ventilation is expected to be present during normal operation. Discontinuities are permitted provided they occur infrequently and for short periods*
>
> *poor: ventilation which does not meet the standard of fair or good, but discontinuities are not expected to occur for long periods"*

As discussed with regards to the power failure abnormal condition (Section 5.4.4.1), availability of ventilation is closely aligned with failure of machinery due to loss of power, as well as mechanical failure of fans. Clause C3.7.3 of AS/NZS 60079.10.1 states:

> "*In assessing the reliability of artificial ventilation, the reliability of the equipment and the availability of, for example, standby blowers should be considered. Good availability will normally require, on failure, automatic start-up of standby blower(s). However, if provision is made for preventing the release of flammable material when the ventilation has failed (for example, by automatically closing down the process), the classification determined with the ventilation operating need not be modified i.e. the availability may be assumed to be good"*

It is important here to highlight that AS/NZS 60079.13 defines the requirements for a ventilation system used in controlling flammable atmospheres, and that adopting duty/standby ventilation equipment outlined in AS/NZS 60079.10.1 is not the sole factor in assessing the availability of a system.

The availability of ventilation for linear asset classification should consider power failure, machinery failure and foreseeable misuse.

A relationship between industry practices and their availability is provided in Table 5-10 below. The table assumes a set of common principles for all rankings:

- Equipment is installed in accordance with manufacturer's written and verbal direction.
- Equipment is maintained in accordance with manufacturer's instructions and at the intervals specified in the operation manual or according to the water agencies standard maintenance plan, whichever is more comprehensive.
- Equipment is operated within its design envelope for its entire asset life.
- Ventilation is designed in accordance with AS 60079.13 (more below).

Table 5-10: Suggested availability of ventilation mapped to common water industry installation practices.

Installed ventilation infrastructure	Availability	
	Zone 0/1	Zone 2
Installed standby on separate power supply, monitoring via battery backed up instruments	Good	Good
Installed standby on same power supply, monitoring via battery backed up instruments, backup generator installed with auto cut in	Good	Good
Installed standby on same power supply, monitoring via battery backed up instruments, generator receiving infrastructure installed	Fair	Good
Installed standby on same power supply, monitoring via battery backed up instruments	Fair	Good
Installed standby on same power supply, monitoring via instruments	Fair (Zone 0) / Good (Zone 1)	Good
Installed standby on same power supply, manual change over via alarm from instruments and operator intervention	Fair	Good
Boxed or warehoused critical spare, manual change over, change over possible within one day	Poor	Fair
Boxed or warehoused critical spare, manual change over, change over possible over within two working days	Poor	Fair
No redundancy	Poor	Poor

Zone 0 and in many cases Zone 1 areas have a stronger need for ventilation to be continuously available than Zone 2 areas. For this reason, an installed standby with battery backed up instruments providing auto-change over in case of failure is considered good ventilation for these areas. In the event of power failure, instruments will show abnormal conditions and allow operators time to respond. In Zone 2 areas which will generally be well below the threshold value most of the time, the chance of the shutdown of ventilation and an increase in flammable vapours occurring simultaneously is very rare, therefore a slower change over from duty to standby ventilation equipment can still be considered good availability. Fair conditions are generally those that will provide slightly longer change over should there be no abnormal event occurring. Poor conditions are those which have unknown or long time between ventilation service resuming or those that can reasonably be expected to not result in same day change over when resources are strained, for example, during abnormal conditions).

The table in this section is provided in order to guide water agencies in a wastewater network context, where there is insufficient information to verify the duration of time that the ventilation system is required for control of flammable atmospheres. Should this information be available, the categories in the table could be inapplicable and the use of the principles of AS 60079.13 regarding ventilation are recommended.

In addition, to be considered fair or good and in addition to the requirements of AS/NZS 60079.13, the following parameters require online monitoring:

- A method of knowing if the duty fan is running and effectively extracting air, such as a flow meter, flow switch, pressure transmitter etc. This can be in the common discharge if there are automated dampers which switch duty and standby machines.
- For larger, more critical machines there should be fault monitoring of the fan to enable planned maintenance or procurement of long lead time spares. Examples of this are vibration monitoring and temperature monitoring of key bearings.
- A method of preventing backflow between duty and standby ventilation equipment.

The nature of the online monitoring does not have to be sophisticated: it can be as simple as a text message to an operator or as complex as differing levels of alarm and automatic work order generation via a SCADA system. Both achieve the same outcome in allowing down time to be notified immediately such that preventive action can be taken.

5.5.3.6 Selection of mechanical ventilation/other equipment

Selection of electrical equipment for use in hazardous areas is dependent on the contaminants of concern. Ideally, the contaminants of concern for an asset should be determined through sampling as per Section 3; this should always be the first choice. However, it is recognised that the methods outlined in this section enable classification of an asset without knowing the contaminants of concern, for example, when the proposed asset has not yet been constructed, as it is a simplified method. If the contaminants of concern are not known, selection of equipment is not possible unless assumptions are made.

This guideline suggests a minimum recommendation based upon historical evidence of compounds regularly present in the municipal sewerage system. As previously stated, determination of contaminants of concern through sampling is always preferred.

There are only three gases that require a grouping of IIC: acetylene, carbon disulphide and hydrogen. These gases are highly explosive and unstable. Their presence in the municipal sewage system is very rare, and where encountered, only in trace amounts insufficient to form a flammable atmosphere. If their presence in the sewerage system in concentrations likely to form an explosive atmosphere is suspected, conduct a sampling campaign and further investigate immediately.

Table 5-11: Suggested minimum hazardous area parameters for use when contaminants of concern and concentrations are not known

Suggested minimum parameter	Rating	Comment
Equipment Group	II	Best fit for wastewater applications
Subcategory	B[27]	Based on the potential presence of common solvents such as MEK or isopropanol

[27] **It is recognised that IIC contaminants may be present in the sewerage system. If their presence is suspected, confirm via a sampling campaign.**

Suggested minimum parameter	Rating	Comment
Temperature Group	T4[28]	Based on the potential presence of ethyl ether (drug manufacture) or acetaldehyde (industrial discharge)

From this point, electrical engineering professionals can make a suitable judgement on the required types of equipment.

5.5.4 Ventilation adjusted zonal classification

Having considered the availability and degree of ventilation, Table D.1 of AS 60079.10.1: 2022 can be applied to the baseline classification determined in Section 5.4.5. In place of the grade of release in the standard, users should use the initial zonal rating previously determined as follows:

- Where an initial zonal rating of Zone 0 has been determined, read from the “Continuous” row of Table D.1
- Where an initial zonal rating of Zone 1 has been determined, read from the “Primary” row of Table D.1
- Where an initial zonal rating of Zone 2 has been determined, read from the “Secondary” row of Table D.1.

[28] **Some IIC and IIB substances can have T5 and T6 ratings. If in doubt, conduct a sampling campaign to confirm.**

Table 5-12: Level of benefit through ventilation. This is taken directly from the standard, Annex D of AS60079.10.1: 2022

Table D.1 – Zones for grade of release and effectiveness of ventilation

Grade of release	Effectiveness of Ventilation						
	High Dilution			Medium Dilution			Low Dilution
	Availability of ventilation						
	Good	Fair	Poor	Good	Fair	Poor	Good, fair or poor
Continuous	Non-hazardous (Zone 0 NE)[a]	Zone 2 (Zone 0 NE)[a]	Zone 1 (Zone 0 NE)[a]	Zone 0	Zone 0 + Zone 2[c]	Zone 0 + Zone 1	Zone 0
Primary	Non-hazardous (Zone 1 NE)[a]	Zone 2 (Zone 1 NE)[a]	Zone 2 (Zone 1 NE)[a]	Zone 1	Zone 1 + Zone 2	Zone 1 + Zone 2	Zone 1 or zone 0[d]
Secondary[b]	Non-hazardous (Zone 2 NE)[a]	Non-hazardous (Zone 2 NE)[a]	Zone 2	Zone 2	Zone 2	Zone 2	Zone 1 and even Zone 0[d]

[a] Zone 0 NE, 1 NE or 2 NE indicates a theoretical zone which would be of negligible extent under normal conditions.

[b] The Zone 2 area created by a secondary grade of release may exceed that attributable to a primary or continuous grade of release; in this case, the greater distance should be taken.

[c] Zone 1 is not needed here. I.e. small Zone 0 is in the area where the release is not controlled by the ventilation and larger Zone 2 for when ventilation fails.

[d] Will be Zone 0 if the ventilation is so weak and the release is such that in practice an explosive gas atmosphere exists virtually continuously (i.e. approaching a 'no ventilation' condition).

'+' signifies 'surrounded by'.

Availability of ventilation in naturally ventilated enclosed spaces is commonly not considered as good.

A zone of negligible extent (NE) only applies when the ventilation is operational. As stated above, if the electrical equipment is intended to operate when ventilation is not operational, it must be rated for the baseline zonal classification.

There are some important caveats to the classifications (either baseline or ventilation adjusted, where applicable) which are obtained via the simplified method provided in this section. These are as follows:

- If there is a confirmed history of flammable immiscible liquids being discharged into the asset, then the minimum classification should be Zone 2.
- If the consequence of an explosion is considered too great by the water agency (see Section Appendices) the equipment installed may have EPL rating of Gc (see section 4.2.5), regardless of the hazardous area zoning.
- Where a Zone 0 or Zone 1 baseline or ventilation adjusted classification is obtained, it is recommended that a monitoring campaign is performed. The zonal classification noted in the above table is recommended to be used until a monitoring campaign can be undertaken. Source of Release methods are to be used based on results of monitoring campaigns.

5.6 Additional considerations in zoning

With the ventilation adjusted classification applied, the asset can be classified using the simplified method outlined. However, there may be other considerations which could affect a water agency's decision in the classification of an asset. These are discussed below.

5.6.1 Consequence

In hazardous area classification, the consequence of an explosive atmosphere is not considered in assigning a zone. The above process has so far investigated the likelihood of an explosive atmosphere occurring which affects the classification requirements. The consequence of any explosion is often considered very high or catastrophic, therefore there may be cases within linear assets where the consequence of an explosion is unacceptable to the water agency. For these locations, even if the likelihood of an explosive atmosphere developing is low, the water agency may choose to have a minimum classification level or to provide equipment protection without a formal zone. The types of consequences where this may occur are described below.

5.6.1.1 Asset criticality

Criticality requirements can influence the consequence of an explosive atmosphere. For example, if a single pumping station experiencing an ignition or explosion could shut down effective management of sewage for an entire city, the risk associated with the asset becomes much higher. Consider how important the asset is to the sewerage system and the operations of your organisation.

5.6.1.2 Location

The location can influence the consequence of an explosive atmosphere igniting by being:

- Within, adjacent or near to a location where an explosion could cause serious harm to people such as being located within a high-density residential building or place of work.
- Near to or within a high-risk site such as a petrol refinery, such that an ignition or explosion causes follow on effects.

5.7 Classification documentation

To formalise this process, the hazardous areas must be fully documented as per the AS/NZS 60079 series. Due to the subjective nature of the likelihood assessment process, the outcomes of the assessment must be transparently recorded. There must also be sufficient detail such that any changes in personnel or external third parties can clearly follow the logic of the assessment and the appending documentation; this is generally through the production of a hazardous area classification report.

Hazardous area zoning drawings should be produced for the asset and documented as per AS/NZS 60079.10.1 recommendations. Some examples of this for linear assets are provided in Section 10.

It is important to note that where the water agency has chosen to apply an EPL to electrical equipment while maintaining an area as non-hazardous, this should not be shown the same way on a drawing as a classified area. Currently AS/NZS 60079.10.1 as well as other hazardous area standards provide no guidance in this regard. The water agency can therefore select another pattern or call out notes next to each relevant asset where the additional protection should apply.

5.8 Competency

Maintenance and engineering personnel, whether internal or external, should be sufficiently experienced in the requirements of working in hazardous areas. This could be in the form of formal training as per the guidance provided in AS/NZS 60079.14 Clause 4.5, as well as AS 4761.1. This guidance varies depending on the role, such as a tradesperson or an engineer, and should be assessed at regular intervals to ensure competence is maintained, either through continuous familiarity with the work or refresher training. Training of personnel should be documented in an organisation’s hazardous area training register where a dedicated register exists, or along with other relevant training where all training is collected into a master register.

6. METHOD OF CLASSIFICATION FOR WASTEWATER TREATMENT PLANT ASSETS

Apart from the inlet works and pre-treatment modules or storage, which can have unknown inputs of a similar nature to a linear asset, wastewater treatment plants have processes which can be predicted. Due to this consistency and with decades of practice and data, the use of one of the ‘Source of release’ methods as described in AS/NZS 60079.10.1, becomes possible. Many facilities nationally are classified with the guidance provided in AS/NZS 60079.10.1. Despite this, many water agencies have observed that differences of opinion between classification professionals can lead to different outcomes in the classification of the same unit processes at different plants.

To provide the possibility of greater consistency for the industry, this section provides guidance on some aspects of the treatment plant classification process. In addition to this guidance, unit process classifications of common wastewater treatment modules are presented for industry reference. If classifications differ substantially from the reference, which may occur in practice, the reasoning behind this can be investigated.

As with linear assets, monitoring data of sufficient length to capture the range of abnormal operating conditions provides the best basis from which to make decisions about classifications of atmospheres. For the classification of new plants, monitoring from similar existing plants, if available, can be conducted. Water agencies are encouraged to collect data from existing assets, or refer to data from similar plants around Australia, to classify assets. This approach should be preferred, where possible, to relying on the example classifications found in this guideline.

6.1 Considerations for treatment plant classification

To assist in consistency of classification, some commentary on the hazardous area classification process for the water industry is made below.

6.1.1 Threshold value for treatment plants

The threshold value is defined as the percentage LFL of the flammable gas or flammable vapour that could be encountered in the space which has the lowest LFL. As discussed in Section 4.2.3, it is necessary to control hazardous atmospheres below the level of the 100% LFL threshold. It is important to emphasise that this threshold value is for control of flammable or explosive atmospheres. Toxic substances can be hazardous to human health at very low LFL levels, for example, H_2S exposure at 1,000 ppm is lethal however its LFL is 40,000 ppm. This is highly dependent on the specific contaminants present in the atmosphere.

Table 6-1 below summarises the guideline recommendations on threshold value. The recommended threshold value is 25% of the LFL of the substance with the highest concentration in the atmosphere (called the contaminant of concern). Various actions are taken from a flammable vapour concentration of 5% of the LFL, with final action being taken at concentrations above 40% of the LFL.

Table 6-1: Guideline recommendations on threshold value for treatment plants. These are based on an alarm level of 5%, an action level of 25% and a critical action level of 40%.

Gas/vapour conc. (%LFL)	Responses Note 1	Comments
> 5%	Initiate stop work order and evacuate space if occupied If regularly exceeding this value, consider monitoring campaign and hazardous area classification Evaluate any installed equipment, and consider its risk of spark, for example consider removal of inherently sparking relays	Possibly a hazardous atmosphere, however, may not be a hazardous area Lowest practical limit of detection for many gas detectors Temporary or permanent mitigation measures such as ventilation should aim to control gas concentrations at or below this level
> 25%	Concentrations are unacceptably high for normal operations Hazardous area classification should be considered unless outside normal/reasonably foreseeable abnormal conditions Monitoring campaign necessary to understand and better classify space Shutdown of all systems and items of equipment that are not rated for hazardous areas	Existing mitigation measures already in place are insufficient If no mitigation measures are in place, these should be evaluated and implemented Further consideration of the source of release and further control measures should be undertaken.
> 40%	Notify fire brigade or local authorities as per State/Territory requirements if event is outside of operator control Hazardous area should be assigned unless outside normal/reasonably foreseeable abnormal conditions	Safety factors are compromised. Automatic shutdown applies to parts of an installation protected by gas detection or ventilation. Unless outside of normal and reasonably foreseeable abnormal parameters, mitigation measures are essential

	Shutdown of all systems and items of equipment that are not rated for hazardous areas

Note 1 – Responses apply where the area is not currently classified. Where the area is classified and is operating within control parameters, responses may not apply

This is supported by the UK DSEAR guideline (clause 6.219), which advises controlling atmospheres with ventilation to 25% LFL, as well as the 2022 ruling of MS-011 on AS 60079.10.1: 2022. This allows ample time to initiate a process shutdown where applicable or take any plant level rectification action. Further justification is as follows:

- Measurements of the kind described in Section 3 are from a single point. This point may not be reflective of the overall hazard, particularly if ventilation is low. Depending on asset geometry, pockets of higher concentrations may exist within a structure. Although measurement should occur from a conservative location, this is not always possible. As such it is possible that the measured value is insufficiently conservative.
- Early indication of an event leading to high concentrations of flammable substances in the space. If such an event is occurring, advance notice should provide the opportunity to take action well before the concentration reaches 100% of the LFL. This is especially true of events which may begin slowly and become stronger over time, such as a malfunction of a high strength trade waste emitters pre-treatment processes.
- Time is required to respond to an event with a potentially explosive atmosphere. Emergency services could need notification, assets may need to be shut down, bypasses may need to be placed into service, back-up power may be required, etc. All these activities require planning time which is less available should higher threshold values be used. This is applicable to cases where high LFLs are expected and managed by the hazardous area systems in place, for example, inside an anaerobic digester.

6.1.2 Security and criticality

Treatment plants can be located in a mix of areas. Many are distant from large urban population areas but some can be in the heart of the communities they serve; there can therefore be questions regarding the consequences of an explosion at a wastewater treatment plant. It is important to note that the consequences of an explosion are not taken into account in a hazardous area assessment; only the likelihood of a (mitigated or unmitigated) flammable atmosphere occurring.

In other industries, statistical analysis of societal risks or modelling of blast or overpressure radius is used to ascertain the probable impact on members of the public. These are specialist subjects and are outside the scope of normal hazardous area classification. For this reason, they are outside of the scope of the guideline.

Where a water agency has conducted a risk assessment and found that the consequences of an ignition are intolerable, equipment in that area can be provided an EPL even where the area classification is non-hazardous.

6.1.3 Abnormal operation

6.1.3.1 Defining abnormal operation

A key area of hazardous area classification is defining the boundaries between normal operation, abnormal operation and catastrophic occurrences. Differences of opinion in the definition of these boundaries can lead to different classifications of the same or similar areas by different hazardous area professionals. This is discussed in Section 4.2.2, where catastrophic events are defined and a broad overview of abnormal operating conditions is introduced.

To provide a clear definition for water agencies, this guide identifies areas which must be considered as part of normal or abnormal operating conditions for a plant. Some items listed below, such as flooding, occur rarely. However, as the design life of a treatment plant is normally greater than 20 years, these events and the impact they may have on assets should be considered as part of the design envelope. Conversely, certain treatment plant aspects may be affected by abnormal conditions frequently. This may be a storm peak wet weather flow event, a plant failure or even a power failure at sites where the power supply may be unstable. The probability of the event occurring should be considered when assessing the impact on the likelihood of a flammable atmosphere occurring. It may, for example, be rare for the failure of ventilation plant to coincide with a trade waste dump.

The same features of abnormal operation discussed in Section 5.4.4 also apply to treatment plants; specific discussion is below.

6.1.3.2 Power failure

Consider the effect of power failure on the process. Loss of power at a treatment plant could mean:

- Loss of flow, mixing or process energy, leading to high residence times, foaming or causing environments which increase hazardous area risk.
- Loss of ventilation for control of flammable atmospheres.
- Loss of monitoring for hazardous area control.

The likelihood of power failure should be taken from plant operating data or operator experience if this is not available. Likewise, the effect of staffing should be taken into consideration, for example, if back up diesel generators require operator intervention to start but operators are engaged with other issues which could occur during a power failure, the actual time to implementation should be considered.

6.1.3.3 Plant/equipment failure

Plant/equipment failure at a treatment plant can cause:

- Loss of flow, mixing or process energy, leading to high residence times, foaming or causing environments which increase hazardous area risk
- Loss of ventilation for control of flammable atmospheres
- Loss of monitoring for hazardous area control.

Likelihood of failure should come from water agency operational data for similar assets or manufacturer's recommended Mean Time Between Failure (MTBF) rates.

6.1.3.4 Varying load cases

The forecast load to be used in the hazardous area assessment should reflect the frequency that the assessment is reviewed. For example, if it is intended that the hazardous area assessment is conducted every 4 years, the forecast load should consider expected variations across the next 4 years. In this assessment, the following should be considered:

- Will lowest dry weather flow affect the formation of flammable atmospheres? If so, how frequently does this occur?
- Will peak dry weather flow affect the formation of flammable atmospheres? If so, how frequently does this occur?
- Will wet weather flow affect the formation of flammable atmospheres? If so, how frequently does this occur?
- Will peak wet weather flow affect the formation of flammable atmospheres? If so, how frequently does this occur?
- Will these flows change significantly in the review period?

6.1.3.5 Blockage or leakage

Blockages and chokes can increase the likelihood of a flammable atmosphere occurring by:

- Restricting headspace and reducing volume, therefore creating an increased likelihood of flammable atmosphere in the downstream air space.
- Rupturing or bursting a pipeline, increasing the possibility of leakage from nearby infrastructure.
- Damaging equipment, leading to plant failure.

Leakage of pipework can increase the likelihood of a flammable atmosphere by:

- Releasing flammable atmospheres into unintended spaces.
- Insufficient control of an atmosphere, for example, leaking ventilation ductwork.

If blockage or leakage in the asset causes a change of atmosphere, consider this in the classification.

6.1.3.6 Flood

The effect of a design flood should be considered on the formation of flammable atmospheres. Floods can:

- Reduce air spaces, leading to higher concentrations of flammable vapour in the reduced volume.
- Disturb sediments, potentially releasing discharges.

- Destroy above ground assets in sensitive areas, making control of flammable atmosphere or emergency response impossible.

Consider the effect of a design flood in line with or of greater magnitude than the asset life. Common industry practice is to consider the 1% AEP for in ground structures; for mechanical equipment, with its lower design life it is generally either the 5% or 2% AEP flood. If flooding increases the likelihood of forming a flammable atmosphere, consider this in the hazardous area classification.

6.1.3.7 Foreseeable misuse

One of the key abnormal conditions to consider in a treatment plant is that of foreseeable misuse, both in relation to incoming sewage and in the internal management of the plant. Because of the open and unmonitored nature of the system, it is open to misuse in both malicious and unintentional ways. Some unintentional ways which can contribute to increased risk of a hazardous atmosphere include:

- Operator error, for example, leaving valves in incorrect position and wrong control sequences initiated.
- Incorrect programming of control systems.

For the secure environment of the treatment plant, the likelihood of foreseeable misuse is lower than encountered in the network environment. It is however relevant to pre-treatment processes such as an inlet works, which receive the same flows as network assets. Consider this foreseeable misuse in classification of any treatment assets.

6.2 Unit process classifications

Some of the common unit processes present in wastewater treatment plants are discussed in this section. The recommendations made are only suggestions as to possible minimum zoning requirements. Greater or lesser zoning may be required according to the individual circumstance, and each and every installation should be properly assessed in accordance with the source of release methods outlined in AS/NZS 60079.10.1.

6.2.1 Pre-treatment

Pre-treatment processes are used to remove large objects such as rags, wet wipes or other debris from the wastewater via screens and screenings processes, as well as removal of sand and other inert, insoluble fines material via grit removal processes and grit washing processes.

Inlet works, containing some or all of the pre-treatment stages, can frequently be situated at the end of a long chains of gravity mains and rising mains from the network, and the sewage may be significantly aged by the time it reaches the inlet works; this can lead to an increased risk of methane gas build up in the head space. In practice, observed levels of methane in inlet works have varied according to many different factors, similar to those described in Section 5.4.1. Depending on the type of inlet conditions, screen and/or grit removal process, inlet works can be significant sources of turbulence. Methane generated throughout the upstream mains can be released readily at inlet works due to this turbulence. This should be considered in any classification exercise.

If there is no free discharge from the inlet works to subsequent stages, immiscible liquids (such as petrol) can pool on the surface of the inlet works; this needs to be considered in any classification.

Inlet works at larger plants are most frequently covered to prevent the release of foul air and mitigate odour risks, although in smaller plants this is not always the case. As a frequently covered asset with significant volumes of raw sewage, an inlet works/grit removal structure has much the same risk profile as a large network pumping station wet well. For this reason, it is recommended that an inlet works be treated as a network asset and that its risk classified in accordance with Section 5, especially as ventilation of inlet works is usually dictated by odour and corrosion control requirements due to the high concentration of H_2S and other odorants which can occur, rather than for control of hazardous atmospheres.

A suggested classification for apre-treatment structure is Zone 2 unless there has been a suitable monitoring campaign to show otherwise.

6.2.1.1 Screen buildings

Some Australian plants have their inlet screens contained inside a building. In these cases, screens are often within a covered channel, with some element of the screen infrastructure sitting above the covers. As the buildings are considered working areas there is a requirement for ventilation; some plants ventilate the building naturally using louvred openings whereas others use mechanical ventilation.

If the screens and screen channels are covered, with extraction taken outside the building, the building itself operates similarly to a network pumping station dry well, with connected or segregated atmosphere to its wet well depending on the building and cover arrangement. For this reason, it is recommended that screen buildings be treated as a network asset and have their risk classified in accordance with Section 5.

6.2.2 Primary treatment

After raw sewage has been screened and de-gritted, primary treatment commonly uses gravity or mechanical equipment (occasionally assisted with chemicals) to allow heavier particles to settle to the bottom of a tank and clearer water to overflow and continue for further treatment.

Primary treatment often has very strong odours associated and is often covered and ventilated to contain these odours. Some older plants, or plants in areas far away from sensitive receptors, are uncovered. As with pre-treatment and inlet works, ventilation is usually dictated by odour and corrosion control requirements due to the high concentration of H_2S and other odorants which can occur. It is common that primary treatment receives flow from an inlet works using a submerged inlet at the inlet works, and a submerged outlet at the primary treatment facility, to reduce turbulence of the water surface and therefore odorous gas release. If this is the case, immiscible liquid such as petrol is unlikely to travel to the primary treatment stage from the inlet works. Flammable substances dissolved in the wastewater may still be released into the gas phase or accumulated as sludge. This presents a risk when liquid levels are low, as there may be a build-up of flammable material in the solids at the base of the reactor. If there is a free discharge from the inlet works to the primary treatment stages such that immiscible liquids can pool on the surface of the primary treatment process, this needs to be considered in any classification exercise.

A suggested classification for primary treatment is non-hazardous where uncovered, or Zone 2 when covered, particularly if the catchment has a high industrial load or if the processes on site are geared towards the production of methane and recycle streams are present in these covered areas, unless there has been a suitable monitoring campaign to show otherwise.

6.2.3 Secondary treatment

Secondary treatment consists of three general phases:

- Anaerobic zones, which allow the release of polyphosphate and the generation of acetate, improving biological phosphorus removal.
- Anoxic zones, where denitrification occurs.
- Aerobic zones, where nitrification occurs.
- Selector zones, which can vary depending on process configuration.

At this stage, any floating or immiscible layer of flammable substance has most likely been removed, either remaining in the inlet works or removed as scum from primary treatment. There remains a minor risk of dissolved flammable substances being released as gaseous vapour from the surface of the liquid, but this is unlikely unless there is a free discharge path for floating substances from the inlet works through to the secondary process.

Anaerobic zones are sometimes covered, receiving primary effluent, and have a very minor potential for methane due to their hydraulic retention times being in the scale of hours rather than days. If covered, these zones are generally ventilated for control of odour and corrosion. These zones can be treated similarly as primary treatment processes in that they are often considered non-hazardous where uncovered, and sometimes Zone 2 when covered, particularly if the catchment has a high industrial load or if the processes on site are geared towards the production of methane and recycle streams are present in these covered areas. The same logic applies for anoxic zones.

Aerobic zones, having been treated prior and which receive large amounts of dissolved oxygen, are often uncovered as they are a very low odour risk. These zones are often classified as non-hazardous.

6.2.4 Solids treatment

In classification of solids treatment, it is important to distinguish between systems which are pre-stabilisation (pre-digestion or thermal treatment) or post-stabilisation (post-digestion or thermal treatment). Risks tend to be greater with solids prior to stabilisation, and within the stabilisation process, as their methane generating potential through the destruction of their volatile components is still present.

6.2.4.1 Aerobic digestion

Aerobic digestion uses dissolved oxygen, like that used in a bioreactor, to biologically stabilise contaminants and thus reduce the volume of sludges. Due to the stabilising effect of the dissolved oxygen, pathogens in the sludge are significantly reduced. It is suggested that aerobic digestion processes be considered non-hazardous when the aerobic process is operating. Any pre-storage holding and delivery as well as conditions which occur during abnormal operation should be assessed separately and are often classified as Zone 2 or Zone 1 depending on the availability of the aeration process and the solids retention times.

6.2.4.2 Anaerobic digestion

Anaerobic digestion is the process by which sludge is kept in an atmosphere without oxygen for long periods of time, usually between two and four weeks. This reduces the volatile content of sludges, produces methane (which is sometimes used for power and/or heating purposes) and destroys some biological pathogens. Anaerobic digestion, as well as associated gas delivery equipment and pipework, is well covered in AS/NZS 60079 10.1. It is recommended that the guidance provided in AS/NZS 60079.10.1 Supplement 1 Section E 2.2.2 – *Landfill gas, farm waste, sewage treatment and sewage pumping plants* be used as an industry standard example in the zoning of anaerobic digestion processes and ancillaries. Due to the high concentrations of methane in the head space of anaerobic digesters, these areas can frequently be above the UFL of methane. However, this is not reflected in the common industry zonal classification.

6.2.4.3 Cogeneration facilities

Cogeneration facilities draw upon the gas in the headspace of the digesters, treating these with various processes such as chillers, activated carbon scrubbers, etc. The clean gas is then passed through a gas turbine engine which can generate both heat for use in digesters and site heating and power for return to the grid or local site use. These systems are generally low-pressure gas systems.

Given the methane content of the biogas stream (35 – 70% vol., well above the UFL) and the minimal expected oxygen (< 1%), the internal volume of the piping system is not expected to give rise to a flammable atmosphere under normal conditions. This approach is consistent with gas industry codes. This means that the internals of gas piping are generally non-hazardous during normal operation. Stopping, starting and abnormal operation should be considered as part of the classification exercise.

Where pipework is susceptible to leakage, it is possible that methane could be released and diluted in ambient air to form concentrations between the LFL and UFL. The area classification here is dependent on both ventilation and the anticipated leak size and pressure.

AS/NZS 60079.10.1 in Supplement 1, Section E.2.1 *Biogases or biomethane* refers readers to two separate sections for biogas equipment:

- For fuel gas train equipment supplying boilers, sludge heaters, incinerators and gas engines which conform to gas industry codes, E.1.2 *Consumer installations.*

- For sampling points or other points designed to release gas during normal operation (which includes operations such as sampling), such as pipework and fittings, gas boosters, compressors, fans and extraction blowers, E.1.6 *Petroleum production and processing and transmission pipelines.*

Section E.1.2 further refers readers to AS 5601.1, which covers the design, installation and commissioning of gas installations.

Section E.1.6 is intended to cover the fuel gas industry but is deemed to be applicable to biogas installations for the equipment nominated.

It is recommended that the guidance in the standard is followed, which leads to a range of zones in the area of biogas equipment.

6.2.4.4 Thermal hydrolysis

Thermal hydrolysis is sometimes used as a pre-treatment prior to anaerobic digestion. Sludge is thickened, pulped and fed into hydrolysis tanks at high temperatures. Temperatures are then increased with steam and reacted for a length of time to induce hydrolysis. Hydrolysed sludge is then cooled to lower temperatures before being introduced to anaerobic digesters.

Thermal hydrolysis processes should be considered similar to pre-treatment stages in anaerobic digesters. The high temperatures involved act as sterilising agents and so methane is generally not produced in the hydrolyser itself, however, it can improve methane generation during downstream anaerobic digestion. The high temperatures involved in the hydrolyser can also release entrained flammable substances that have made their way through the sludge lines of the plant.

A suggested classification for thermal hydrolysis processes is non-hazardous in the majority of areas. There are areas of thermal hydrolysis plants which should be zoned, for example, pressure relief valves or any air/gas management valves. These can be classified as they would be for an anaerobic digester.

The steam generation systems, any boilers and any conveyance pipework should be assessed separately to the thermal hydrolysis process.

6.2.4.5 Gas flaring

Gas flaring is used to combust and flare any excess biogas not used by the plant, or for certain plants not equipped with cogeneration facilities, to burn all digester gas accumulated. Flares are usually designed to the gas industry codes that cover both gas fired industrial and gas fired consumer installations, namely AS 1375, AS/NZS 3814 (AG501) and AS/NZS 5601 (AG601). Zoning of these sorts of appliances are outlined in AS/NZS 60079.10.1 Supplement 1 Section E.1.2 as discussed above. Consumer gas applications are generally classified as non-hazardous.

The exemption for gas appliances and equipment covered by gas industry codes is based on the fact that these codes provide an installation that produces a non-hazardous environment. The installer and operator needs to ensure that the facility is installed in accordance with AS/NZS 5601.1 and AS 3814 to ensure that this premise is true in actual practice.

6.2.4.6 Storage

The risks associated with the storage of sludge are dependent on the source of the sludge being stored and the method by which it is stored:

- Pre-stabilisation: there is a much higher chance of methane generation from the biological material, for example, in a digester feed well or a primary sludge holding tank
  - Primary sludge has a greater risk of methane generation and potentially having flammable contaminants entrained within the sludge compared to waste activated sludge.
  - Waste activated sludge coming from an aeration process with a high sludge retention time (>20 days) has a low risk of methane generation.
- Post-stabilisation: there remains a risk of methane generation however this risk is reduced when compared with the above case.
- Anaerobically digested biosolids have a greater risk of continued methane generation or release compared to aerobically digested biosolids.
- Sludge/biosolids stored within an enclosed structure have a greater risk than those stored in the open (such as piles or sludge beds). This is due to factors such as:
  - Elevated temperatures within enclosed structures
  - Accumulation of gases in enclosed structures which are not free to disperse.

Sampling and analysis of the source sludge will reveal the methane production, which is the best way to understand the risk. If this is not available, then a suggested classification is:

- Covered/enclosed storage of pre-stabilisation primary sludge: Zone 1
- Covered/enclosed storage of pre-stabilisation waste activated sludge: Zone 2 negligible extents (NE)
- Covered/enclosed storage of post-anaerobically stabilised sludge (for example biosolids): Zone 2
- Covered/enclosed storage of post-aerobically stabilised sludge (for example biosolids): Zone 2 NE
- Storage of sludge/biosolids in uncovered drying beds: Non-hazardous.

The specific processes within the sludge/biosolids treatment application should be considered in making the hazardous area assessment. Refer also to AS/NZS 60079.10.1 Supplement 1 E.2.5.

6.2.4.7 Thickening/dewatering/conveyors

It is suggested that the internals of sludge conveyors (either screw or belt), centrifuges, screw presses and the like should be classified as per AS/NZS 60079.10.1 Supplement 1 E.2.4 and E.2.5. The risks associated with this equipment are similar to those of sludge storage tanks, with the added risk of pressure and shear stresses forcing greater amounts of methane into solution, either within the equipment itself or for release at a later time.

6.2.4.8 Buildings

Biosolids buildings, both outloading and infrastructure buildings housing equipment and closed storage tanks are generally well ventilated to control methane build up. This occurs either with forced ventilation of a closed building, or with an open-sided building with natural ventilation.

For biosolids building as well as truck outloading enclosures, the primary risk is occupational exposure to hydrogen sulphide. If ventilation, either natural or forced, is sufficient to control this possibility then it is suggested a biosolids building or outloading enclosure can generally be considered a Zone 2 NE area; that is, that the ventilation is sufficient to reduce the zone to a negligible extent. Where this is not provided, then a Zone 2 rating as per AS/NZS 60079.10.1 Supplement 1 E.2.5. may be most applicable. To assess the adequacy of the ventilation in controlling occupational exposure and methane build up, consideration of the sources of release in both normal and abnormal conditions is recommended.

6.2.4.9 Lagoons

The classification of biosolids lagoons depends upon:

- The nature of the solids stored in the lagoon
- Their cover arrangement
- Their degree of ventilation.

Biosolids lagoons that are open-topped and used for stabilisation are generally considered non-hazardous.

Anaerobic lagoons that are used for secondary treatment processes can have a higher degree of zoning due to the methane produced during treatment. These lagoons are often covered and the area within them is treated similarly to an anaerobic digester.

6.2.5 Tertiary treatment

By the time the bulk wastewater has reached the tertiary stage, most or all of the contaminants of concern have typically been removed from both liquid and solid phases. Tertiary processes are often un-ventilated as wastewater at this stage is not frequently odorous, but there are cases where ventilation is required, for example, a UV treatment module stored in a building which is ventilated for temperature control of proprietary control equipment.

Unless there is a specific risk with the tertiary treatment process itself (for example it requires a chemical of a type which could cause an explosive atmosphere), then tertiary treatment processes are generally considered non-hazardous.

6.2.6 Chemical storage

There are certain common chemical uses in the wastewater treatment environment which can cause flammable atmospheres. One key example is methanol, which, when dosed presecondary treatment, can provide additional readily biodegradable organic carbon for use by the biological processes present in the reactor.

Each chemical system should be assessed individually. Many common chemicals (sodium hydroxide, sodium hypochlorite, alum, ferrous/ferric chloride) are dangerous goods, but are not flammable in isolation. Chemicals such as ferrous chloride can react with metals to form hydrogen gas. Although outside the scope of this document, these risks must be managed.

Common coagulants and flocculants, often delivered in liquid emulsion form, are also generally non-hazardous. This should be confirmed in each individual case.

Liquid emulsion polymer is generally considered non-hazardous. On the other hand, powdered polymer can, in some instances, form combustible dust clouds[29]. This should be confirmed in each specific case. As outlined in the BASF Zetag® 8165 safety data sheet:

> "*This type of product has a tendency to create dust if roughly handled. The product does not burn readily but as with many organic powders, flammable dust clouds may be formed in air. The product is under certain conditions capable of dust explosion*."

This can lead to certain dry polymer powder areas being classified Zone 22 (for hazardous dusts). This should be considered in any assessment of polymer dosing areas.

6.2.7 Odour control facilities

Odour control plants are generally designed to serve multiple process areas encompassing pre-treatment, primary treatment, sludge digestion and biosolids storage and treatment. Odour control ductwork is therefore often classified in accordance with the worst-case zonal rating of the areas being served. This means that odour control ductwork can commonly range from non-hazardous to Zone 1. For a treatment plant environment, the most common zoning for odour control ductwork and vessel internals is Zone 2, consistent with common classifications of biosolids, pre-treatment and primary treatment systems. This is consistent with AS/NZS 60079.10.1 Supplement 1 A.3.2. The internals of these vessels and ductwork are typically classified as Zone 1 or Zone 2. Classification of the internals of ducts downstream of odour control units should consider the cases of bypass around the treatment units. Vent shaft discharges of Zone 1 or Zone 2 odour control systems are typically Zone 2 for a 1 m radius around the discharge point.

[29] **Refer to AS/NZS 60079.10.2 for classification information regarding dust clouds, which are beyond the scope of this guideline**

7. ZONAL EXTENTS FOR LINEAR ASSETS

7.1 Zoning of linear assets

Due to the buried nature of sewers and other linear assets, the classifications outlined in this section are intended to be applied to the air volume of the asset only. Exceptions to this are where discharge to atmosphere occurs intentionally. Some limits of application are discussed and a number of examples are provided.

7.1.1 Limits of application

The example classifications provided in the section have some limits to their application. These should be fully understood before applying any examples.

These examples should only be applied when the simplified method determines a classification of Zone 2 or Zone 1. It is exceptionally rare to have a Zone 0 linear asset. In such cases additional caution should be exercised when determining the extent of a zone around the asset.

The examples only apply to wastewater of predominantly municipal origin, with minor and pre-treated trade waste contributions. They do not apply to full strength untreated discharges or situations where the contribution of other liquids is greater than that of municipal origin.

Finally, these are the most common examples present in the industry and do not cover every case. There is opportunity for water agencies to use concepts outlined in these examples in other cases but no guidance is provided to dictate this.

7.1.2 Example classifications

Odour Control Units (OCU) discharge stacks:

- Apply a 1 m distance all around the discharge stack as Zone 2, as per Figure A.3.2 of AS/NZS 60079.10.1 Supplement 1.

Vent shafts:

- Apply distance at the same rating as the zone all around the shaft with the centre at the point of discharge, as per Table 7-1 below adapted from EI15, Table 3.2.

Table 7-1: Clearance distance away from vent shaft tip. Adapted from EI15, Table 3.2 for a G(i) gas (similar to methane) by dividng the values in two. As these are based on a pure substance, they are conservative estimates of distance and should be investigated prior to their use

	Vent Shaft Diameter		
Discharge flow (m^3/hr)	**50 mm**	**100 mm**	**250 mm**
250	1 m	1 m	2 m
500	1 m	1 m	2 m
1000	1.5 m	1.5 m	2 m
2500	2 m	2m	2.5 m

For air valves or relief valves during their release function, that is, when operating in discharge rather than vacuum break mode, based on advice in EI15 Clause 3.6.2.5:

- Apply a 1 m distance at the same rating as the zone all around discharge point if outdoors.
- When inside a pit with a closed lid, the inside of the pit is at the same rating as the air/gaseous vapour being discharged.
- When an air valve is inside a pit with the lid open, apply a distance of 1 m at the same rating as the air/gaseous vapour being discharged.

Leakage points such as threads, flanges, valves and the like above the ground transporting atmosphere from the zone such as ventilation ductwork and fans, as well as for leakage points of small sizes (< 50 mm in diameter), for example, leaking penetrations in wet wells:

- Apply a 0.25 m distance all around these points. In AS/NZS 60079.10.1 Supplement 1 Table E.1.6.5 (B) begins from a pressure of 200 kPa and above. In practice, in wastewater linear assets ductwork is rarely above 10 kPa positive or 5 kPa negative pressure. Therefore, half the listed distance has been adopted.

Closed lids of wet well, dry well, MH, etc:

- Apply a distance of 0.25 m all around the closed lid horizontally and vertically unless a sustained suction pressure of 15 Pa is achieved under the covers (see Appendices). This is half of the distance taken from AS/NZS 60079.10.1 Supplement 1 E.3.2.2I) for a MH on a digester roof.

Open lids of wet wells, dry wells, MH etc:

- Where there is insufficient or no active mechanical ventilation, for example, a pressure difference of -15 Pa is not achieved with the lid open: 1.5 m[30] minimum all around the

[30] **A low-level lid or opening with low discharge velocity will result in a plume which is not dispersed into the atmosphere like a vent shaft, but one that rolls over the discharge point and out to the ground. For this reason, it is likely that for these kinds of openings the safe exclusion distance is larger than that of a vent shaft such as those described in Figure A.3.2 of AS/NZS 60079.10.1 Supplement 1. The actual extent is very case dependent. A distance of 1.5 m has been chosen, providing a 50% safety factor on the vent shaft case. This should in all cases be verified by monitoring where personnel access is required.**

open lid unless temporary active gas monitoring (ideally such as that described in Section 3, or at a minimum calibrated personal gas monitors complying with AS/NZS 60079.29.2) of the atmosphere around the release point is conducted. If gas monitoring shows a flammable atmosphere to be present, the zonal extent should be increased depending on the level.

- Where there is sufficient active ventilation which ensures -15 Pa with the lid open: apply a distance of 0.25 m all around the open penetration.

8. EMERGENCY RESPONSE RECOMMENDATIONS

Where an explosive atmosphere has been detected, it is critical that a water agency has a plan in place for a series of responses. These responses will vary according to the water agency's individual circumstances as they will be affected by geography, state based legislative environment, urban, regional or rural location, including the time it generally takes for emergency services to arrive at the asset and so on. Some considerations when developing the organisation's plans are highlighted below.

First and foremost, it is important to stress that a key suggestion of this section is that water agencies develop a strong relationship with their local emergency services organisation. Having this relationship developed early in the life of an asset and maintained through regular contacts and practice drills is essential to effective emergency response.

In commercial construction in NSW the fire department is responsible for inspecting each new residential building for emergency services access such as emergency exits, air movement in an emergency, path to Fire Indicating Panels (FIP), etc. In other jurisdictions the building surveyor or certifier can also carry out this function. They also provide commentary on air movement in underground car parks in case of emergency. For this type of project, engagement with emergency services of this nature is mandatory. For water agencies, this type of feedback can be key to best practice safety in design.

It is common practice for large construction sites such as a large treatment plant upgrade to show the local emergency services around the site, so that their familiarity can assist in the case of any event where they are required. This familiarity could be extended with a site visit when a site is completed, especially in the case of pumping stations and treatment plants.

When new treatment plants or large pumping stations are being designed, emergency services can make recommendations about where, for example, they may require a hydrant point for firefighting purposes, or where they require a larger turning circle for an emergency access vehicle. A hazardous zoning exercise as outlined in previous sections of this guideline can assist the emergency services in making recommendations.

It is recognised that these suggestions must fit within each water agency's safety management systems and thus may be substantially different. The suggestions outlined below do not form a complete plan and should not be used as such.

8.1 Linear infrastructure responses

8.1.1 Gas leak

Gas leaks are usually discovered by confined space entry crews or by sudden spikes of fixed LFL monitors. The working group has had various experiences with nearby gas leaks creating flammable atmospheres in the sewerage network. It is important to note that some gas utilities are not concerned with loss of product through minor leaks in their network as they have some allowance for leakage in their business models. It is generally, however, unacceptable for public safety for a water agency to have gas in their asset from an external source. Most gas utilities have a publicly advertised phone number to call to report a gas leak if the gas leak is before the meter to the property. If the gas leak is after the property meter, a licensed gasfitter is often recommended.

Some suggestions as to an overall strategy are as follows:

- For each site, determine who the service provider is (consult Before You Dig Australia (BYDA) or nearby signage pits/junctions) and consult their website for the relevant phone number to report a leak. Record this number, along with relevant details, in the site's safety management plan.
- If a gas leak is determined either by smell or by a monitor reading above 40% of LFL, notify emergency services.
- Report the leak to the relevant service provider in the area.
- Notify affected parties of the leak and the associated risks, and try to temporarily ventilate the space to below the LFL with appropriately rated hazardous area rated ventilation.
- Spend time with appropriately trained and equipped internal resources to try and locate the source of the leak without excavation if possible.
- When reasonably confident, mobilise appropriately trained and equipped internal teams to try and diagnose the leakage point prior to the arrival of the gas provider's representative.
- Work with the representative from the gas authority to locate and repair the leak.

8.1.2 Major trade waste discharge or illegal dump

A major trade waste discharge which significantly alters the flammability of the network's atmosphere should be notified by the discharger. If not, it may only be possible to detect this when it arrives at location such as a pumping station or treatment plant inlet works; a gas or flammable vapour monitor can assist in detecting this. Other indications, such as smells, oily sheens or different coloured wastewater could also indicate the possibility that a flammable gas or vapour is present. An illegal dump has the same characteristics of a large discharge of trade waste, such as a large and sudden spike in concentration of contaminants of concern, or a break from historical trends in atmospheric monitoring. Realistically, it is exceptionally difficult to trace the source back on a single, isolated event. Some suggestions are as follows:

- When becoming aware of the change in atmosphere, notify all relevant parties.
- Take a sample of the contaminated wastewater, or of the flammable atmosphere, as soon as it is safe to do so and using non-sparking equipment and tools. All operators taking samples should wear full cover cotton based PPE, or equivalent PPE appropriate for the application, with non-sparking tools. If the toxicity of the atmosphere is in doubt, ensure that appropriate breathing PPE such as gas masks are in place to safeguard from

toxic effects while measuring the samples. Temporary ventilation suitable for a hazardous atmosphere should be provided where natural ventilation is insufficient to protect personnel. Work only where the atmosphere is being monitored online for increases in flammability.

- If the substance in the network is identified, try to sample it as it moves through and as it enters the inlet works. Have these samples lab tested as soon as reasonably practicable.
- Eventually, the discharge will arrive at a pumping station:
  - If the network receiving the discharge is serviced by a wet well style pumping station, the pump itself is rarely a risk. However, if the electrical connection to the wet well pump is degraded over time, this can be a source of ignition along with others identified in Section 1.6.4.
  - If the pumping station has a hazardous area classified odour control or ventilation system, this should run to help control the atmosphere. It may inhibit or damage biological systems and may saturate an activated carbon system necessitating a carbon change out. This should be investigated when the event is over[31].
  - If it can be stored at a pumping station safely with no possibility of spark and ventilation in place, shut the pumps down and store the contaminated wastewater at that location. Mobilise a tanker truck (use a tanker truck suited to petrol, which should be set up to extract from hazardous areas) and extract the contaminated wastewater for disposal as hazardous liquid waste.
  - Depending on pumping station condition, pumping of the discharge can be possible. This would depend on the contaminant, as well as the electrical and mechanical construction of potentially sparking assets in the station; it would also depend on the asset condition. Pumping should be deferred until the downstream locations have been ventilated with temporary ventilation and are being monitored for possibility of sparks and explosive atmospheres. Do not pump the contaminated wastewater if the flammable vapours in the atmosphere are above 50% of the LFL, unless the pumping station and the next pumping station in the network have equipment with an appropriate EPL.
  - At the treatment plant, try to re-direct the flow to a storage location such as an old balance tank, a seldom used pumping station, a bypass tank, an emergency storage tank, etc. for ventilation and monitoring prior to clean up. If sampling shows it is safe to do so, it can be reintroduced to the process for treatment by the plant, with discharge below the water level where possible. It may require some local treatment

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[31] **With activated carbon systems, many substances can have an exothermic reaction upon adsorption if in a high enough concentration. Certain substances, most commonly aldehydes and ketones, can adsorb onto activated carbon systems and, when ventilation is switched off, start breaking down with large heats releases causing bed smoulders or fires. If an activated carbon system experiences high concentrations of contaminants in its incoming stream, care should be exercised in turning off the ventilation through the carbon. Manual water sprays may be used prior to, or as the ventilation is turned off, to prevent smoulders. If an explosive atmosphere is measured in a foul air stream, the activated carbon system should be bypassed where possible, either manually or automatically. This may not prevent a bed fire but could prevent an explosion. Nitrogen purges are sometimes also used in industrial activated carbon installations to remove oxygen from the system and prevent bed fires.**

prior to this. Sampling should be assessed by a suitably qualified engineer for its effect on processes.

8.1.3 Notification of authorities

According to the experiences of the working group, the fire department generally requests to be notified of events which could lead to an explosive atmosphere in the sewerage system so that they can be ready and can occasionally attend site. If there is a possibility of a flammable atmosphere above 40% of the LFL occurring, this guideline recommends that planning with the fire department begins. It may be possible that in some jurisdictions, the fire department would expect contact either earlier or later; this should be confirmed for the jurisdiction local to the asset.

Members of the working group also work with police as police can get to know of locations where illegal dumping may be occurring, for example, by illegal drug labs. There has been some work in a joint water agency and police effort to identify illegal drug labs; this helps keep the network safe and assists police in their work. Such benefits are only clear with good communication between authorities and water agencies.

8.2 Treatment plant responses

8.2.1 Standard operating procedures

To capture the risks associated with a flammable atmosphere occurring, it is recommended that a Standard Operating Procedure (SOP) for each unit process or the plant as a whole be developed, which has the operational steps that should occur where changing atmosphere is detected. An SOP describes how a process is operated; rather than describing make and model of a valve (as is usual in an Operation and Maintenance Manual), it instructs to open certain valves, close certain valves, notify certain parties or make certain operational changes.

Another appropriate place to describe the actions required to mitigate a hazardous atmosphere may be the Unit Process Guidelines (UPG) for a particular treatment asset. The UPG describes process performance parameters such as flows, removal rates, maximum levels, etc. The SOP and UPG have some overlap, and many water agencies choose to have them incorporated as part aofone overarching process manual. This is particularly true of smaller assets.

Some suggestions for inclusion in these documents are:

- Whom to raise an alarm with if the atmosphere is seen to be hazardous: supervisor, process controller, emergency services, etc.
- Any mitigation actions such as flow isolation, bypass, redirection to different asset, powering down the site, etc.

- Signs to look for which would indicate a high potential for flammable atmosphere formation if there is no online monitor installed. This may include oily sheens, solvent or petrol smells, discoloration etc.
- Potential process impacts, for example, biological process die off and odour generation in case of flammable liquid/gas entry into the process.
- Changes to operation in the event of a flammable vapour being detected in the atmosphere being detected, for example bypassing activated carbon processes.

8.2.2 Emergency preparedness

Treatment plants are large, interconnected and often congested spaces. Their navigation can be difficult for new personnel. As such, a large part of effective response to flammable atmospheres is simply good emergency response practice. This includes:

- Fire infrastructure such as hydrants, etc. maintained in good condition, with regular inspections and the required available pressure.
- A plan in place for power failure or plant failure, for example a generator hard stand for an in-place or offsite generator and a procedure about where to source the power from, how to connect it and who to notify should it happen.
- Items like temporary ventilation stored in an accessible and clean way, which are regularly tested and tagged to ensure working condition.
- Clear access roads with good access into areas where emergency services may need to attend.
- Emergency equipment: torches, appropriate PPE etc., confined space entry gear, fire blankets, fire extinguishers, visual indicators, megaphones, rescue equipment and other equipment in place for use. All equipment should be rated for the hazard condition expected[32].
- Emergency evacuation plans and instructions, with regular drills such that operations staff are well practised in implementing these plans and instructions.

[32] **It is important to stress that this list is not exhaustive, as the emergencies which should be planned for are asset specific. Emergency preparedness can be a significant risk at certain assets and should be considered by water agencies as part of their duty of care for their on-site personnel and external contractors.**

9. EXAMPLES

This section applies the methods of Section 5 to several common linear asset examples. As best as possible, these examples are based on real world situations to ensure that the guidelines are applied practically. Each example will be described in words and has a score associated with it. The summarised scoring table is provided in Table 9-1. It is important to note that this system is by nature subjective: an identical asset could be scored differently by two different water agencies, depending on their risk appetite and the experience of the professionals doing the scoring however the subjectivity associated with the scoring system is reduced by providing this guided framework.

Table 9-1: Scoring criteria for classification of a linear asset by the simplified method

Section	Area	Likelihood of atmosphere exceeding the chosen threshold value			Weight (A)	Score (B)	Out of (C)	% (D = A x (B / C))
		3	2	1				
5.4.1	Hydraulic features Note 1	High	Medium	Low	40%		3	
5.4.2	Catchment composition				40%		9	
5.4.2.1	Chance of flammable liquid discharge from a trade waste connection	High	Medium	Low	30%		3	
5.4.2.2	Stormwater infiltration	High	Medium	Low	5%		3	
5.4.2.3	Local ground conditions	High	Medium	Low	5%		3	
5.4.3	Security				10%		6	
5.4.3.1	Location	High	Medium	Low	5%		3	
5.4.3.2	Security of site	High	Medium	Low	5%		3	
5.4.4	Abnormal operation				10%		18	
5.4.4.1	Power failure	High	Medium	Low	2%		3	
5.4.4.2	Plant/equipment failure	High	Medium	Low	2%		3	
5.4.4.3	Varying load cases	High	Medium	Low	2%		3	
5.4.4.4	Blockage or leakage	High	Medium	Low	2%		3	
5.4.4.5	Flood	High	Medium	Low	2%		3	
5.4.4.6	Foreseeable misuse	High	Medium	Low	2%		3	
						Total		
	Initial zonal rating (based on Table 5-6)							

Note that the scoring of each criteria in the examples below have been rounded up or down to meet for clarity of presentation. This means that, in some cases, the final score will differ from the sum of the scores in the table.

9.1 Pumping station (industrial)

A pump station is located in an industrial area with many automotive businesses as well as a plastics product manufacturer. Flow analysis shows that there are large flow spikes at times of the day that are not consistent with municipal wastewater diurnal patterns as evidenced by fast rates of filling of the wet well. The system is fed by gravity flows from several upstream industrial zones, and the time taken for these flows to arrive at the pump station is less than 3 hours. During wet weather, the wet well fills substantially faster than during dry weather. The asset is fenced but in the heart of the industrial area and easily accessed by members of the public. There are no nearby gas lines or deposits. The pump station mechanical assets frequently fail, and a previous upgrade upsizing the line was not able to increase the size of the discharge cast in, which has been known to catch rags. The pump station electricals were upgraded recently to bring the switch room above the 1% AEP flood level. The site is not actively ventilated but has a passive vent shaft.

Section	Area	Likelihood of atmosphere exceeding the chosen threshold value			Weight	Score	Out of	%
		3	2	1				
5.4.1	Hydraulic features	High	Medium	Low	40%	1	3	13%
5.4.2	Catchment composition				40%	7	9	
5.4.2.1	Chance of flammable liquid discharge from a trade waste connection	High	Medium	Low	30%	3	3	30%
5.4.2.2	Stormwater infiltration	High	Medium	Low	5%	3	3	5%
5.4.2.3	Local ground conditions	High	Medium	Low	5%	1	3	2%
5.4.3	Security				10%	4	6	
5.4.3.1	Location	High	Medium	Low	5%	3	3	5%
5.4.3.2	Security of site	High	Medium	Low	5%	1	3	2%
5.4.4	Abnormal operation				10%	12	18	
5.4.4.1	Power failure	High	Medium	Low	2%	1	3	1%
5.4.4.2	Plant/equipment failure	High	Medium	Low	2%	3	3	2%
5.4.4.3	Varying load cases	High	Medium	Low	2%	2	3	1%
5.4.4.4	Blockage or leakage	High	Medium	Low	2%	3	3	2%
5.4.4.5	Flood	High	Medium	Low	2%	1	3	1%
5.4.4.6	Foreseeable misuse	High	Medium	Low	2%	2	3	1%
							Total	63%
							Zone 2	

In this example, without knowing the exact contribution of flow, it can be inferred from the flow pattern that the flow into the pump station has times of the day which are predominantly industrial. Coupled with the industries being served by the pump station, the chance of flammable liquid discharge is high. Methane generation is not an issue as flows into the pump station are fast. Stormwater infiltration is high, as evidenced by the additional inflow during wet weather. Local ground conditions are good with low likelihood of acid sulphate soil. The site itself is secure, however, the location is one that is more likely to be targeted by illegal dumpers; this means foreseeable misuse that has a medium likelihood. Flood risk is low, as is power failure, but the equipment is old and fails often so has a high chance of not being operational.

An initial zonal rating of Zone 2 is provided given the sum of weighted scores is over 60% but less than 70%. As the ventilation is likely poor and its availability is 'fair', it does not get any further benefit in terms of zoning and its final classification, without further sampling, would be Zone 2.

9.2 Pump station in chain of pump station

A wet well submersible pump station is part of a chain of pump stations (also called a "daisy chain"). It is the second last pump station in a long line of pump stations. It is fed by two rising mains: one which comes from a significant distance away with pumped retention times at minimum flow conditions of approximately 15 hours. Another pump station transports wastewater from a housing development at the bottom of the hill. This pump station is close by, with minimum flow retention times of 2 hours. Finally, a local gravity network enters the pump station. This gravity network feeds a mixed residential/commercial district, with many restaurants and a 5-star hotel. Levels in the pump station follow a diurnal pattern typically associated with municipal wastewater. Power supply is occasionally out of service due to under-sized electrical infrastructure. The pump station is mid-way through a refurbishment, so the pumps have recently been replaced. The area is being renewed, so stormwater upgrades have been completed recently and wet weather results in negligible additional inflows. A low-pressure gas main runs approximately 2 m away from the wet well. The site is open, but the lids are covered and locked. The site is in the flood plain and the pipework is well sized and not prone to blockage. The site is not actively ventilated but has a passive vent shaft.

Section	Area	Likelihood of atmosphere exceeding the chosen threshold value			Weight	Score	Out of	%
		3	2	1				
5.4.1	Hydraulic features	High	Medium	Low	40%	3	3	40%
5.4.2	Catchment composition				40%	4	9	
5.4.2.1	Chance of flammable liquid discharge from a trade waste connection	High	Medium	Low	30%	1	3	10%
5.4.2.2	Stormwater infiltration	High	Medium	Low	5%	1	3	2%
5.4.2.3	Local ground conditions	High	Medium	Low	5%	2	3	3%
5.4.3	Security				10%	4	6	
5.4.3.1	Location	High	Medium	Low	5%	2	3	3%
5.4.3.2	Security of site	High	Medium	Low	5%	2	3	3%
5.4.4	Abnormal operation likelihood				10%	11	18	

Section	Area	Likelihood of atmosphere exceeding the chosen threshold value			Weight	Score	Out of	%
5.4.4.1	Power failure	High	Medium	Low	2%	3	3	2%
5.4.4.2	Plant/equipment failure	High	Medium	Low	2%	1	3	1%
5.4.4.3	Varying load cases	High	Medium	Low	2%	1	3	1%
5.4.4.4	Blockage or leakage	High	Medium	Low	2%	1	3	1%
5.4.4.5	Flood	High	Medium	Low	2%	3	3	2%
5.4.4.6	Foreseeable misuse	High	Medium	Low	2%	2	3	1%
							Total	68%
							Zone 2	

This pump station's primary risk is methane generation from the long upstream rising main. As the pump station is a wet well submersible type, the methane will be liberated by the long upstream rising main and discharged into the wet well head space. This methane will not be carried through by the pumps to downstream pump stations, as it will tend to be released through turbulence at the wet well. Therefore, downstream pump stations are only at risk of methane generation should there be additional long retention times in travel and are not affected by the gaseous methane concentrations. Flooding is moderately likely and the ground conditions are moderately risky due to the nearby gas main. The area is not fenced and is an area where some of the smaller businesses could consider illegal dumping. There is no power failure or asset failure applicable. The rising main is new, so blockage is not an issue.

An initial zonal rating of Zone 2 is provided given the sum of weighted scores is over 50% but less than 70%. As the ventilation provided medium to low dilution and its availability is 'fair', it does not get any further benefit in terms of zoning, and its final classification (without further sampling) would be Zone 2.

9.3 Odour control unit on PS

A pump station has a history of strong odours, both rotten egg and other smells. There are a number of rising mains feeding the pump station, all with retention times less than 6 hours long, and a gravity main from an industrial catchment known for its strong wastewater which is a large contributor in worst case flow conditions. The site of the pump station is in a small industrial catchment with many textile businesses and is in a high crime area. The site is unfenced but the lid is locked. The pump station is known to discharge heavily to its emergency storage tank in moderate to heavy rain. The ground conditions are normal: no gas deposits or nearby infrastructure which could influence classification. The pump station discharge is prone to blockage. The site is out of the flood zone. The mechanical and electrical infrastructure is old and unreliable, needing frequent repair and shut-down, exacerbating odour complaints.

To provide corrosion protection and in response to odour complaints from the community, an OCU has been provided. The OCU is an activated carbon system with an upstream air heater. Air is blown through the carbon unit. The air extraction fans are duty/standby on the same power supply, with auto change over via battery backed up instruments. There is air flow monitoring in the form of a flow switch on the common manifold, as well as downstream pressure transmitters. The ventilation system is designed in accordance with AS 60079.13 and is used as ventilation to control an explosive atmosphere. Ventilation is deemed to provide high dilution based on a theoretical petrol dump and controlling the concentration of petrol vapour in the bulk gas phase to 5% of the LFL. This requirement was slightly larger than the air flow required to provide effective odour and corrosion control, and the fans were upsized to provide the larger duty.

Section	Area	Likelihood of atmosphere exceeding the chosen threshold value			Weight	Score	Out of	%
		3	2	1				
5.4.1	Hydraulic features	High	Medium	Low	40%	1	3	13%
5.4.2	Catchment composition				40%	7	9	
5.4.2.1	Chance of flammable liquid discharge from a trade waste connection	High	Medium	Low	30%	3	3	30%
5.4.2.2	Stormwater infiltration	High	Medium	Low	5%	3	3	5%
5.4.2.3	Local ground conditions	High	Medium	Low	5%	1	3	2%
5.4.3	Security				10%	5	6	
5.4.3.1	Location	High	Medium	Low	5%	3	3	5%
5.4.3.2	Security of site	High	Medium	Low	5%	2	3	3%
5.4.4	Abnormal operation				10%	12	18	
5.4.4.1	Power failure	High	Medium	Low	2%	3	3	2%
5.4.4.2	Plant/equipment failure	High	Medium	Low	2%	3	3	2%
5.4.4.3	Varying load cases	High	Medium	Low	2%	2	3	1%
5.4.4.4	Blockage or leakage	High	Medium	Low	2%	1	3	1%
5.4.4.5	Flood	High	Medium	Low	2%	1	3	1%
5.4.4.6	Foreseeable misuse	High	Medium	Low	2%	2	3	1%
							Total	65%
							Zone 2	

The high concentration of trade waste discharge along with site security issues and poor asset reliability result in a Zone 2 classification.

Based on the Zone 2 baseline classification and referring to Table 5-10, the availability of ventilation is good. Using Table D.1 of AS 60079.10.1:2022, the resulting zonal classification is Non-Hazardous or more accurately, a Zone 2 area of negligible extent. It should be noted that the ventilation equipment must always be rated for the underlying zone; in this case, the fans must be rated for a Zone 2 hazardous area.

In this example, the water agency evaluated the items in the wet well. The electrically powered items they found were the following:

- Wet well submersible pumps x 3
- Radar level transmitter x 1

- Ball float x 3.

In the OCU air stream or near the flange leakage points, they found:

- Temperature transmitter x 6
- Flow switch x 1
- Pressure transmitter x 1
- Damper actuator x 4
- H_2S analyser x 2.

After a discussion with the operations team, it was determined that all of these items were required in the event of a failure of the ventilation system. Although the ventilation allowed the use of non-protected equipment, the need for everything to remain online meant that the Zone 2 classification remained the governing requirement.

This example is a complex one as activated carbon units can experience smouldering and bed fires in the absence of ventilation and depending on the contaminants which they absorb[33]. The heating of the air stream could also change the likelihood of substances, although in general carbon air heaters operate at a bulk air stream temperature of 60°C (a coil temperature of 180 - 200°C) and the auto-ignition point of many fuels is greater than this. There are however exceptions, such as carbon disulphide. This example is one where GC-MS speciation of the air stream would prove helpful in identifying the extent of contaminants that are being adsorbed by the activated carbon system.

[33] **Ketones in particular are known to create hotspots in activated carbon systems which are exacerbated when the ventilation is turned off.**

Table D.1 – Zones for grade of release and effectiveness of ventilation

Grade of release	Effectiveness of Ventilation						
	High Dilution			Medium Dilution			Low Dilution
	Availability of ventilation						
	Good	Fair	Poor	Good	Fair	Poor	Good, fair or poor
Continuous	Non-hazardous (Zone 0 NE)[a]	Zone 2 (Zone 0 NE)[a]	Zone 1 (Zone 0 NE)[a]	Zone 0	Zone 0 + Zone 2[c]	Zone 0 + Zone 1	Zone 0
Primary	Non-hazardous (Zone 1 NE)[a]	Zone 2 (Zone 1 NE)[a]	Zone 2 (Zone 1 NE)[a]	Zone 1	Zone 1 + Zone 2	Zone 1 + Zone 2	Zone 1 or zone 0[d]
Secondary[b]	Non-hazardous (Zone 2 NE)[a]	Non-hazardous (Zone 2 NE)[a]	Zone 2	Zone 2	Zone 2	Zone 2	Zone 1 and even Zone 0[d]

[a] Zone 0 NE, 1 NE or 2 NE indicates a theoretical zone which would be of negligible extent under normal conditions.

[b] The Zone 2 area created by a secondary grade of release may exceed that attributable to a primary or continuous grade of release; in this case, the greater distance should be taken.

[c] Zone 1 is not needed here. I.e. small Zone 0 is in the area where the release is not controlled by the ventilation and larger Zone 2 for when ventilation fails.

[d] Will be Zone 0 if the ventilation is so weak and the release is such that in practice an explosive gas atmosphere exists virtually continuously (i.e. approaching a 'no ventilation' condition).

'+' signifies 'surrounded by'.

Availability of ventilation in naturally ventilated enclosed spaces is commonly not considered as good.

9.4 Discharge maintenance hole

A new, long rising main discharges municipal sewage from an area on the outskirts of a city's developed area into a discharge maintenance hole, which has a gravity connection to a downstream pump station. The wastewater is almost entirely municipal in nature with the exception of a small convenience store. The rising main was built for planned flows up to 2053, with a design velocity at this time of 1.5 m/s and retention time at this velocity of 7 hours. The rising main follows the natural contour of the ground and therefore undulates. The maintenance hole has an unlocked lightweight lid and is in a park. The lightweight lid is well sealed against ingress, and there are no nearby gas services or geological features.

Section	Area	Likelihood of atmosphere exceeding the chosen threshold value			Weight	Score	Out of	%
		3	2	1				
5.4.1	Hydraulic features	High	Medium	Low	40%	2	3	27%
5.4.2	Catchment composition				40%	3	9	
5.4.2.1	Chance of flammable liquid discharge from a trade waste connection	High	Medium	Low	30%	1	3	10%
5.4.2.2	Stormwater infiltration	High	Medium	Low	5%	1	3	2%

Section	Area	Likelihood of atmosphere exceeding the chosen threshold value			Weight	Score	Out of	%
5.4.2.3	Local ground conditions	High	Medium	Low	5%	1	3	2%
5.4.3	Security				10%	2	6	
5.4.3.1	Location	High	Medium	Low	5%	1	3	2%
5.4.3.2	Security of site	High	Medium	Low	5%	1	3	2%
5.4.4	Abnormal operation				10%	6	18	
5.4.4.1	Power failure	High	Medium	Low	2%	1	3	1%
5.4.4.2	Plant/equipment failure	High	Medium	Low	2%	1	3	1%
5.4.4.3	Varying load cases	High	Medium	Low	2%	1	3	1%
5.4.4.4	Blockage or leakage	High	Medium	Low	2%	1	3	1%
5.4.4.5	Flood	High	Medium	Low	2%	1	3	1%
5.4.4.6	Foreseeable misuse	High	Medium	Low	2%	1	3	1%
						Total		47%
						Non-Hazardous, however deemed Zone 2		

This example is misleading in that when using Table 5-2, the hydraulic retention risk is moderate. However, this is for the design condition in 2053; that is, a distant future load case. The flow at this current stage of the asset's design life is likely to be in the high likelihood category and is therefore an automatic Zone 2. All other factors are low likelihood. As the retention time begins to drop, this asset can be revisited and have a different zone rating assigned.

As there is no ventilation acting on this maintenance hole it does not receive any further benefit in terms of zoning, and its final classification without further sampling would be Zone 2.

9.5 Maintenance hole

A large trunk gravity main, carrying the wastewater for 25% of a large city, passes through a very large maintenance hole. It carries wastewater from both industrial and residential portions of the city. Its flow strongly follows a diurnal pattern of wastewater as measured by the level in the maintenance hole. Its access hatch is fenced and has a locked lid to prevent entry into the main, which is large enough to stand in. It flows significantly fuller in wet weather. A high pressure gas main passes by the maintenance hole at a distance of 5 m. Power failure and plant/equipment failure do not affect the atmosphere, although level display will be lost if power fails. The gravity main does not experience blockage and is not expected to experience vastly different future flows. Flooding does not impact the asset's atmosphere.

Section	Area	Likelihood of atmosphere exceeding the chosen threshold value			Weight	Score	Out of	%
		3	**2**	**1**				
5.4.1	Hydraulic features	High	Medium	Low	40%	1	3	13%
5.4.2	Catchment composition				40%	7	9	
5.4.2.1	Chance of flammable liquid discharge from a trade waste connection	High	Medium	Low	30%	1	3	10%
5.4.2.2	Stormwater infiltration	High	Medium	Low	5%	3	3	5%
5.4.2.3	Local ground conditions	High	Medium	Low	5%	3	3	5%
5.4.3	Security				10%	2	6	
5.4.3.1	Location	High	Medium	Low	5%	1	3	2%
5.4.3.2	Security of site	High	Medium	Low	5%	1	3	2%
5.4.4	Abnormal operation				10%	8	18	
5.4.4.1	Power failure	High	Medium	Low	2%	1	3	1%
5.4.4.2	Plant/equipment failure	High	Medium	Low	2%	1	3	1%
5.4.4.3	Varying load cases	High	Medium	Low	2%	1	3	1%
5.4.4.4	Blockage or leakage	High	Medium	Low	2%	1	3	1%
5.4.4.5	Flood	High	Medium	Low	2%	1	3	1%
5.4.4.6	Foreseeable misuse	High	Medium	Low	2%	2	3	2%
							Total	41%
							Non-Hazardous	

In this case, the likelihood of industrial discharge or upstream rising main gaseous methane being transmitted into the asset is significantly moderated by the size of the asset's ordinary, municipal flows. Having recognised the maintenance hole as critical, the security provisions reduce the weighted scoring although even if the site were not fenced, it would still maintain a non-hazardous rating. If an oily sheen or a solvent smell was observed here, there may be a case for a higher rated zone or further monitoring.

9.6 Pump station (municipal)

A pump station is planned for a new housing development, a planned community in a greenfield area to be built over 30 years in three stages. The community has a gravity network which drains directly into the inlet maintenance hole of the pump station. The pump station will transport the development's sewage to a nearby gravity maintenance hole. The housing development will occur in three stages, and the pump station is sized for Stage 3 but is installed during Stage 1, which has a third the flow. The Stage 3 retention time is 2 hours, the Stage 1 retention time is 6 hours. The area is on the flood plain and the developer has run nearby gas infrastructure close to the pump station to minimise service easements. The development is in a rough area, and no fencing has been placed. There are no standby pumps, pipework has been sized at Stage 2 flows and the local substation will not be upgraded until Stage 2 meaning power is intermittent. The development is close to (but does not service) an industrial area and is easily accessed from that area.

Section	Area	Likelihood of atmosphere exceeding the chosen threshold value			Weight	Score	Out of	%
		3	2	1				
5.4.1	Hydraulic features	High	Medium	Low	40%	1	3	13%
5.4.2	Catchment composition				40%	7	9	
5.4.2.1	Chance of flammable liquid discharge from a trade waste connection	High	Medium	Low	30%	1	3	10%
5.4.2.2	Stormwater infiltration	High	Medium	Low	5%	3	3	5%
5.4.2.3	Local ground conditions	High	Medium	Low	5%	3	3	5%
5.4.3	Security				10%	6	6	
5.4.3.1	Location	High	Medium	Low	5%	3	3	5%
5.4.3.2	Security of site	High	Medium	Low	5%	3	3	5%
5.4.4	Abnormal operation				10%	18	18	
5.4.4.1	Power failure	High	Medium	Low	2%	3	3	2%
5.4.4.2	Plant/equipment failure	High	Medium	Low	2%	3	3	2%
5.4.4.3	Varying load cases	High	Medium	Low	2%	3	3	2%
5.4.4.4	Blockage or leakage	High	Medium	Low	2%	3	3	2%
5.4.4.5	Flood	High	Medium	Low	2%	3	3	2%
5.4.4.6	Foreseeable misuse	High	Medium	Low	2%	3	3	2%
							Total	53%
							Non-Hazardous	

In this example, there is a low likelihood of any methane build up upstream of the pump station, and also a low risk of any trade waste.

This example has many high likelihood influencing factors outside of retention time and industrial discharge. It is presented to demonstrate that for many assets, which do not have industrial discharge or long upstream retention times, a default rating of non-hazardous will apply unless there is a history of illegal dumping. The lower weighted factors will not in and of themselves make the pump station a hazardous area. They are however important in considering if an asset is Zone 2, Zone 1 or Zone 0, where medium or high likelihoods of high-risk trade waste discharge or head space methane generation mean that there is a likely hazardous area.

10. HAZARDOUS ZONE DRAWINGS

10.1 Linear infrastructure

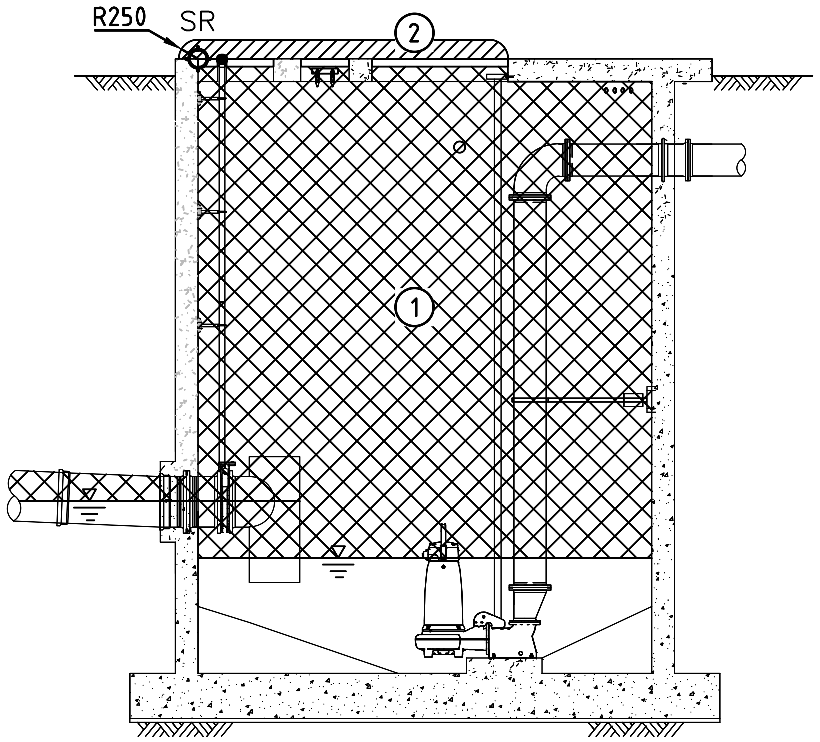
10.1.1 Maintenance hole/scour pit

10.1.2 Wet well/dry well

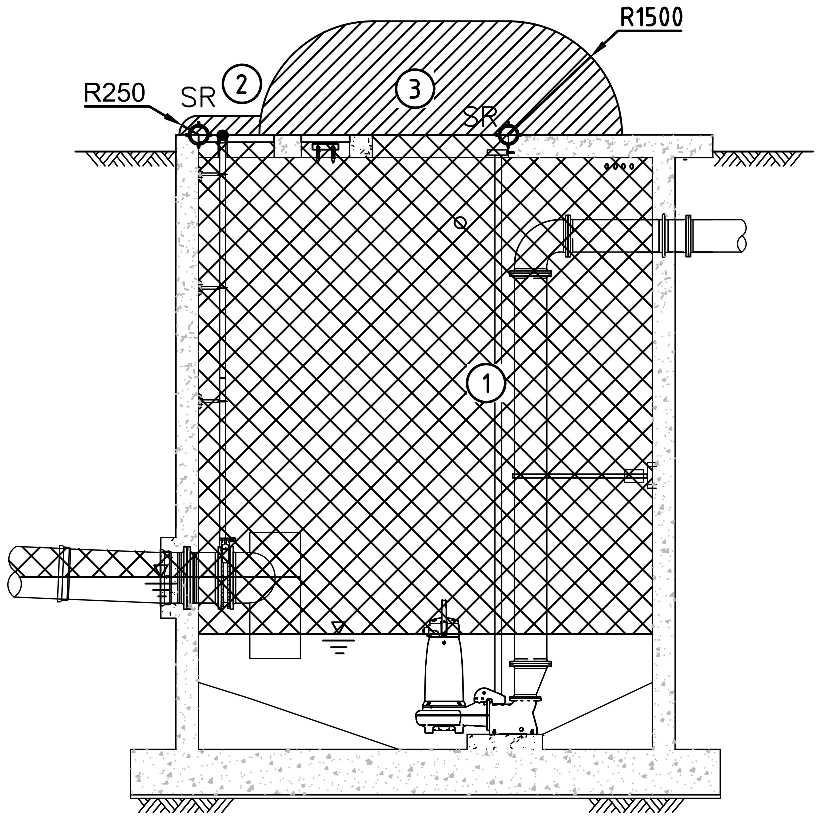
10.1.3 Wet well/valve chamber

10.1.4 Emergency storage tank

10.1.5 Air valve pit/air valve



SECTION 1
NTS



SECTION 2
NTS

LEGEND:

ZONE 0

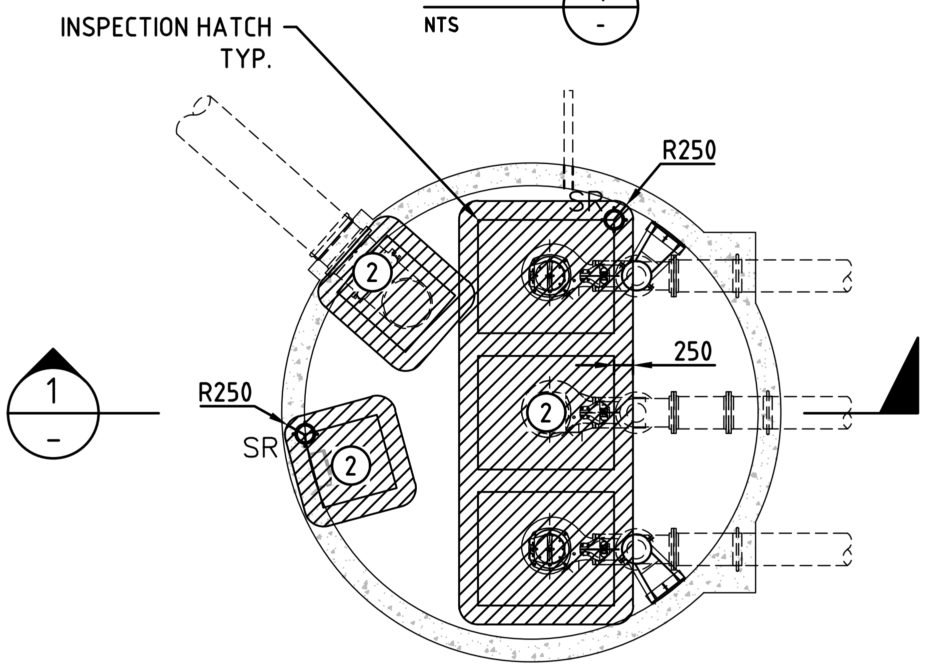
ZONE 1

ZONE 2

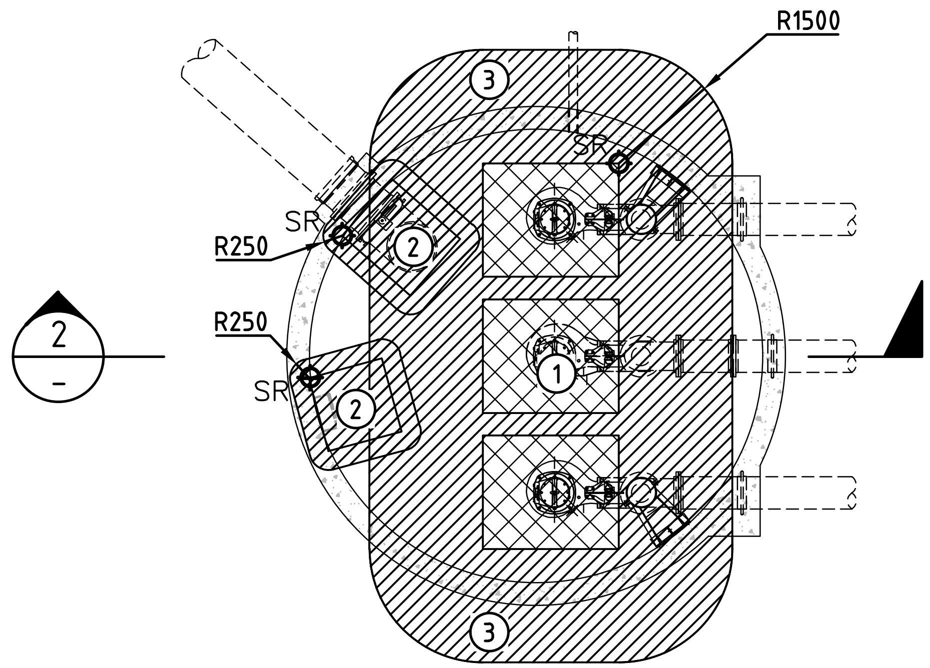
1 WET WELL

2 OPENING WITH CLOSED LID

3 OPENING WITH OPEN LID



WET WELL WITH LID CLOSED - PLAN



WET WELL WITH LID OPEN - PLAN

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Level 16, 207 Kent Street
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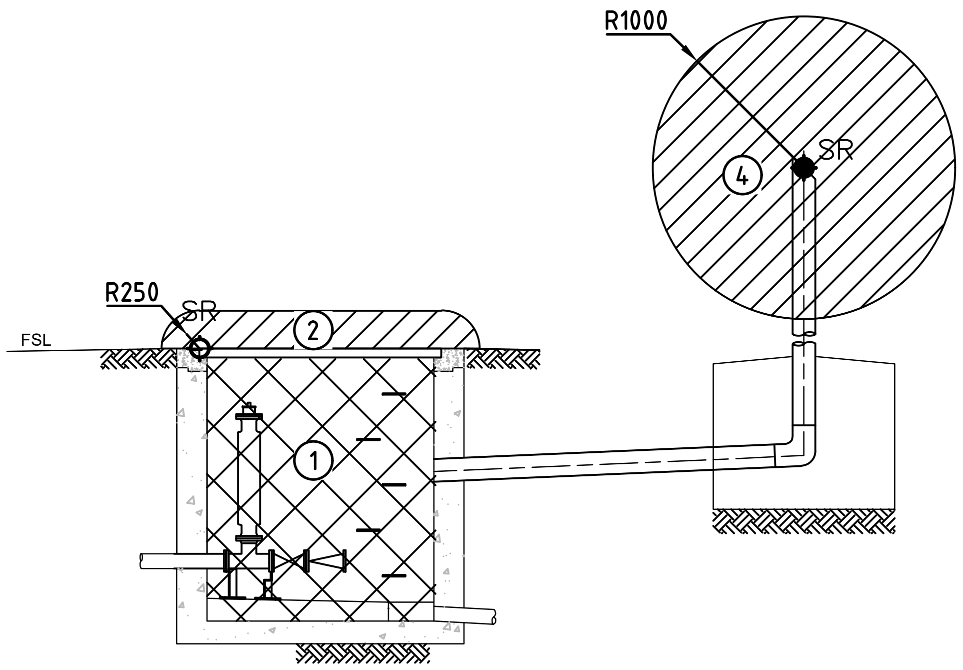
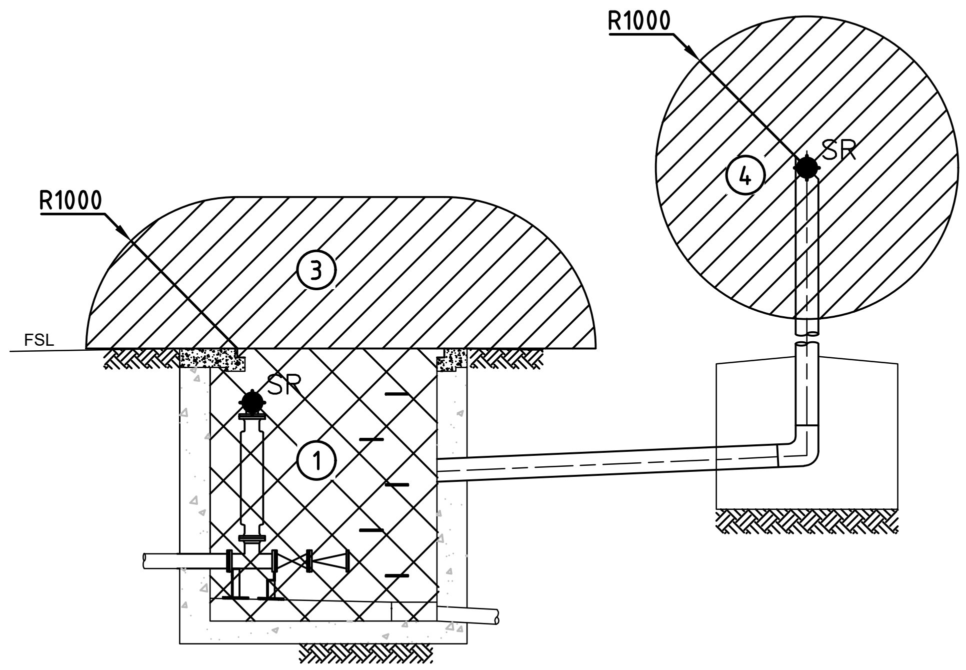
NOTES:
1. ALL DIMENSIONS IN MILLIMETRES.
2. WET WELL INTERNAL SHOWN AS ZONE 1. IF ZONE 2, EXTERNAL ZONES REMAIN ZONE 2.

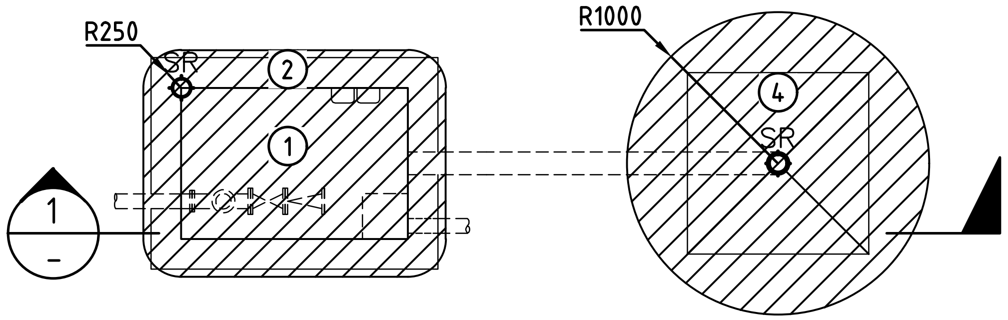
WATER SERVICES ASSOCIATION *of Australia*	EXPLOSIVE ATMOSPHERE GUIDELINES	NOT TO SCALE
	SEWERAGE WET WELL HAZARDOUS AREA CLASSIFICATION EXAMPLE DRAWING	HAC-0001



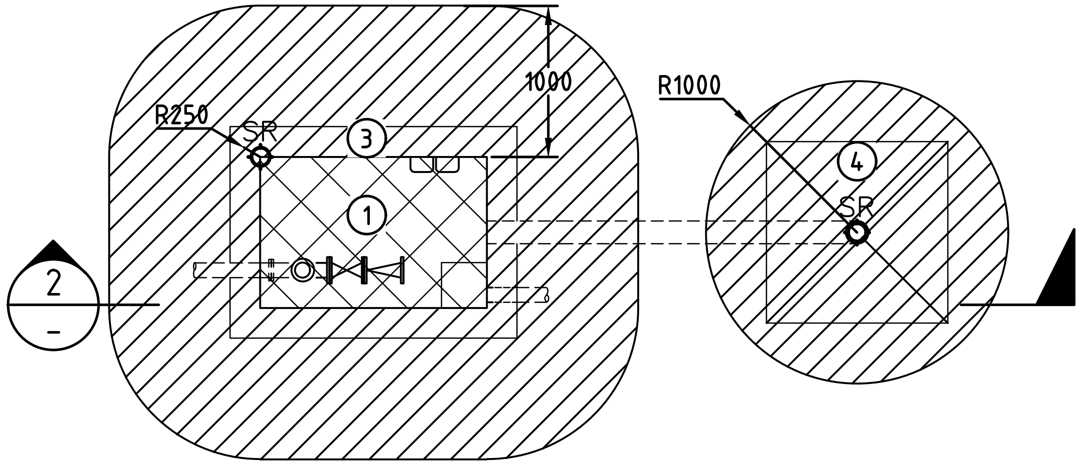
SECTION 1
NTS
-



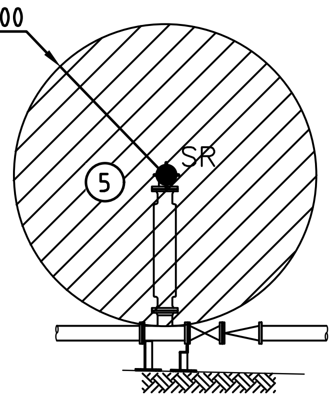
SECTION 2
NTS
-



AIR VALVE PIT WITH LID CLOSED - PLAN



AIR VALVE PIT WITH LID OPEN - PLAN



AIR VALVE OUTDOOR INSTALLATION - ELEVATION VIEW

LEGEND:

ZONE 0

ZONE 1

ZONE 2

1. VALVE CHAMBER
2. INSPECTION HATCH WITH CLOSED LID
3. INSPECTION HATCH WITH OPEN LID
4. GAS VENT
5. OUTDOOR INSTALLATION

NOTES:
1. ALL DIMENSIONS IN MILLIMETRES.
2. AIR VALVE DISCHARGE SHOWN AS ZONE 1. IF ZONE 2, EXTERNAL ZONES REMAIN ZONE 2.

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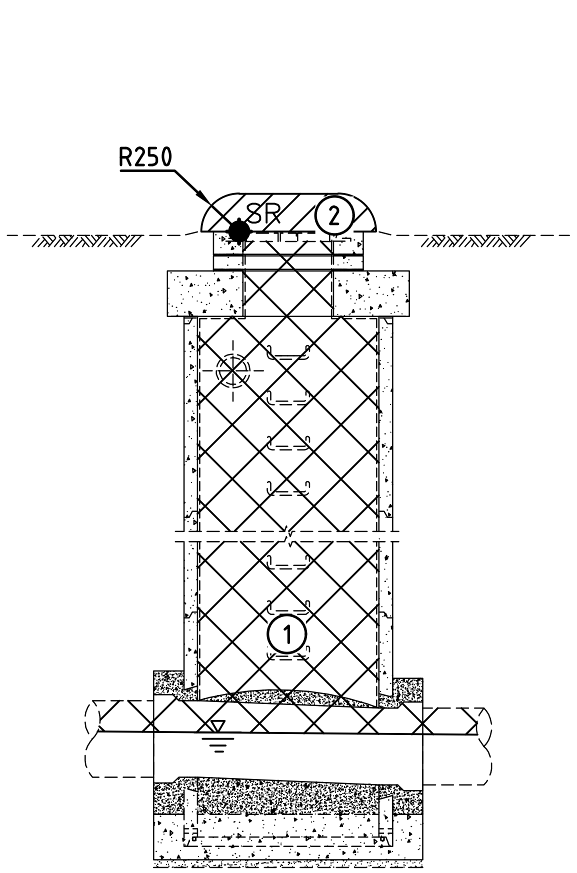
WATER SERVICES ASSOCIATION of Australia

EXPLOSIVE ATMOSPHERE GUIDELINES

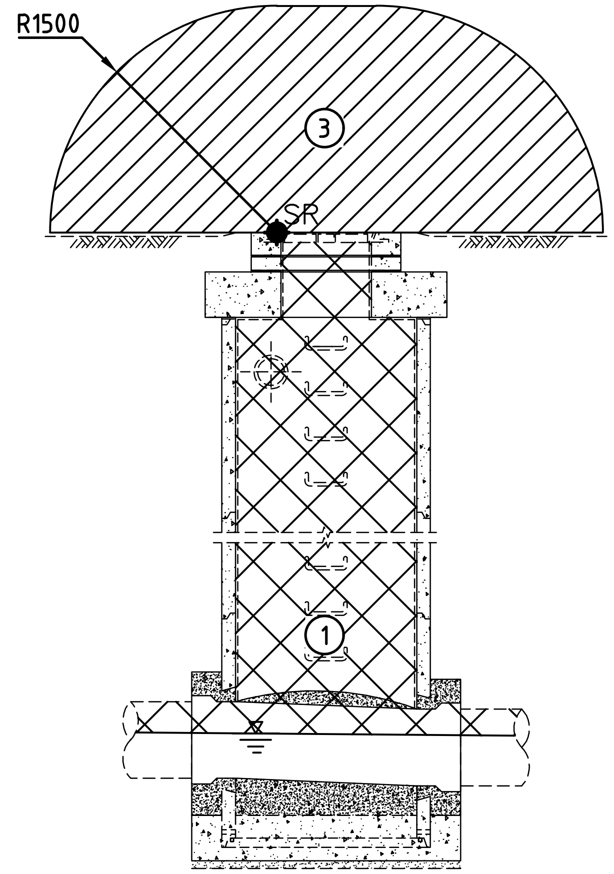
AIR VALVE
HAZARDOUS AREA CLASSIFICATION
EXAMPLE DRAWING

NOT TO SCALE

HAC-0002

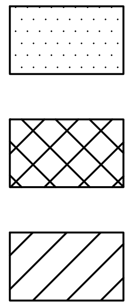


SECTION 1
NTS

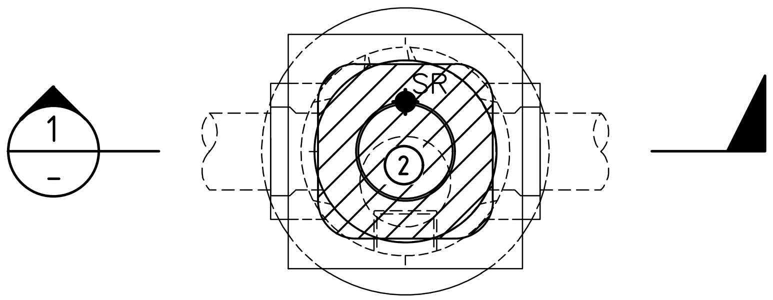


SECTION 2
NTS

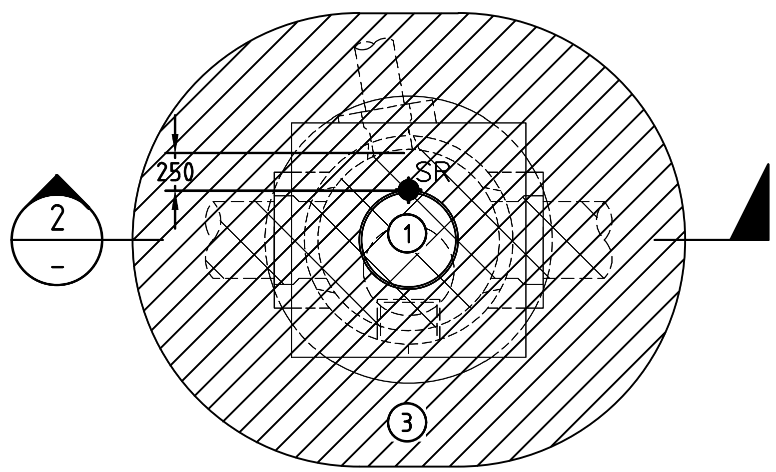
LEGEND:



1. MAINTENANCE HOLE
2. OPENING WITH CLOSED LID
3. OPENING WITH OPEN LID



MAINTENANCE HOLE WITH LID CLOSED – PLAN

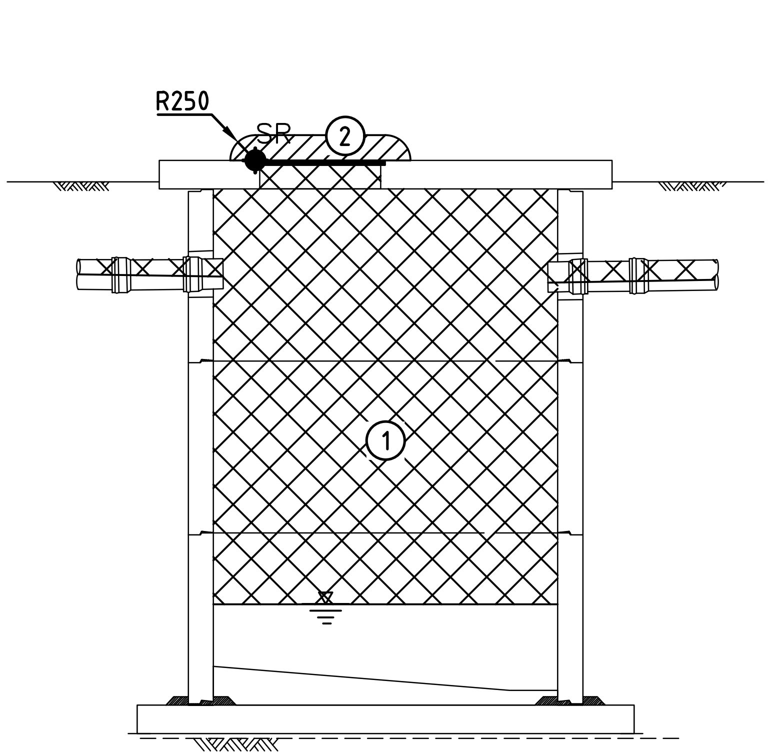


MAINTENANCE HOLE WITH LID OPEN – PLAN

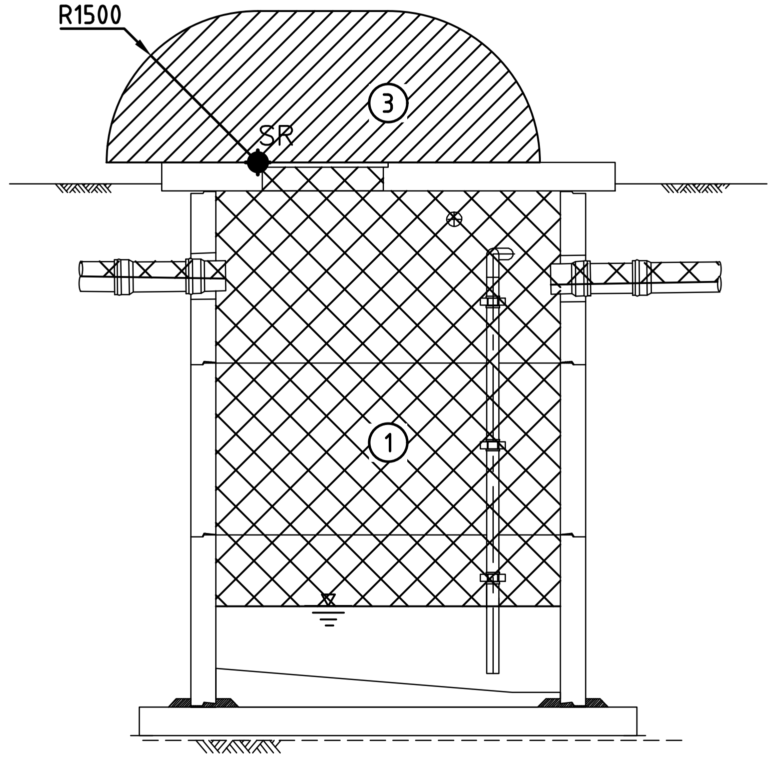
Stantec
Level 16, 207 Kent Street
Sydney, NSW 2000
ABN: 17 007 820 322
Tel: 02 9493 9700
Fax: 02 9493 9799
Business.Services.NSW@mwhglobal.com

NOTES:
1. ALL DIMENSIONS IN MILLIMETRES.
2. MAINTENANCE HOLE INTERNAL SHOWN AS ZONE 1. IF ZONE 2, EXTERNAL ZONES REMAIN ZONE 2.

WATER SERVICES ASSOCIATION of Australia	EXPLOSIVE ATMOSPHERE GUIDELINES	NOT TO SCALE
	MAINTENANCE HOLE HAZARDOUS AREA CLASSIFICATION EXAMPLE DRAWING	HAC-0003



SECTION 1
NTS -

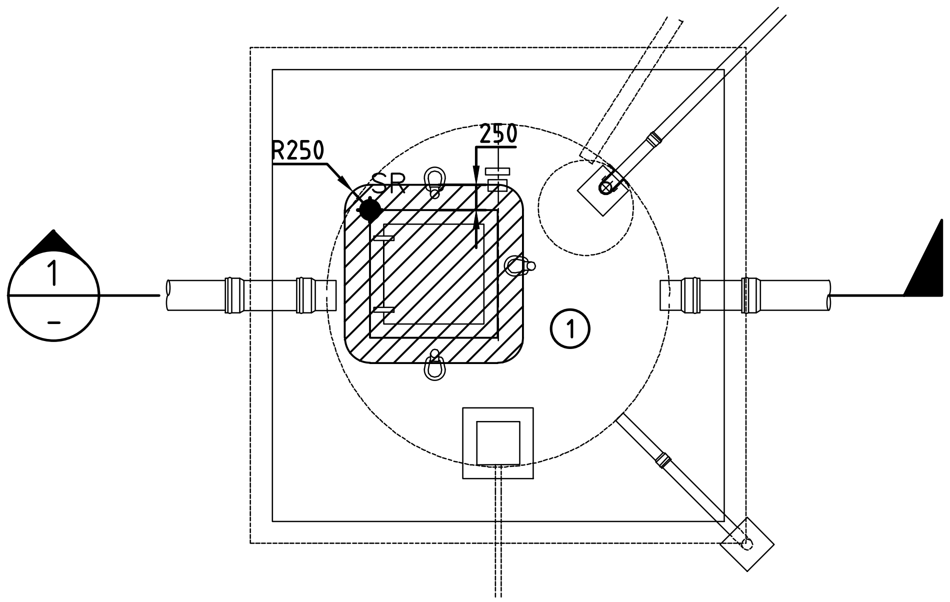


SECTION 2
NTS -

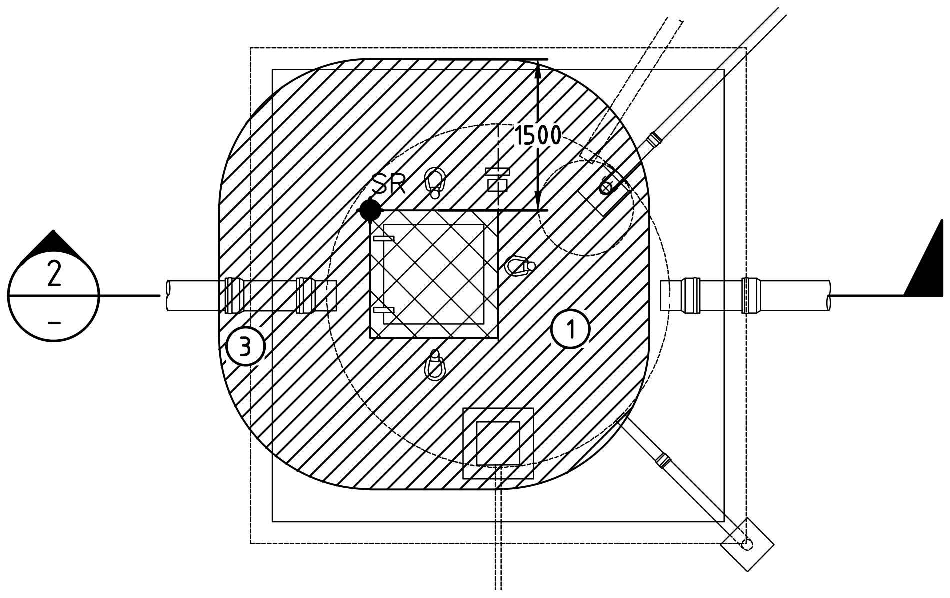
LEGEND:

- ZONE 0
- ZONE 1
- ZONE 2

1. EMERGENCY STORAGE TANK
2. OPENING WITH CLOSED LID
3. OPENING WITH OPEN LID



STORAGE TANK WITH LID CLOSED - PLAN



STORAGE TANK WITH LID OPEN - PLAN

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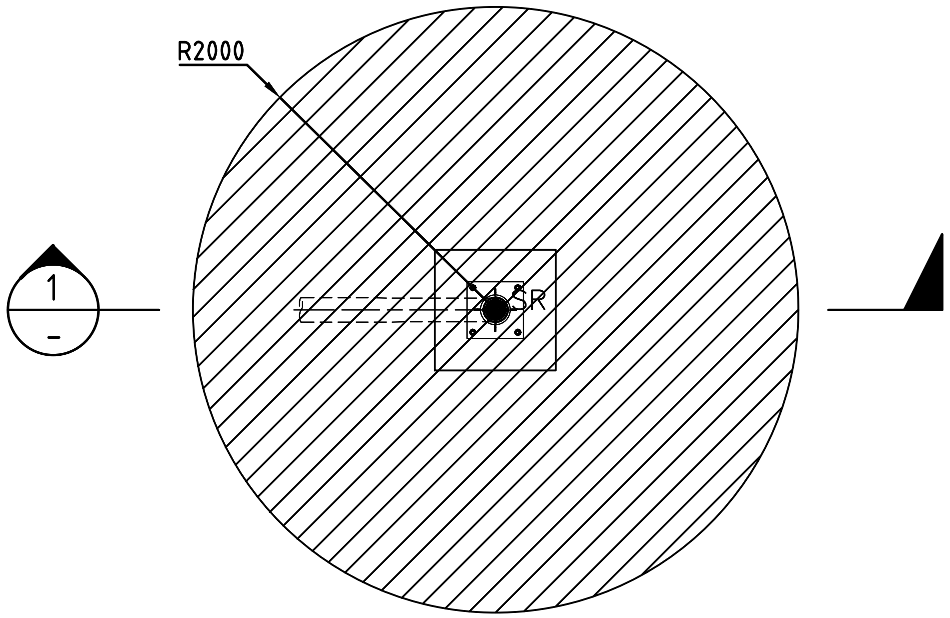
WATER SERVICES ASSOCIATION of Australia	EXPLOSIVE ATMOSPHERE GUIDELINES	NOT TO SCALE
	EMERGENCY STORAGE TANK HAZARDOUS AREA CLASSIFICATION EXAMPLE DRAWING	HAC-0004

LEGEND:

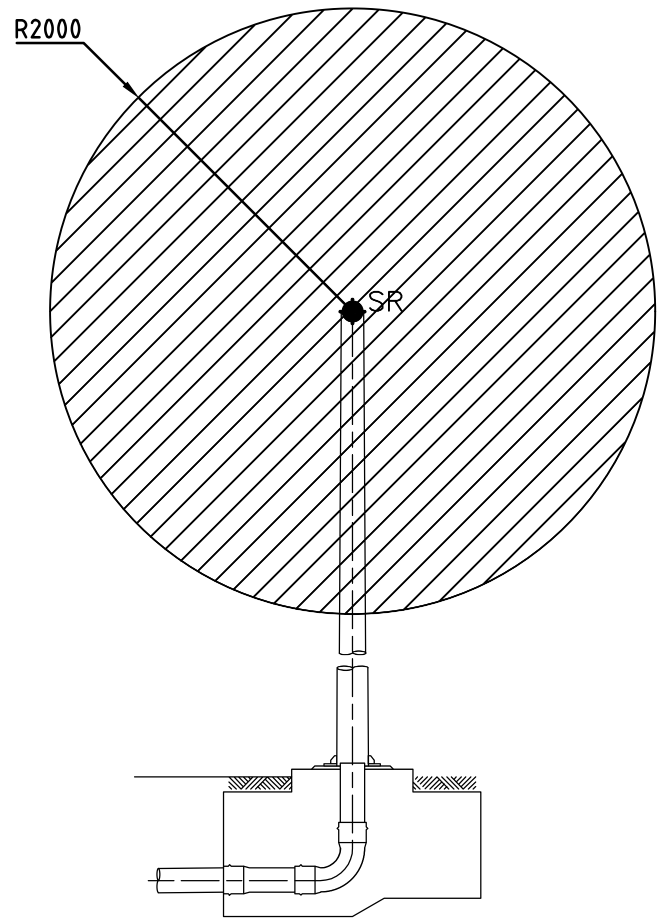
ZONE 0

ZONE 1

ZONE 2



VENT SHAFT - PLAN



SECTION 1 -
NTS

	VENT SHAFT DIAMETER		
DISCHARGE FLOW (M3/HR)	50MM	100MM	250MM
250	1 M	1 M	2 M
500	1 M	1 M	2 M
1000	1.5 M	1.5 M	2 M
2500	2 M	2 M	2.5 M

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NOTES:
1. ALL DIMENSIONS IN MILLIMETRES.

WATER SERVICES ASSOCIATION
of Australia

EXPLOSIVE ATMOSPHERE GUIDELINES

VENT TSHAFT
HAZARDOUS AREA CLASSIFICATION
EXAMPLE DRAWING

NOT TO SCALE

HAC-0005

Appendix A: Trade waste risk categories

It is recognised that different authorities have different classifications for the risk associated with trade wastes. The table below provides general guidance: it does not necessarily align with any or all organisation's risk framework.

Industry	Contaminants of Concern	Risk Profile
Food processing and manufacture	Chlorinated hydrocarbons from disinfecting procedures, solvents from maintenance activities.	Medium – Low due to maintenance / disinfectant procedures
Abattoirs (red meat) **Poultry slaughter or processing** **Seafood processing and aquaculture** **Pet food manufacture**	High BOD / COD waste can promote anaerobic activity and methane production; discharges with significant rising mains can have a high risk of methane generation	Medium to High due to methane generation
Beverage processing and manufacture	Methanol, ethanol and other primary, secondary and tertiary alcohols. High BOD / COD waste can promote anaerobic activity and methane production; discharges with significant rising mains can have a high risk of methane generation	Medium – High
Tanning and textiles	Highly volatile solvents from processing and maintenance. Formaldehyde, Azo dyes, Chlorobenzene and other chlorinated hydrocarbons, glutaraldehyde	Medium
Petroleum-based activities	Highly volatile solvents, hydrocarbons, aromatic hydrocarbons	Very High
Pharmaceutical and cosmetic activities	Volatile solvents, phenolic compounds and ethers	Medium – High
Chemicals, plastics and surfactants	Many highly volatile flammable organics including organic resins, organic acids, tetrahydric alcohol, pentaerythritol, formaldehyde, acetaldehyde, phenols, benzene & other aromatic hydrocarbons, aldehydes and ketones.	Medium – High
Metals and surface coatings	Acidic effluents, contaminated with solvents	Low – Medium
Paper, board, photographic and printing	Photography and printing utilise a number of solvents in the processing and in cleaning activities including nitrocellulose, maleic resins, vinyl acetate resin, Gilsonite, or natural resins in solvents, as xylol, toluol, and high-boiling mineral thinners. If volatile, partly soluble ketones (such as methyl ethyl ketone or methyl isobutyl ketone)	Medium

Industry	Contaminants of Concern	Risk Profile
	these can form volatile and explosive atmospheres, risk profile should increase to Medium-High.	
Cement, stone and abrasives	Mostly inorganic solids	Low
Waste and wastewater treatment	Methane, VOCs and substances from trade waste dischargers upstream	Medium – High
Sewer mining and decentralised wastewater treatment	Methane, VOCs and substances from trade waste dischargers upstream	Medium to High
Retail food	Long chain organics (fat/grease). Some volatile solvents used in cleaning. High BOD/COD waste can promote anaerobic activity and methane production; discharges with significant rising mains can have a high risk of methane generation	Low – Medium
Restaurants, takeaway food outlets, function centres, hospital and nursing home kitchens, caterers, butchers, delicatessens and retail bakeries	Mostly volatile solvents/chlorinated hydrocarbons used in cleaning/sterilising. High BOD/COD waste can promote anaerobic activity and methane production; discharges with significant rising mains can have a high risk of methane generation	Low – Medium
Automotive **Service stations, panel beaters and spray painters, car detailers, car wash – hand wash and pressure spray, car wash <12 kL/day, mechanical workshops, auto recyclers, construction equipment hire**	Highly volatile solvents, organics, hydrocarbons such as octane (petrol) and other wastes	High
Commercial laundries **Laundromats, commercial laundries < 2 ML/year, and hospital, nursing home and hotel laundries**	Chlorinated hydrocarbons and other volatile solvents including tetrachloroethylene (perchloroethylene), known in the industry as "per", 1-bromopropane and petroleum spirits amongst others	High if discharging to sewer
Photographic	Many chemicals including; metol (monomethyl-p-aminophenol hemisulfate), phenidone (1-phenyl-3-pyrazolidinone), dimezone (4,4-dimethyl-1-phenylpyrazolidin-3-one), hydroquinone (benzene-1,4-diol), Aminophenol, Ethylene Glycol, Formaldehyde,	Medium

Industry	Contaminants of Concern	Risk Profile
	Monoethanolamine, 1,1,1,-Trichloroethane, Triethanolamine If volatile, partly soluble ketones (such as methyl ethyl ketone or methyl isobutyl ketone) these can form volatile and explosive atmospheres, risk profile should increase to Medium-High.	
Hospitals	Organic disinfectants, detergents, pharmaceutical residues, solvents, X-ray contrast media, aromatic hydrocarbons and phenolics	Medium – High
Minilabs, medical facilities using X-rays, graphic arts and professional photographic laboratories	See Photographic and Hospitals Misc solvents, amines, alcohols, aldehydes, ketones, aromatic hydrocarbons and other volatile organics. If volatile, partly soluble ketones (such as methyl ethyl ketone or methyl isobutyl ketone) these can form volatile and explosive atmospheres, risk profile should increase to Medium-High.	Medium
Shopping centres with centralised pre-treatment	High BOD/COD waste can promote anerobic activity and methane production; discharges with significant rising mains can have a high risk of methane generation	Low – Medium
Shopping centres with shared pre-treatment other than grease traps	High BOD / COD waste can promote anerobic activity and methane production; discharges with significant rising mains can have a high risk of methane generation	Low – Medium

Whilst the authors have endeavoured to capture the majority of high risk chemicals used in various industrial processes, there may be local practices that use different chemicals which can increase or decrease the risk profiles listed. It is recommended that a full assessment is made with all chemicals used on site.

Appendix B: Supplementary information on the effects of explosions

Explosions can be broadly described as follows:

(i) A flammable substance which is capable of burning in the presence of oxygen between the upper and lower flammability limits (UFL/LFL) in a deflagration event, defined as combustion which propagates through a gas or across the surface of an explosive mixture at subsonic speeds, driven by the transfer of heat. Significant heat and modest overpressures are achieved – generally below 50 kilopascals (kPa).

(ii) An ignited flammable substance may also undergo Deflagration to Detonation Transition (DDT). This refers to a phenomenon in ignitable mixtures of a flammable vapour/gas and air (or oxygen) when a sudden transition takes place from a deflagration type of combustion to a detonation type of explosion.

(iii) A detonation is characterised by a flammable mixture of gas which has supersonic flame propagation velocities and substantial overpressures (up to 2 megapascals (mPa)). The mechanism of detonation propagation is a powerful pressure wave that compresses the unburnt gas ahead of the wave to a temperature above the autoignition temperature, rather than the conduction of heat.

Many compounds that can be found in wastewater systems are known to ignite in a deflagration event but can also detonate as a result of DDT. Both events can be characterised as an explosive event (accompanied by a heat and overpressure wave), however a detonation is a far more violent event, generally causing far more extreme damage. Having stated this, overpressures formed by a deflagration event are more than enough to cause serious harm to personnel and damage to structures.

The human body can survive relatively modest blast overpressure without experiencing barotrauma (damage due to pressure changes). A 34 kPa blast overpressure will rupture eardrums in approximately 1% of subjects. The threshold for lung damage occurs at approximately 100 kPa (15 psi), with 380 – 450 kPa (55 to 65 psi) causing up to 99% fatalities (Glasstone and Dolan, 1977; TM 5-1300, 1990).

The table below shows the maximum wind speed associated with the given overpressure generated. In explosion events it is the blast wind resulting from the blast overpressure that leads to most injuries and fatalities due to blunt force trauma or shrapnel.

Table B-1: Department of Defence data from Glasstone and Dolan (1977) and Sartori (1983), effects of increasing blast pressure on various structures and the human body.

Peak overpressure	Max wind speed	Effect on structures	Effect on human body
7 kPa	61 km/h	Window glass shatters	Light injuries from fragments occur

Peak overpressure	Max wind speed	Effect on structures	Effect on human body
14 kPa	113 km/h	Moderate damage to houses (windows and doors blown out and severe damage to roofs)	People injured by flying glass or debris
21 kPa	164 km/h	Residential structures collapse	Serious injuries are common, fatalities may occur
35 kPa	262 km/h	Most buildings collapse	Injuries are universal, fatalities are widespread
69 kPa	473 km/h	Reinforced concrete buildings are severely damaged or demolished	Most people are killed
138 kPa	808 km/h	Heavily built concrete buildings are severely damaged or demolished	Fatalities approach 100%

Unfortunately the full mechanism of DDT is not fully understood, with variables such as air turbulence, geometry and compound specifics at play. DDT can occur in closed and open spaces or in the open atmosphere and is the basis of Fuel Air Explosives (FAE or thermobaric weapons). Within this document differentiation between deflagration and detonation events are not made; both cases are referred to as an “explosive event” caused by a flammable or explosive atmosphere.

Appendix C: Discussion of sampling technologies

The main types of detectors (other niche instruments are available) for the detection of explosive atmospheres or the VOCs that can form them are provided below. It is important to note that if the monitoring location is suspected of having a potentially explosive atmosphere (as per guidance in Section 1.5) the sampling assembly must be appropriately rated for the suspected hazardous area. Consult with the manufacturer to ensure that this is the case and where doubt exists, refer to the requirements of AS/NZS 60079.29.1 and AS/NZS 60079.29.2.

Pellistor/catalytic oxidising type sensor

Type of monitoring: Continuous, logged

Results: Online, with response time noted

Response time: Dependent on gas being detected and the unit but generally 10 to 60 s

Ideal for: Determining percentage of LFL for a wide range of gases in an asset to inform classification of hazardous areas, or for shutting down equipment, especially when used in conjunction with a PID

Main challenges: Regular calibration, response time and poisoning

These sensors are one of the most used combustible gas sensors, with operation dependent upon the oxidation of the target gas within the instrument. The flammable contaminant is oxidised on the surface of a pellet resistor (or “pellistor”) located within the sensor.

The unit contains two coils of fine platinum wire which are each coated with a ceramic/porous alumina material to form beads. One bead is “activated” by being coated with a catalyst (platinum of palladium), with the other “reference bead” being identical but uncoated. The two pellistors (active and reference) are wired into opposing arms of a balanced Wheatstone Bridge electrical circuit. As long as there is oxygen present, combustion of the contaminant can occur on the active bead at concentrations far below the LFL. A sintered glass or similar protection is applied to the cell to allow diffusion of gas but prevention of flame propagating out.

A voltage is applied across both active and reference beads causing them to heat up. Note that the temperature of the active bead must be high enough for the gas to be oxidized, with the bead needing to be raised to 500ºC to detect methane (for example).

In uncontaminated air, the Wheatstone Bridge circuit is balanced with an output voltage of zero. If a combustible gas is present, oxidation heats the active bead further, however the temperature of the reference bead is unaffected. This difference in resistance caused by the temperature differential is then used by the detector to determine the gas concentration.

Historically such detectors have had limited battery life, however advances in battery technology and the repeatable size of the pellistors have mostly overcome this issue.

These gas sensors are unable to differentiate between different combustibles and simply provide a percentage of LFL of the combined gas, the accuracy of which is dependent upon the gas which the unit was calibrated against. They respond to a wide range of ignitable gases and are ideal for determining a baseline measurement of flammable compounds on a continuous basis.As a general rule, the larger the molecule the slower the response time. Some of these gas sensors also have difficulty in adequately detecting heavy long chain molecules or the vapours from high flashpoint liquids such as turpentines, diesel fuel or jet fuel.

In order to ensure full coverage of potential compounds, a pellistor type detector can be used in combination with a photoionization detector (PID). There are detectors available that have both pellistors and PID sensors together, enabling monitoring for the presence of a wider range of vapours than possible with either one in isolation.

Pellistor-type instruments can be ‘poisoned’ by hydrogen sulphide or many other common chemical vapours, with high concentrations of a gas or particularly corrosive gases both presenting risk factors in this process. For some chemical vapours, this ‘poisoning’ can occur even at low concentrations. As such, they need to be calibrated on a regular basis.

IR absorption

Type of monitoring: Continuous, logged

Results: Online, with response time noted

Response time: Dependent on the unit but generally 10 to 20 s

Ideal for: Determining percentage of LFL for a range of hydrocarbons. More selective than pellistors in gas detection and require less calibration

Main challenges: Poor/no detection of some flammables

Infrared (IR) detectors work on the principle of differing absorption of infrared radiation at specific wavelengths as it passes through a volume of gas, picked up by detectors. Two cells, a reference cell and a sample cell, are used. If a gas intervenes between the source and the detector, the absorption is detected and both the type of gas and its concentration can be identified.

Infrared gas detection is based upon the ability of the gases being detected to absorb IR radiation, with many hydrocarbons absorbing IR at a wavelength of approximately 3.4 microns.

Benefits of IR sensors include:

- Lower power consumption than catalytic sensors
- Ability to operate in oxygen deficient atmospheres
- Greater resistance to damage by exposure to silicones or other poisons which may affect catalytic sensors

IR detectors are excellent for the detection of common combustible gases such as methane and propane. As it is the chemical bonds in the molecules being measured that actually absorb the infrared light, larger molecules generally absorb more infrared. IR sensors are therefore generally more sensitive to larger combustible gas molecules like hexane, octane and nonane.

Unfortunately IR sensors cannot measure a gas unless the bonds in the molecules absorb IR at the measurement wavelengths. It should be noted that there are some hydrocarbons and other flammable substances (such as aromatics, acetylene, hydrogen and ammonia amongst others) that respond poorly or not at all to a general-purpose IR sensor. Depending on the manufacturer, they may or may not be able to detect benzene or other “unsaturated” VOC vapors such as those identified with one or more benzene rings or with chemical behavior similar to benzene. This can cause an issue in identifying specific contaminants when the potential contaminant is unknown. It is therefore important to verify that the IR LFL sensor is able to detect the gas(es) of interest before use.

PID/FID

Type of monitoring: Continuous, logged

Results: Online

Response time: Dependent on the unit but generally a few seconds

Ideal for: Determining the presence of a wide range of low concentration VOCs such as the case in wastewater networks, shown as ppm by volume

Main challenges: PID does not detect methane. FID requires hydrogen cylinder. High concentrations of contaminants (5,000 to 10,000ppm) will rapidly render a PID unit inoperative, usually requiring expensive repair

Continuous VOC logging can be conducted using a photoionisation detector (PID) or Flame ionisation detector (FID), the difference being that FIDs include methane detection whereas PIDs do not.

These units are generally handheld which include a moisture trap, a pump and some tubing to direct the sample to the detector. They generally sit outside the asset with a sample tube extending into the asset. They tend to have an in-built battery life of 8–- 20 hours (depending on type) and the moisture trap needs changing every 1 – 2 days. When more than 8 hours of sampling is needed, these units are often plugged into mains power or can be installed with separate large batteries (for example 1 weeks’ worth of sampling requiring 3 car batteries in parallel to provide enough charge). PID units can be poisoned by large spike concentrations, whereas FID units are not susceptible to such damage.

PID units themselves are available from a number of suppliers and can be readily hired for short durations.

The PID sensors will be able to give an approximation of total VOCs (without methane). They will give a level in ppb or ppm, based on an assumption that all VOCs present are a reference substance to which the unit is calibrated, normally isobutylene. This type of analysis allows the user to identify a relative level of VOCs present, as well as a diurnal profile, but not what compounds constitute the VOCs. PIDs detect gases that ionise at the machine lamp voltage, with 10.6 eV being the most common lamp. As each VOC has different LFLs, high concentrations as indicated by a PID or FID may need further quantification using Gas Chromatography Mass Spectrometry (GC-MS, see below).

Where there is an unknown source of VOCs in the asset, PID/FID monitoring at one location can identify a diurnal profile. Subsequent monitoring at various upstream branches of the sewer can help narrow down which branch is carrying the VOC laden waste and help isolate a potential discharger.

Suitable Lab based technologies (GC-MS)

Type of monitoring: Spot sample only

Results: 24 to 48 hrs depending on the laboratory used and the distance the sample must travel to that laboratory

Response time: N/A – lab-based equipment

Ideal for: Determining all of the compounds present so that all flammables are identified at the point in time the sample was taken, to allow risk to be determined or intervention to take place. Generally used in conjunction with pellistor or PID unit, with spot samples taken when high VOC load is detected

Main challenges: Expensive with costs of approximately $800 per sample (inclusive of sampling and analysis) in a major metro area with a lab in the same city. Lab based analysis is time consuming. Results only provide a snapshot of when the sample was taken and therefore may miss target discharges or peaks unless multiple samples are taken or the sample is targeted at a previously determined peak time, for example by use of online PID monitoring.

Previously discussed technologies that provide continuous monitoring are generally unable to specify the compounds present, with some IR exceptions, where compound recognition is limited.

Gas Chromatography (GC) – Mass Spectrometry (MS) can provide both concentration and detailed breakdown of contaminants. The units are large, generally lab based and require significant training to operate and maintain. They cannot provide continuous monitoring within normal economic restrictions, but instead rely upon a gas sample to be taken, transported to the lab, then analysed. The GC determines the concentration of the compound then the MS determines the compound species through comparing its mass spectra with a computer library. Gas samples can be analysed for a certain set of analytes (such as through the USEPA TO-15 process[34]) or library matched for all known substances in a set larger library, which is more commonly conducted by universities. Testing for specific sets of analytes rather than library matching generally leads to misreporting, as gases in sewer headspaces can have differing components depending upon the catchment. Library matching is therefore considered best practice unless the specific components present are known.

[34] The USEPA TO-15 (and more recently, TO-15a) method nominates 97 chemicals that can be analysed through this process. These 97 chemicals are from the list of 187 chemicals listed in the US Clean Air Act, which also includes non-flammable substances. Many labs will only offer analysis of a sub-set of the 97 chemicals listed in the USEPA TO-15 method due to the costs involved in calibrating the instruments for such a large number of substances.

Appendix D: Suitability of natural ventilation for control of flammable atmospheres in the sewerage system

Natural ventilation is commonly used throughout sewerage networks around the country to equalise pressure fluctuations associated with movement of liquid and air. As liquid levels inside the system rise, air is driven out of the system by the displacement effect of the water. If discharge points such as a vent shaft are not provided, the entrapped air can form pockets which inhibit flow. As the liquid levels fall, air will be drawn into the system to make up the lost volume of liquid and create an equilibrium with the pressure outside the network. This is generally done through induct points such as cowls, valves or an open lid.

In a sewer network context, high wind speeds are usually only applicable to vent shafts, air inlets and open top pumping stations. All other assets are generally buried below ground, such as dry wells, access pits, wet wells, air valve pits, maintenance holes, etc. This means that the wind cannot be relied upon and the asset cannot be considered to have good ventilation with natural ventilation as its only source of air movement.

Although natural ventilation is sufficient to allow the functioning of the sewerage network as a hydraulic system, this approach cannot be relied upon for the removal of the contaminants from the air space in the system for the following reasons:

- It is heavily climate dependent, relying on temperature differences, pressure differences and wind speeds (called micro-climatic conditions). This makes ventilation difficult to predict and therefore unable to be relied upon
- Open lids, which have better access to wind to drive the stack effect, are now less common in general industry practice due to current and future odour considerations
- It is highly susceptible to blockages and fouling, as the very low-pressure drops associated with natural air movement are more easily impeded than the induced negative pressure of a forced ventilation system. This applies both to the intake pathway such as the air inlet point as well as the air discharge point

To demonstrate this, an example pumping station is used. Its features are presented in the table below:

Parameter	Value	Symbol
Diameter (m)	3	D
Depth (m)	7	h
Minimum liquid depth (m)	2	h_{hs}
Air volume @ min. liquid depth (m^3)	35.3	V_{hs}
Surface area of liquid (m^2)	7.1	A_s

Common industry practice for the natural ventilation of pumping stations and other network assets is via the use of a vent shaft. Air flow through a vent shaft is based on the differences in temperature between air inside the asset and air outside the asset, with warmer and less dense air rising to the top of the shaft; this is temperature induced buoyancy flow. A simple equation to model this effect is as follows:

$$Q = C_d A_{sq} \sqrt{2gh \frac{(T_i - T_o)}{T_i}} \; (L/s)$$

The table below provides describes and assigns a value to of each of the parameters in the equation.

Parameter	Symbol	Value
Discharge coefficient	C_d	0.65
Shaft area	A_{sq}	For a DN150 and a DN300 shaft
Gravitational acceleration	g	9.8 m/s^2
Vent shaft height	h	9 m
Internal temperature	T_i	30°C
External temperature	T_o	Variable

To obtain the specific air changes per hour for the reference case, the flow in L/s is converted to m^3/h and divided by the volume of the head space:

$$ACPH = \frac{Q \times 3.6}{V_{hs}}$$

The discharge co-efficient, stack height and stack sizes are typical of common wastewater industry practice. The temperature difference is the difference between the internal wet well temperature. For the purposes of example, the internal wet well temperature is fixed at 30 degrees. This was selected based on common for temperatures inside the sewerage system to be between 25 – 30 degrees.

The data is plotted, showing air flow and air changes per hours for each of the stack sizes, in Figure D-1 below.

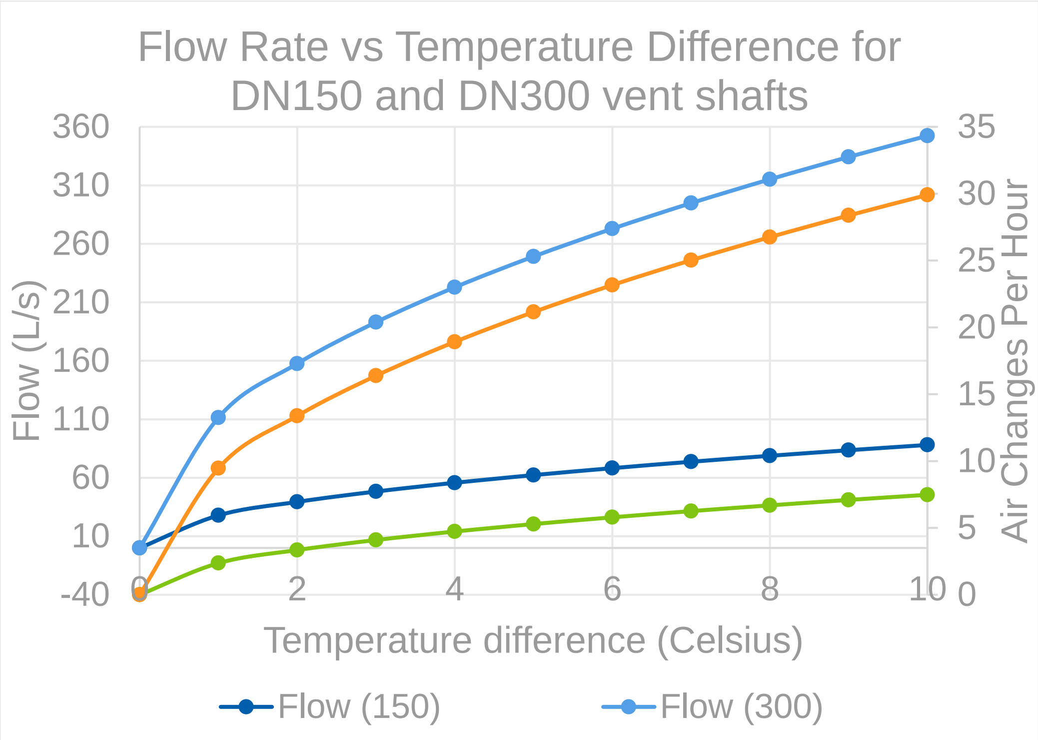

Figure D-1: Two different vents shaft sizes and the effect on ventilation. As the temperature difference increases, the airflow and therefore the ACPH increase. Big temperature differences can have substantial air flows

At high temperature differences, the larger diameter shaft provides very high air flow and ACPH. In fact, for this sample asset the larger shaft may provide sufficient ventilation to control the formation of an explosive atmosphere even with substantial concentrations of flammable material. However the effect of wind on the ventilation rate has not been considered; this may assist or impede ventilation based on its direction and magnitude. Also not considered is the effect of increasingly warmer temperatures; when the external temperature is greater than or equal to the internal wet well temperature, ventilation will be substantially reduced. As per Clause C 3.7.2 of AS/NZS 60079.10.1, when discussing the availability of natural ventilation:

> "*In the case of natural ventilation, the worst case scenario shall be considered to determine the ventilation rate*"

Additionally:

> "*In the case of natural ventilation of enclosed spaces, consideration of unfavourable conditions needs to be accounted for, i.e. frequency and probability of occurrence of such situations.*"

These worst case situations affect vent shafts nationally and should be carefully assessed when assessing the dilution and the availability of natural ventilation. This impediment is especially pronounced in the northern regions of Australia as far north Queensland. In these locations, the relative humidity and temperature differences between the sewerage network internals and the ambient conditions are such that vent shafts do not operate as intended for many days of the year.

This guideline considers that natural ventilation has poor availability, and in some cases a less than poor availability and cannot be relied upon to control a flammable atmosphere. The degree of dilution can be medium, based on micro-climatic conditions, but as a baseline which can be depended upon during normal operation it is generally considered a low dilution. A poorly available, low dilution system has no effect on the zoning of any hazardous area, according to Table D.1 of AS/NZS 60079.10.1: 2022, and in fact can increase the zonal classification.

In the rare case that a water agency should be interested in using passive ventilation for control of flammable atmospheres in a linear asset, there are various tools available to calculate air flow within these systems. One such tool is the ARC Ventilation tool, developed as part of the Sewer Corrosion Odour Research program (called SCORe).[35] These tools can supplement simple calculations of the nature shown in this Appendix. This is not recommended by this guideline.

[35] https://water360.com.au/wp-content/uploads/2022/02/ARC_Ventilation_Tool_User_Manual_-_Final_Mon16Aug2011-1.pdf

Appendix E: Importance of negative pressure in the contained environment

Provided that a sufficient negative pressure differential can be maintained between the covers and the external environment, effectiveness of capture due to ventilation is ensured. Many water agencies will specify an overarching differential pressure between 15 to 25 Pa to ensure less than 1% leakage.

The negative pressure required to reduce leakage is a function of cover size, type and wind loading. The magnitude of the negative pressure which can be sustained under covers is a function of:

- Negative pressure provided by the system fan at the extraction point
- Number of extraction points and dispersal over the cover
- Type of cover, number of cover joints, penetrations and cover flexibility which define the leakage rate
- Air inlet configuration, for example provision of weighted air inlet dampers or grills
- Degree of interconnection of process areas under the covers allowing inter-process distribution of air

If a design negative pressure of -150 Pa produced by the ventilation system is assumed at the extraction point then the negative pressure sustained is dependent upon the free area available for air ingress from the atmosphere or other process area, and the gas flow rate through that space. As the free area is decreased the gas velocity and therefore pressure drop is increased, leading to a higher negative pressure sustained under the covers.

Figure E-1 below shows the approximate relationship between maximum negative pressure that can be achieved under covers versus air exchange rate, derived from standard head loss equations. A hypothetical 10 m by 5 m rectangular covered structure with a 2 m headspace is considered, with one number 100 mm diameter air inlet. The covers are comprised of 10 No 1 m by 5 m panels. Achievable negative pressure is shown with varying gaps between the cover sections.

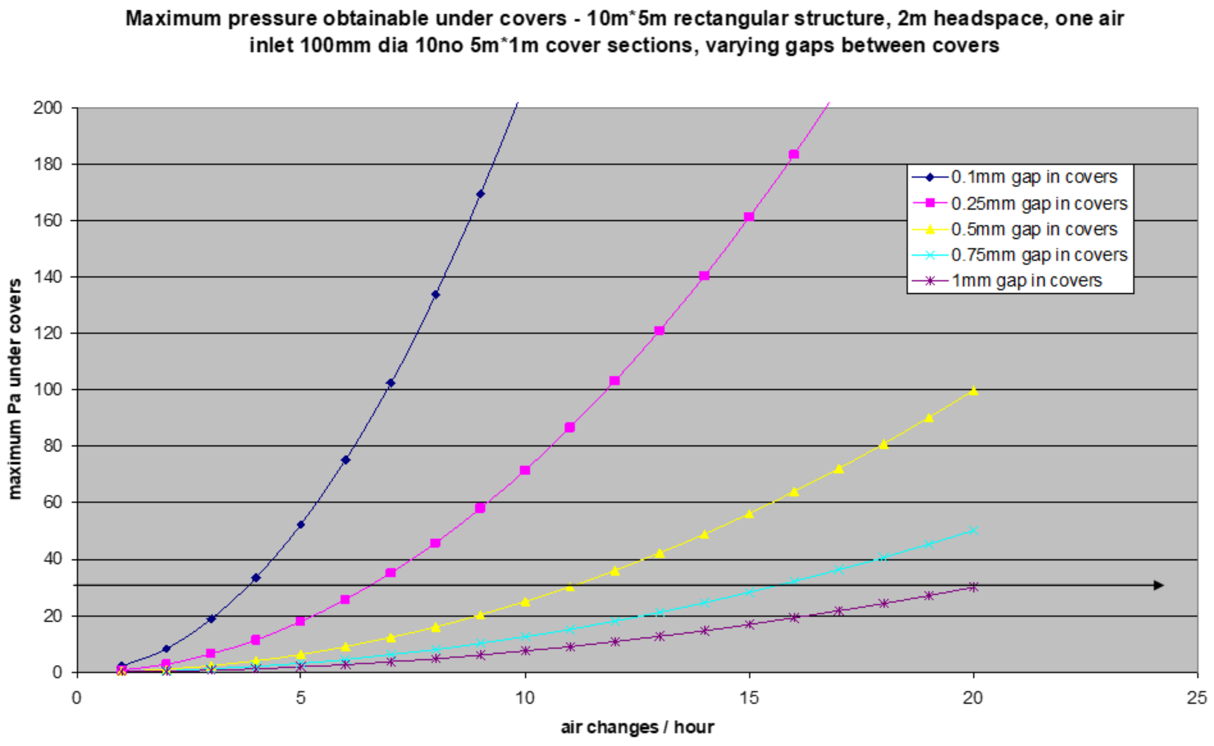

Figure E-2: Example of Achievable Negative Pressure for Varying Air Exchange Rates. As the gap between the covers increases, the amount of air changes per hour required to achieve the target negative pressure increases.

The achievable negative pressure is dependent upon both the ventilation rate and the gaps between the cover sections, with a high sensitivity to the gaps between the cover sections and the number of penetrations within the cover. The higher the free area between the atmosphere and the tank air space volume, the higher the extraction required.

Historically, to reduce the air infiltration to a level which enables a realistic extraction rate to be used (whilst still achieving > -25 Pa static pressure under the cover), the following is required:

- Foam or rubber gasket seals are required between covers and concrete tank walls, and the seal held under compression by suitable fixings
- Penetration of any service must be carefully considered and be installed with effective collar seals
- Covers not requiring removal should be gas-sealed with a flexible sealant (example given in Figure E-2 below)
- Weighted air inlet dampers to maintain a constant negative pressure differential under the covers during varying flow conditions should be employed

Figure E-3: FRP Cover Sections Sealed with flexible, air tight sealant. This image is taken from a wastewater treatment plant odour cover and shows a flexible sealant (e.g an appropriately UV stable and corrosion resistant SikaTank) sealing the join between two odour covers

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