Appendix 17.1

HAZID&RA Report

Appendix 17.1 HAZID&RA Report

Hazard Identification and Risk Assessment at Duleek

***Prepared for*:**

Indaver Ireland Ltd

Ref: 462-20X0066. Rev.1

23rd April 2020

Byrne Ó Cléirigh, 30a Westland Square, Pearse Street, Dublin 2, D02 PN76, Ireland.
Telephone: + 353 – 1 – **6770733**. Facsimile: + 353 – 1 – **6770729**. Email: **Admin@boc.ie**. Web: **www.boc.ie**

DISCLAIMER

This report has been prepared by Byrne Ó Cléirigh Limited with all reasonable skill, care and diligence within the terms of the Contract with the Client, incorporating our Terms and Conditions and taking account of the resources devoted to it by agreement with the Client.

We disclaim any responsibility to the Client and others in respect of any matters outside the scope of the above.

This report is confidential to the Client and we accept no responsibility of whatsoever nature to third parties to whom this report, or any part thereof, is made known. Any such party relies upon the report at their own risk.

Contents

1 INTRODUCTION

1.1 Background

At the request of Indaver Ireland Ltd, Byrne Ó Cléirigh (BÓC) has conducted a Hazard Identification and Risk Assessment (HAZID&RA) exercise for the waste-to-energy centre at Duleek. The Waste-to-Energy site was constructed in 2011 and is designed to recovery energy from the residual fraction of non-hazardous household, commercial and industrial waste.

The HAZID&RA described in this report examines the potential for major accident hazards associated with the existing plant and for the proposed development at the site, with the installation of a an aqueous waste solvent tank farm and a hydrogen generation unit.

1.2 Description of Site

The Duleek Waste-to-Energy site was constructed in 2011. It is situated on the R152 Drogheda to Duleek road and is located in the townland of Carranstown, approximately 3 km north east of Duleek, Co. Meath. The facility consists of a 70 MW WtE plant for the acceptance of up to 235,000 tonnes per annum of household, commercial and industrial waste.

The facility comprises the following main elements:

- the main process building (comprising of tipping hall, waste bunker, furnace boiler, steam turbine, flue gas treatment and ash storage)
- a solidification plant
- an air cooled condenser building
- a maintenance workshop
- a transformer compound and ESB substation with emergency generator
- a security building with weighbridge at facility entrance
- a water storage tank and pump house
- a surface water attenuation pond fire water retention tank

Waste is transported to the site daily by waste contractors. On entering the site, waste contractors follow a two-way route to the tipping hall where inspections on the waste are conducted by Indaver on a routine basis. In the tipping hall, waste is then deposited into the waste bunker where it is mixed by the grab before being placed in the hopper that feeds the furnace. In the furnace, the waste is incinerated at temperatures in excess of 850^{o}C. The ash collected from the bottom of the furnace passes through a wet bath before being stored for collection and removal from the site. The combustion gases from the incineration process pass through a series of treatment stages. These include two stages of dosing (lime milk and lime) for acid removal and two stages of dosing (expanded clay and activated carbon) for dioxin removal, before passing through filter bags and being discharged to atmosphere via the stack.

A site layout drawing is included in Appendix 1.

Figure 1-1: Site and Surroundings

1.3 Description of Surroundings

1.3.1 Neighbouring Land Use

The site is located at Carranstown, Duleek. The other developments in the vicinity of the site are described here.

There are several small scale industrial / commercial developments to the south of the site. The closest of these are Paul Kavanagh VTN, which is at a distance of c.235 m from the Flue Gas Treatment plant and DSG Stores, at a distance of c.270 m from the Tipping Hall.

The nearest residence is located to the south of the site, at a distance of c.165 m from the site boundary and 315 m from the closest installation at the site (the Tipping Hall). The site is located at a distance of approximately 3 km from Duleek.

There are no Seveso establishments in the vicinity of the site. The closest large scale industrial development in the vicinity is Irish Cement, to the north of the site. The distance between the site boundaries for the two sites is c.260 m at the closest point.

1.3.2 Geology and Hydrogeology

Referring to the Geological Survey of Ireland (GSI) website[1], we have obtained details of the geology and hydrogeology of the site and surrounding area.

The bedrock under the site is identified on the GSI website as “Crinoidal peloidal grainstone-packstone” and is part of the Platin Formation (CDPLTN). The rock type is limestone and the website states that “the dominant lithology is crinoidal and peloidal grainstone, locally conglomeratic. Cherty and micritic units are also present. It is generally coarser, paler and less well-sorted than the underlying Crufty Formation. Local dolomitisation is common.”

The aquifer beneath the site is identified as Rkd “Regionally Important Aquifer - Karstified (diffuse).” The vulnerability of this aquifer is identified as M: Moderate.

[1] http://www.gsi.ie/

Figure 1-2: Details of bedrock in vicinity of the Indaver site (© Geological Survey of Ireland)

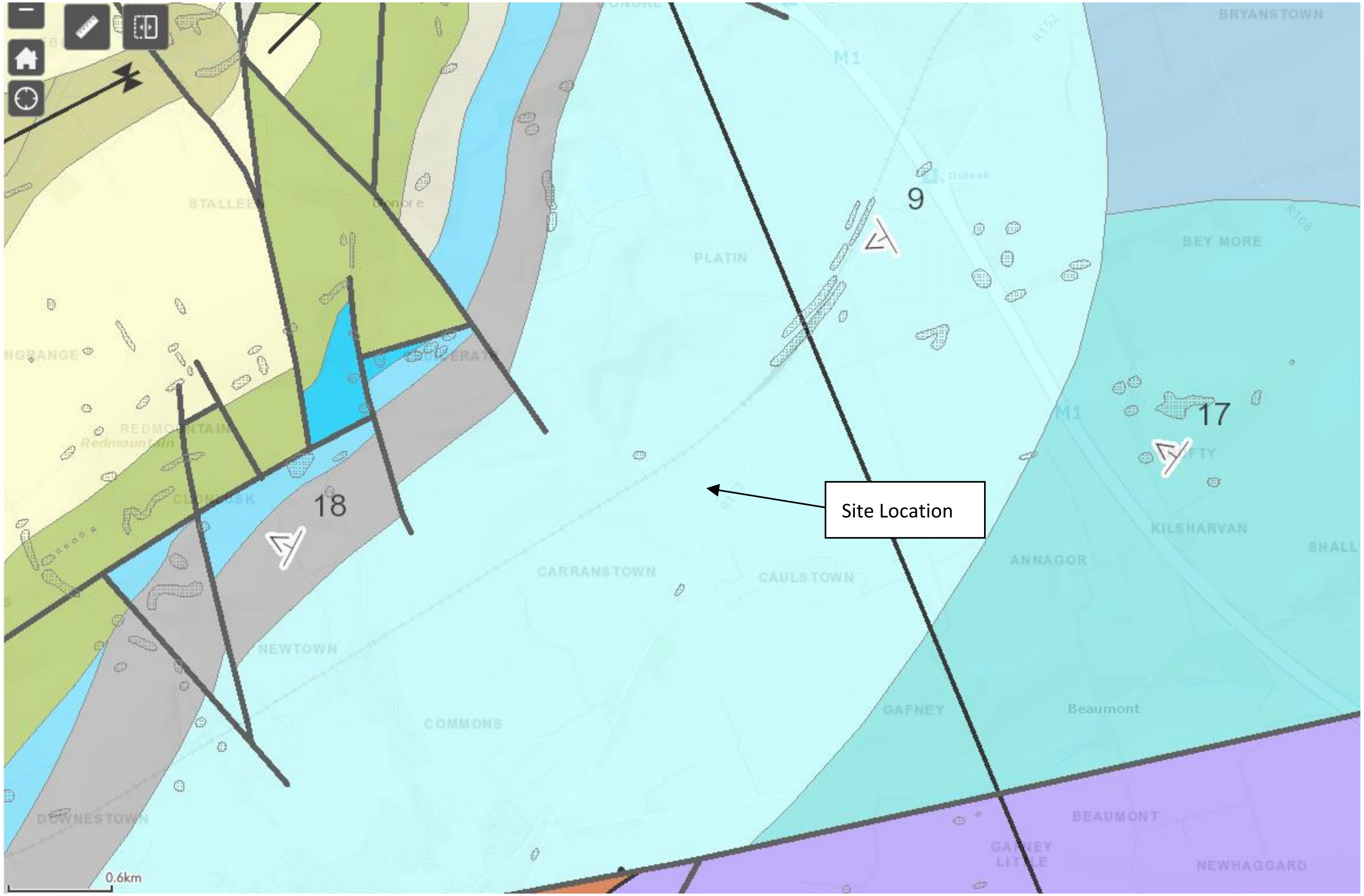


Figure 1-3: Details of Aquifer Classification in Vicinity of the Indaver Site (© Geological Survey of Ireland)

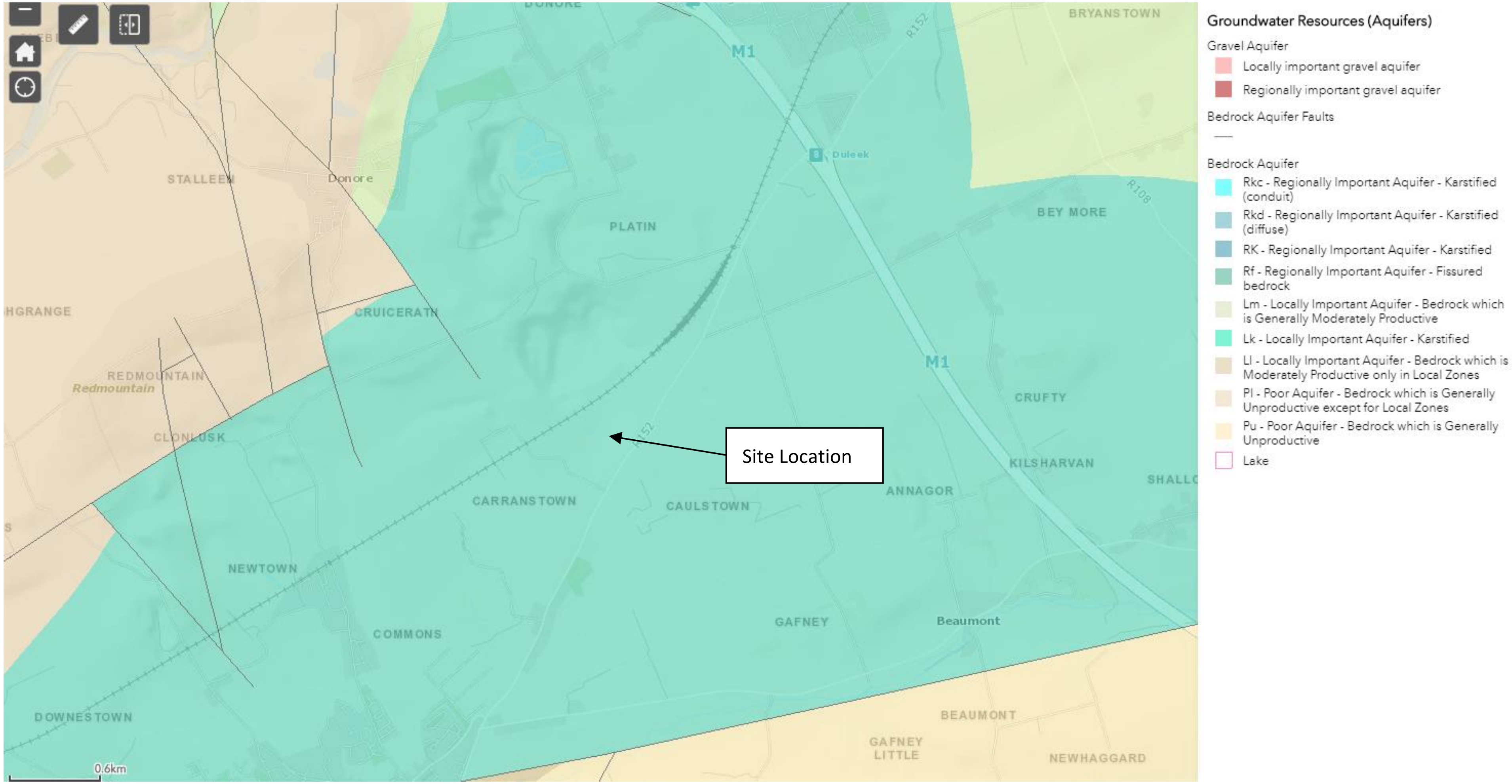
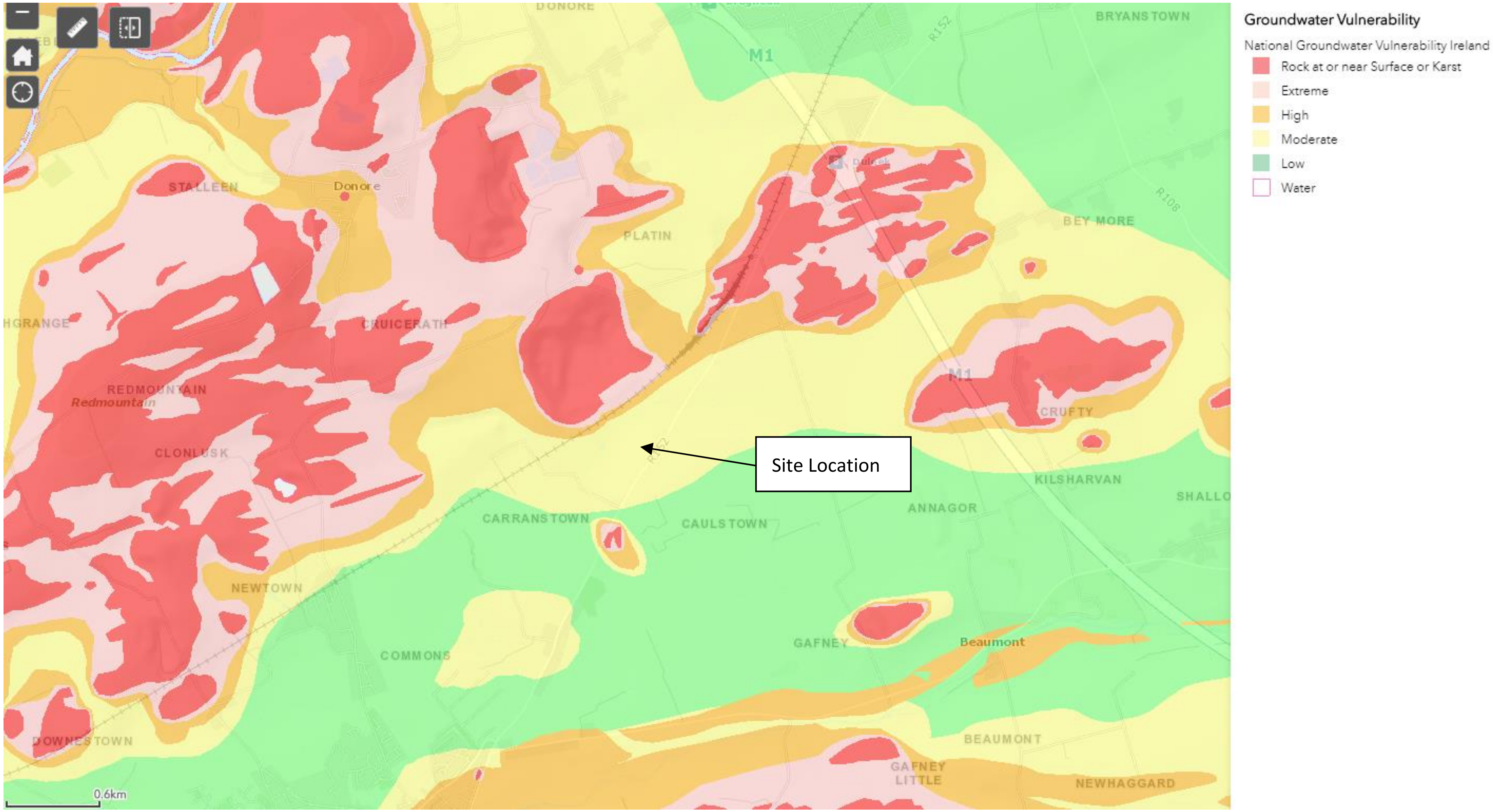


Figure 1-4: Details of Aquifer Vulnerability in Vicinity of the Indaver Site (© Geological Survey of Ireland)



1.3.3 Flora and Fauna

There are no environmental designations pertaining to the site footprint; in other words, the site does not form part of any Natural Heritage Area (NHA), Special Protection Area (SPA), Special Area of Conservation (SAC) or candidate Special Area of Conservation (cSAC), Nature Reserve, or National Park.

Referring to the NPWS map viewer, the closest such protected site to the Indaver facility is the River Boyne and River Blackwater (SAC 002299 and SPA 004232), which is over three kilometers distance away. There are no accident scenarios identified in which a loss of containment at the Indaver site would reach the SAC / SPA. Figure 1-5 is taken from the NPWS viewer. The River Boyne and River Blackwater (SAC 002299 and SPA 004232) is shown to the north west of the map.

Figure 1-5: Protected sites (source NPWS)

1.3.4 Weather Conditions

For the purposes of the risk assessment exercise detailed in this report, the meteorological parameters of most interest are ambient temperature, wind speed, atmospheric stability and rainfall. High ambient temperatures lead to increased evaporation rates from spilled materials. Low wind speeds and high atmospheric stability lead to reduced dispersion of a release, allowing higher concentrations to accumulate in the atmosphere. High wind speeds on the other hand can give rise to high angles of flame tilt in the event of a pool fire.

Dublin Airport is the closest weather monitoring station to the site and weather data for this station was obtained from Met Éireann for the period 1981 to 2010, which is the latest 30-year period reported on by Met Éireann. This is shown in Table 1-1 overleaf.

The temperature data shows that the average daily maximum temperature varies from 8.1°C in January to 19.5°C in July. The highest temperature recorded at the station over the 30-year reporting period was 28.7°C.

Wind speed and atmospheric stability are strongly interrelated. Greater atmospheric stability is found at low wind speeds and only certain combinations of wind speed and stability can occur. The data shows an average wind speed of 10.3 knots or 5.3 m/s.

Table 1-1: Dublin Airport Weather Data, 1981 – 2010 (Met Éireann)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature (degrees Celsius)													
mean daily max	8.1	8.3	10.2	12.1	14.8	17.6	19.5	19.2	17	13.6	10.3	8.3	13.3
mean daily min	2.4	2.3	3.4	4.6	6.9	9.6	11.7	11.5	9.8	7.3	4.5	2.8	6.4
mean temperature	5.3	5.3	6.8	8.3	10.9	13.6	15.6	15.3	13.4	10.5	7.4	5.6	9.8
absolute max.	16.5	16.2	17.2	20.5	23.5	25.7	27.6	28.7	24.6	21	18	16.2	28.7
min. maximum	-3.1	-0.1	2.4	4.5	6.6	10.4	11.7	11.9	11.2	5.3	-1.8	-4.7	-4.7
max. minimum	11.8	11.9	11.9	12.8	13.2	16.2	19	18.2	17.3	15.2	12.8	12.9	19
absolute min.	-9.5	-6.7	-7.9	-4	-1.6	2.1	4.6	2.4	1.2	-3.3	-8.4	-12.2	-12.2
mean num. of days with air frost	6.4	6.5	3.8	2.4	0.3	0	0	0	0	0.5	3	6.4	29.4
mean num. of days with ground frost	15	14	12	10	3	0	0	0	0	4	10	14	82
mean 5 cm soil	3.8	3.8	5.4	8.2	12.2	15.2	16.7	15.8	13.1	9.4	6.2	4.5	9.5
mean 10 cm soil	4.1	4.1	5.5	7.9	11.5	14.6	16.2	15.4	13	9.7	6.6	4.8	9.4
mean 20 cm soil	4.6	4.7	6.1	8.4	11.7	14.8	16.5	16	13.7	10.5	7.3	5.3	10
Relative Humidity (%)													
mean at 0900 UTC	87	86.4	84	79.5	76.9	76.7	78.5	81	83.4	85.5	88.5	88	83
mean at 1500 UTC	80.6	75.7	71	68.3	68	68.3	69	69.3	71.5	75.1	80.3	83.1	73.3
Sunshine (hours)													
mean daily duration	1.9	2.7	3.5	5.3	6.2	5.8	5.3	5.1	4.3	3.3	2.4	1.7	3.9
greatest daily duration	8.1	9.8	11.9	13.3	15.4	15.9	15.6	14.2	12.4	10.2	8.8	7.3	15.9

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
mean num. of days with no sun	9.1	6.2	4.7	2.5	2	1.9	1.4	1.5	2.6	4.8	7.3	10.5	54.6
Rainfall (mm)													
mean monthly total	62.6	48.8	52.7	54.1	59.5	66.7	56.2	73.3	59.5	79	72.9	72.7	758
greatest daily total	27.1	28.1	35.8	30.4	42.1	73.9	39.2	72.2	40.6	53.2	62.8	42.4	73.9
mean num. of days with ≥ 0.2mm	17	15	17	15	15	14	16	16	15	17	17	17	191
mean num. of days with ≥ 1.0mm	12	10	11	10	11	10	10	11	10	11	11	12	129
mean num. of days with ≥ 5.0mm	4	3	3	3	3	3	3	4	4	4	4	4	42
Wind (knots)													
mean monthly speed	12.5	12	11.6	9.9	9.2	8.6	8.7	8.7	9.2	10.4	11	11.3	10.3
max. gust	80	73	66	59	58	53	54	56	59	69	66	76	80
max. mean 10-minute speed	53	49	45	39	39	38	36	37	36	51	43	55	55
mean num. of days with gales	2.3	1.5	1.1	0.1	0.1	0.1	0.1	0.1	0.2	0.5	0.8	1.3	8.2
Weather (mean no. of days with…)													
snow or sleet	4.6	4.2	2.8	1.2	0.2	0	0	0	0	0	0.8	2.9	16.6
snow lying at 0900 UTC	1.6	0.6	0.1	0	0	0	0	0	0	0	0.1	0.9	3.4
Hail	1.2	1.5	2	1.9	1.3	0.1	0.2	0.1	0.1	0.3	0.3	0.7	9.7
Thunder	0.3	0.2	0.3	0.2	0.9	0.8	0.8	0.9	0.3	0.3	0.2	0.2	5.5
Fog	3.3	3.1	3.6	3.6	3.4	2.8	3.3	3.8	4.2	3.2	3.1	4.1	41.5

1.3.5 Listed Buildings and Monuments

Figure 1-6 is a map of the site and surroundings, taken from the Archaeological Survey of Ireland's website[2].

There are four monuments shown in the vicinity, each located to the southeast of the site. Details are shown below. Descriptive text is taken from the Archaeological Survey of Ireland's website:

- ME027-109----: Ringfort - rath

  Located on a fairly level landscape. The cropmark of a circular enclosure (int. diam. c. 45m; ext. diam. c. 52m) defined by a single fosse feature (Wth c. 3-4m) with a wide entrance gap (Wth c. 8m) at ESE is visible on aerial images (Digitalmap 2018). It is just SW of the embanked enclosure (ME027-078----) and was first noted by Tom Condit.

- ME027-078----: Embanked Enclosure.

  Situated on a fairly level landscape. A LiDAR survey, provided courtesy of Steve Davies, shows a large circular enclosure (int. diam. c. 120m; ext. diam. c. 200m) defined by a broad bank feature (Wth c. 30-40). A gradiometry survey within and around the portion of the enclosure in Caulstown during 2018 produced no indication of the bank of the large enclosure, but did identify a probable enclosure (ME027-078001-) inside its perimeter at E and another less certain feature c. 100m to the S (Leigh 2018, 3).

- ME027-078001-: Enclosure

  Situated on a fairly level landscape. A gradiometry survey conducted within and around the portion of embanked enclosure (ME027-078----) in Caulstown identified a small D-shaped enclosure (dims c. 27m N-S; c. 23m E-W) defined by what are probably ditches with the straight edge at W (Leigh 2018, 3).

- ME027-079----: Redundant record

  Situated on a broad low rise. There is no evidence of an enclosure at this location on any known series of aerial photographs.

There are two further monuments to the northwest of the site. These are as follows:

- ME027-058----: Fulacht fia

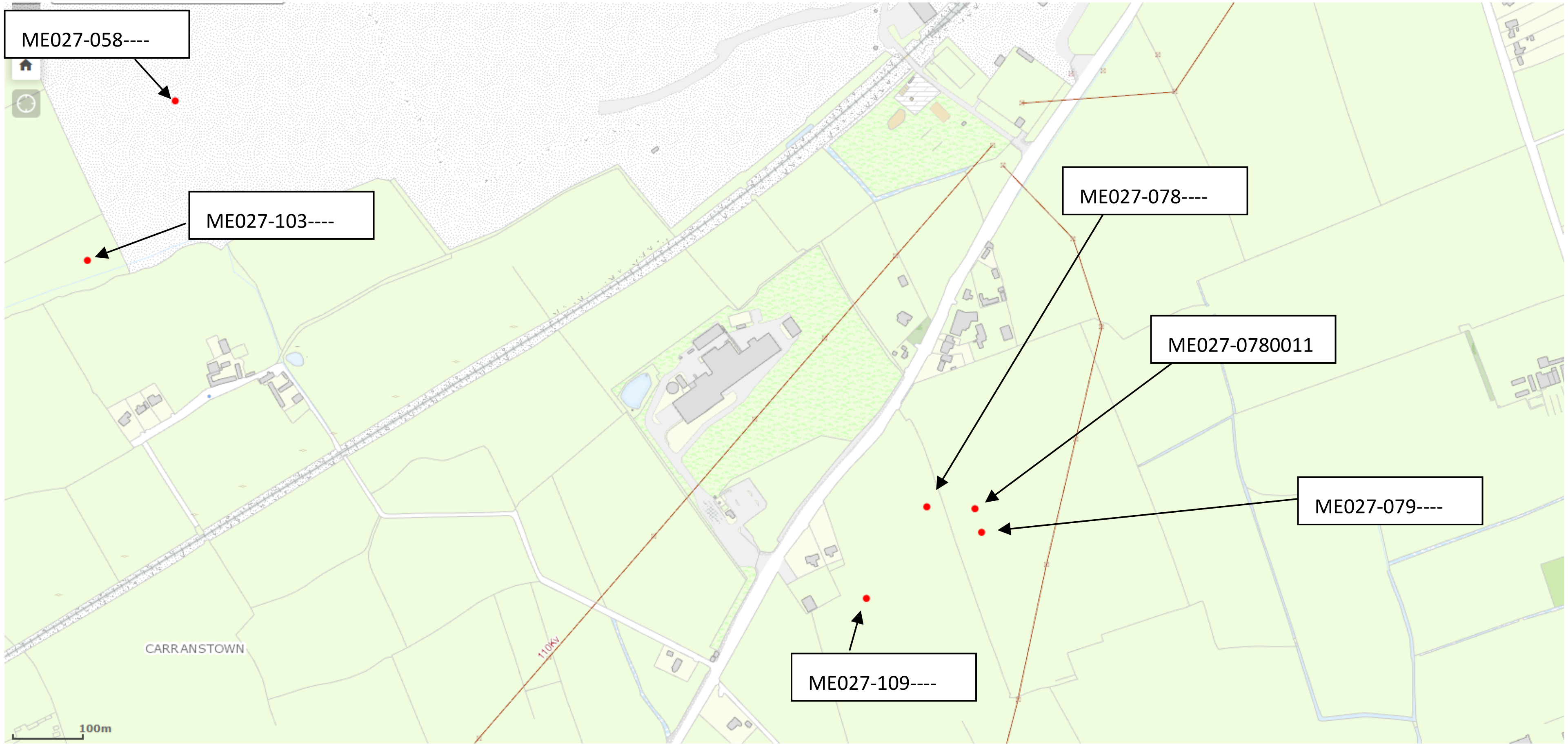
  No details.

- ME027-103----: Fulacht fia

  No details.

[2] https://www.archaeology.ie/

Figure 1-6: Location of National Monuments in Vicinity of Site (© Archaeological Survey of Ireland and Ordnance Survey Ireland)



2 HAZARD IDENTIFICATION AND RISK ASSESSMENT

2.1 Risk Assessment Methodology

A formal Hazard Identification & Risk Assessment exercise (HAZID&RA) was carried out to identify all potential accident scenarios that could arise at each area of the site where dangerous substances are stored or handled. Each scenario was assessed using the HAZID&RA methodology to determine its likelihood of occurrence and the severity of impact to human health and to the environment if it did occur. This approach gives a semi-quantitative assessment of the overall level of risk associated with each accident scenario identified by the HAZID&RA Team. The Team took account of any relevant prevention or mitigation measures in place when assessing the risks associated with each scenario.

Each scenario was assigned a semi-quantitative Risk Rating, based on the findings of this analysis. The Risk Ratings were then compared with the various criteria established in the risk assessment methodology in order to determine the significance of the risks associated with each scenario. This approach allowed Indaver to prioritise attention on the scenarios presenting the highest risk and to ensure that all necessary measures would be in place to prevent accidents occurring and to limit the consequences of any such accidents for human health and the environment.

The methodology used is based on a technique outlined in Annex D of BS 8800: 1996, Guide to Occupational Health and Safety Management Systems. Similar risk assessment techniques have also been outlined by the IChemE[3] and the US Naval Weapons Centre's Practical Risk Analysis for Safety Management. It is described in more detail in the following sub-sections. A flowchart to illustrate this methodology is included in Appendix 2.

2.1.1 HAZID&RA Team

The HAZID&RA Team comprised the following personnel:

- Conor Jones, Regional Engineering Director, Indaver
- Paul Schutze, Project Engineer, Indaver
- Tom Leonard, Partner, Byrne Ó Cléirigh

The Team members between them have appropriate training in hazard identification, risk assessment and consequence analysis and had knowledge of the complete range of operations that will be conducted on the site. They also drew upon specialist input from other members at Indaver and at BÓC where required.

2.1.2 Areas Assessed

The Duleek site was divided into the following areas, each of which was assessed in turn by the HAZID&RA Team.

- Bunker and Tipping Hall
- Furnace

[3] Institute of Chemical Engineers Course, Practical Quantitative Hazard Assessment, 1985

- Boiler
- Spray Dryer
- Raw Material Bulk Storage (expanded clay, activated carbon, quick lime and hydrated lime)
- Bag House
- Flue Gas Residue and Boiler Ash Storage and Treatment
- Chemstore Units
- ID Fan
- Stack
- Piperacks
- Bulk Liquid Storage Areas
- Nitric Acid Storage
- Warehouse / Workshop
- Air Cooled Condenser
- Roads (onsite)
- Bottom Ash Storage Building
- Hydrogen Generation Unit
- Turbine

These areas represent the various locations at the site where dangerous substances are stored or handled and which were considered as potentially presenting a risk of a significant accident scenario. Following the assessment of the HAZID&RA Team, not all of these areas were found to present a credible risk of an accident scenario. Further details of the assessment can be obtained from the HAZID&RA Worksheets in Appendix 3.

2.1.3 Accident Scenarios

Each area was assessed in detail by the HAZID&RA Team. For each area the Team identified the various accident scenarios, or end events, that could arise and noted them in the HAZID&RA Worksheets. This process involved cataloguing all the potential scenarios that could occur for each area; each scenario was described and an assessment made of the potential consequences that could result. A copy of the Worksheet is included in Appendix 3.

2.1.4 Assessment of Severity Ratings

Each scenario was assigned two Severity Ratings with values between 1 and 5, in accordance with the criteria set out in Table 2-1. The first Severity Rating was used to characterise the potential impacts to people, while the second Severity Rating was used to characterise the potential impacts to the environment.

Table 2-1: Severity Ratings for Accident Scenarios

Severity Rating	Category Description	Health & Safety		Environmental Impact
		On-Site	Off-Site	
0	Negligible	None	None	None
1	Minor	Minor injury	None	None
2	Appreciable	Multiple injuries with return to work	Discomfort	Discoloration of water or air
3	Severe	Major permanent disability	Some hospitalisation for screening	Minor short term damage to adjacent land or water courses
4	Very Severe	Single fatality	Minor injuries	Significant short term damage or minor long term damage requiring clean up action
5	Catastrophic	Multiple fatalities	Major injuries or fatalities	Major incident with significant loss of species or habitat

When assessing the impacts of accident scenarios to human health, consideration is given to both on-site and off-site impacts to determine the appropriate Severity Rating, based on the descriptors above.

2.1.5 Identification of Initiating Events

Once the various accident scenarios for a particular area have been identified and Severity Ratings assigned to each, the HAZID&RA Team then examined the various initiating events which could potentially give rise to each scenario and the details were set out in the Risk Assessment Register (RAR) sheet. The potential initiating events which were considered included, inter alia, mechanical failure, human error, control equipment failure, as well as external events such as lightning strike or domino effects from an external event. A copy of the RAR worksheets is included in Appendix 3.

2.1.6 Assessment of Frequency Ratings

Each scenario (based on the combination of End Event and Initiating Event) was assigned a Frequency Rating using the HAZID&RA methodology. Table 2-2 shows the criteria used when assigning Frequency Ratings for each scenario.

Table 2-2: Frequency ratings for accident scenarios

Frequency Rating	Descriptor	Frequency Range per Annum
1	Virtually Impossible	$< 1 \times 10^{-8}$
2	Improbable	1×10^{-8} to 1×10^{-5}
3	Unlikely	1×10^{-5} to 1×10^{-3}
4	Infrequent	1×10^{-3} to 0.1
5	Occasional	0.1 to 10
6	Frequent	> 10

The following sources of information were referred to when assigning Frequency Ratings to the various scenarios:

- Literature review: Published figures of generic data, including those developed by the Dutch Committee for the Prevention of Disasters' Guidelines for Quantitative Risk Assessment (the Purple Book) and industry specific studies. Historical data of this type encompasses all relevant contributory aspects including the reliability of equipment, human factors, operational methods, quality of construction, inspection, maintenance, operation, surrounding environment etc.
- Operational conditions: The HAZID&RA Team explicitly accounted for the planned level of activity at the site and on the site layout (e.g. deliveries per annum of material, lengths of unbunded pipeline sections, etc.). The potential risk of knock-on effects from adjacent establishments or other external factors was also considered.
- Professional judgement: The Team members, between them, had appropriate training in hazard identification, risk assessment and consequence analysis and had knowledge of the complete range of operations on site.

2.1.7 Calculation of Risk Rating

The HAZID&RA Team calculated numerical Risk Ratings for each scenario identified in the course of the exercise using the following equations:

$$R_H = S_H \times L$$
$$R_E = S_E \times L$$

Where: R_H is the overall Risk Rating with respect to health and safety for a scenario

R_E is the overall Risk Rating with respect to the environment for a scenario

S_H is the Severity Rating with respect to health and safety for an end event

S_E is the Severity Rating with respect to the environment for an end event

L is the Likelihood Rating for a specific initiating event – end event combination

The Risk Ratings for each scenario were assessed using a matrix, as set out in Table 2-3.

Table 2-3: Matrix of Risk Ratings

Risk Rating		Severity 1	2	3	4	5
Frequency	1	1 - Trivial	2 - Trivial	3 - Trivial	4 - Trivial	5 - Minor
	2	2 - Trivial	4 - Trivial	6 - Minor	8 - Minor	10 - Moderate
	3	3 - Trivial	6 - Minor	9 - Moderate	12 - Substantial	15 - Priority
	4	4 - Trivial	8 - Minor	12 - Substantial	16 - Priority	20 - Priority
	5	5 - Minor	10 - Moderate	15 - Priority	20 - Priority	25 - Priority
	6	6 - Minor	12 - Substantial	18 - Priority	24 - Priority	30 - Priority

A Risk Reduction Register (RRR) was then completed for each scenario on the back of this assessment. This was used to set out any specific scenarios or locations at the site where the HAZID&RA Team identified or recommended additional risk reduction or mitigation measures. When making these recommendations, consideration was given to the risk level associated with each scenario using the criteria set out above.

The findings of the Hazard Identification & Risk Assessment (HAZID&RA) exercise are discussed in more detail in the following sub-sections and copies of the HAZID&RA Worksheets are included in Appendix 3.

Table 2-4: Significance of Risk Ratings

Risk Rating	Risk Level	Action and Timescale
≤ 4	Trivial	Generally no action is required for scenarios with such low risk levels and if so there would be no need for detailed working to demonstrate ALARP (i.e. are As Low As Reasonably Practicable).
5 to 8	Minor	No additional controls are required in most cases. Consideration may be given to a more cost-effective solution or improvement that imposes no additional cost burden. Monitoring is required to ensure that controls are maintained.
9 to 11	Moderate	Efforts should be made to reduce the risk, but the cost of prevention should be carefully measured and limited. Risk reduction measures should be implemented within a defined time period. Where a moderate risk is associated with a scenario whose consequences are in the category of Very Severe or Catastrophic (Severity Rating 4 or 5) further assessments may be necessary to establish more precisely the likelihood of harm as a basis for determining the need for improved control measures.
12 to 14	Substantial	The activity should not be started until the risk has been reduced. Considerable resources may have to be allocated to reduce the risk. Where the risk involves a current activity, urgent action should be taken.
≥ 15	Priority	The activity should not be started or continued until the risk has been reduced. If it is not possible to reduce risk, even with unlimited resources, this activity must be prohibited.

2.2 Human Factors

The possibility of human error was considered throughout the various areas covered by the risk assessment exercise. For all transfers of materials at the site, there are procedural controls in place to supplement the technical controls that are designed to prevent accidents, including loss of containment of hazardous materials, from occurring.

All deliveries or movements of waste are controlled by ensuring that they are carried out in accordance with documented Standard Operating Procedures and are carried out by trained personnel.

The layout of the site is also designed with the consideration of good separation distances between the locations of occupied buildings and the arrangements where operators must use or handle dangerous substances.

The layout is designed to minimise the risk of uncontrolled sources of ignition from reaching hazardous areas. This includes ATEX zoning of the site, where required, and the use of suitable (Ex-rated) equipment in zoned areas.

Where an operator's activities involve the use or handling of dangerous substances, they are provided with training on the tasks to be carried out as well as with information on the hazards associated with the materials involved. Personnel are also provided with appropriate PPE for the tasks being carried out.

For any instances in which an operator is required to provide direct intervention in the event of abnormal operating conditions and/or a developing accident scenario, they are provided with the necessary training to do so (Emergency Response Team members).

In each case the roles to be taken by personnel are documented. Operators who are required to carry out these response plans receive training to ensure that they are fully aware of the steps to be carried out in response to an accident or incident and also that they are fully aware of the hazards and risks associated with the relevant plant or equipment. They are also provided with appropriate PPE to assist them in carrying out their required tasks.

Indaver also ensures that there are appropriate staffing levels at the site at all times to ensure safe operating and to implement emergency response measures, where necessary. Training is provided to operators, to ensure that they are aware of their duties and have sufficient knowledge of the tasks that they must carry out. They are also provided with awareness training of the hazards associated with the activities carried out on site. In addition to the training that is provided to ensure safe operations at the site, Indaver also provides emergency response training to personnel on the emergency response team (ERT). Indaver conducts monthly drills and exercises for the ERT, including drills and tests at the site covering specific events, together with offsite training on fire prevention and fire response. The training plan and drills are developed for each year and the ERT members are advised of the schedule.

2.3 Criteria for eliminating scenarios from the risk assessment

The HAZID&RA methodology used for this report involves the systematic assessment of all scenarios identified by the HAZID&RA Team, which includes events which are considered to have very low probability of occurrence. Table 2-2 shows that any scenario identified which was found to have a frequency of occurrence of less than 10^{-5} per annum would be assigned a Likelihood Rating of 2. In other words, the methodology allows for extremely remote events to be included in the risk assessment exercise.

It can be seen in Table 2-3 that highly remote events with potentially catastrophic consequences are considered to present a Medium Risk rather than a Low one. This means that these scenarios are examined further, particularly with respect to determining the potential impacts arising from such an event. This means that Indaver would need to consider implementing further risk reduction measures for these scenarios if the HAZIRD&RA Team found it necessary or desirable to do so.

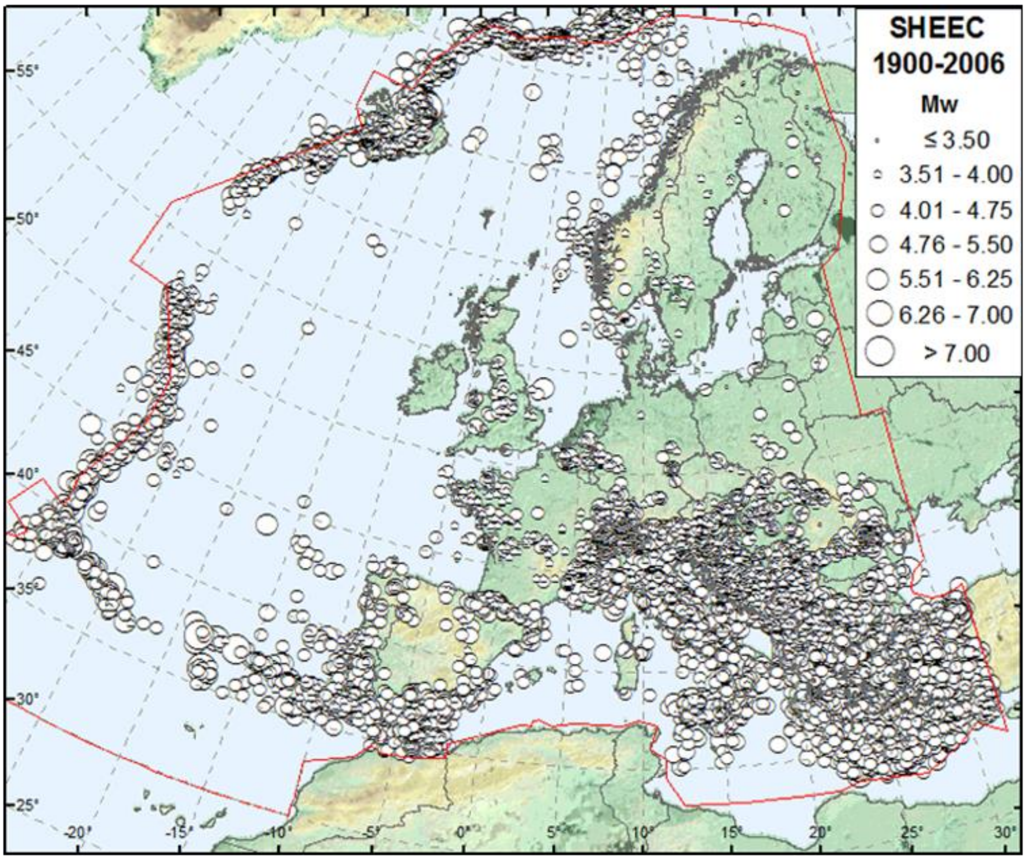
2.4 External Impacts / Off Site Risks

2.4.1 Earthquake

The level of seismic activity in Ireland is very low[4]. The School of Cosmic Physics, which has had a seismic network in operation in Ireland since 1978, has indicated that there is nothing to suggest that this will change in the coming millennia.

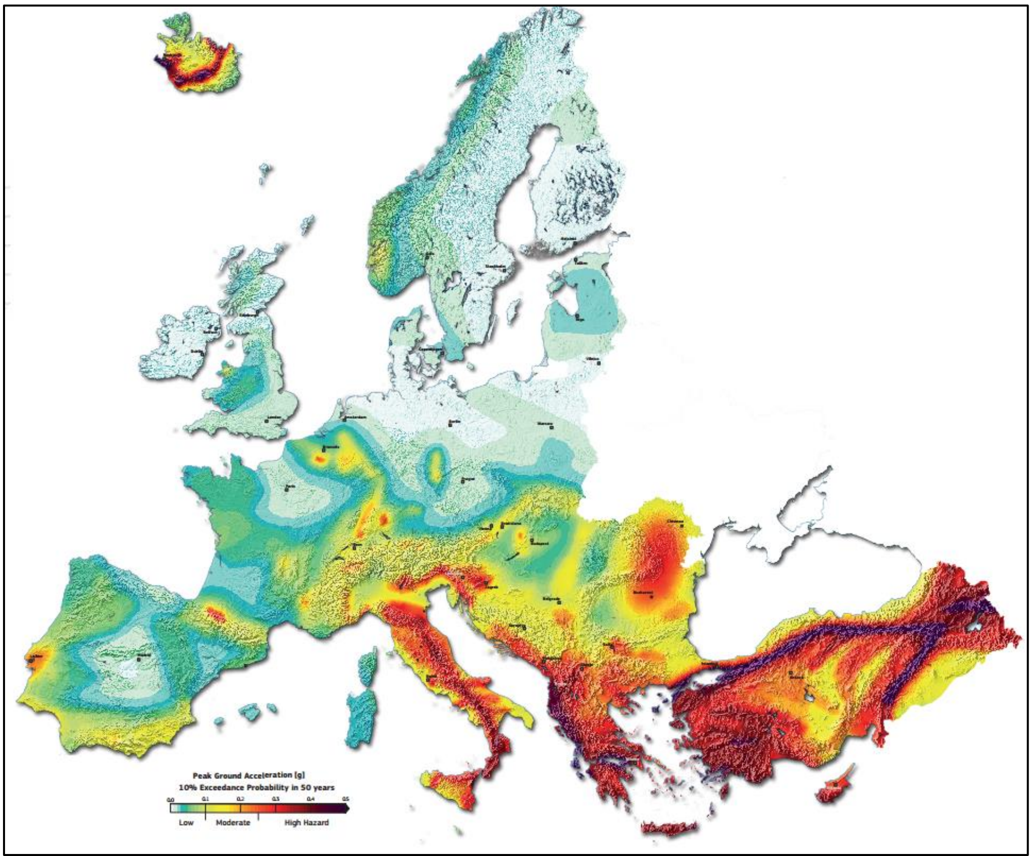
The *Seismic Hazard Harmonization in Europe* (SHARE) project, comprising eighteen European partner institutions, has compiled two European Earthquake Catalogues, one for the period 1000 to 1899, and one for the period 1900 to 2006, which show the locations of seismic events across Europe. The map for the period 1900 to 2006 is shown in Figure 2-1. This shows that there is relatively little seismic activity in Ireland.

Figure 2-1: SHARE European Earthquake Catalogue (1900 to 2006)



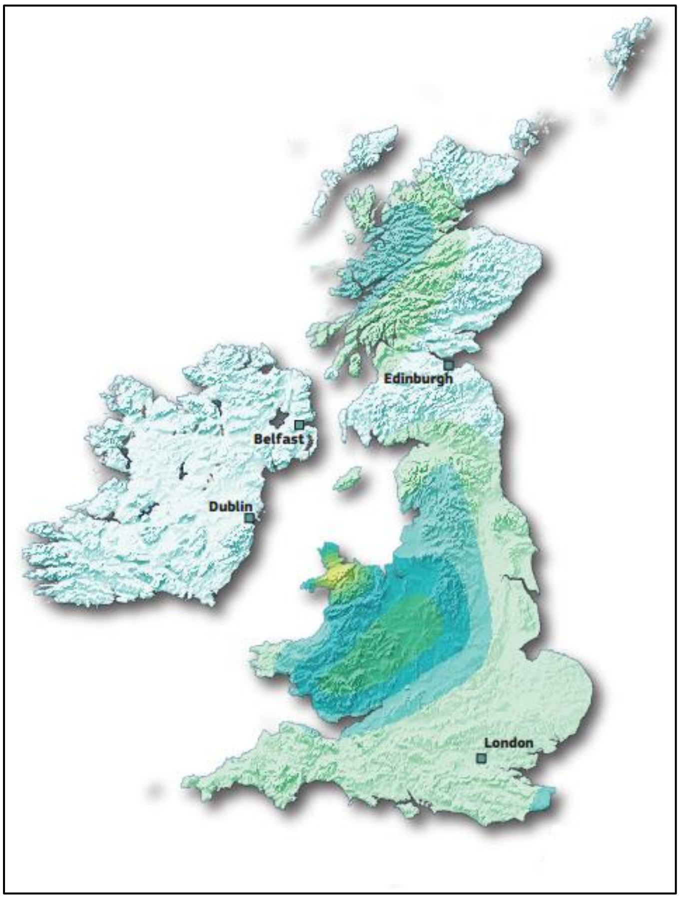
[4] *Seismic Hazard in Ireland*, Jacob, W.B. (1993), Dublin Institute for Advanced Studies, School of Cosmic Physics, Geophysics Section

Figure 2-2: European Seismic Hazard Map



The SHARE project has also developed a European Seismic Hazard Map, shown in Figure 2-2. The map shows the peak horizontal ground acceleration (measured in 'g' – gravitational acceleration) predicted to be reached or exceeded with a 10% probability in 50 years. This corresponds to the average recurrence of such ground motions every 475 years, as prescribed by the national building codes in Europe for standard buildings. Low hazard areas (PGA ≤ 0.1 g) are coloured in blue-green, moderate hazard areas in yellow-orange and high hazard areas (PGA > 0.25 g) in red. As can be seen from Figure 2-3, Ireland is a low hazard area.

Figure 2-3: Seismic Hazard for Ireland



2.4.2 Flooding

Referring to the meteorological data for Dublin Airport in the HAZID&RA report, in the worst case rainfall event, the highest quantity of rainfall that could fall onto a bund area would be 73.9 mm in 24-hours. Any build-up of water in the bunds can therefore be easily managed by Indaver operators by allowing the rainwater to drain via oil-water separators, in accordance with normal operating procedures at the site.

Indaver has conducted a flood risk assessment at the site, examining the following:

- Fluvial Flooding
- Tidal/Coastal Flooding
- Groundwater Flooding
- Pluvial/Urban Drainage Flooding

The flood risk assessment found that the risks associated with each of these mechanisms was minimal, due to the nature and location of the site and the controls that are in place. A copy of the risk assessment was included in the EIAR for the proposed development at the site.

2.4.3 Power Failure

There are no accident scenarios identified at the site which would be associated with a power failure. There will be no materials at the site which are unstable or which require a power supply to ensure that they are stored or handled safely, e.g. materials requiring a temperature controlled environment.

The site has an uninterruptible power supply (UPS) system and emergency diesel generator to provide power in the event of a power cut. This means that Indaver retains the facility to activate the fire protection systems in the event of a disruption to the electrical supply to the site.

If a power failure occurred to a key item of plant or equipment at the same time as potentially hazardous materials were being delivered to the site (e.g. a delivery of aqueous ammonium hydroxide to the storage tank), the transfer would be halted for the duration of the loss of power event.

Based on the controls that will be in place it was considered that there was no credible risk of a major accident scenario associated with a power failure to the site.

2.4.4 Lightning

Referring to guidance from the UK HSE, it advises that the use of BS 62305 is the expected standard for lightning protection at hazardous industries[5]. The HSE states that the likelihood of a major accident being initiated by a lightning strike at a well-designed and maintained hazardous installation is, therefore, low so Inspectors must act proportionately to focus on those major hazard installations where reasonably foreseeable risk remains.

In other guidance, the UK HSE notes that the probability of an accident arising as a result of lightning strike at a typical facility involved in the storage of flammable liquids is extremely remote, with a probability of 1×10^{-7} per annum[6]. This guidance is for activities involved in the storage and handling of materials which would present a greater fire hazard than the materials at the Indaver facility.

All areas of the site which are used for the storage and handling of dangerous substances have been assessed under BS EN/IEC 62305 and, where required, are fitted with lightning protection systems which are designed and installed in accordance with same. The proposed new development will also be fitted with appropriate earthing protection.

Based on the measures that will be in place and on the guidance from the UK HSE, it was considered that the risk that a lightning strike could initiate a major accident was found to be negligible.

2.4.5 Extreme Weather Conditions

The potential for extreme weather conditions was considered during the HAZID exercise. The HAZID Team considered whether such events could act to initiate and/or escalate a major accident hazard event at the site.

---

[5] http://www.hse.gov.uk/foi/internalops/og/og-00044.htm

[6] http://www.hse.gov.uk/comah/sraghfl/highly-flammable-liquids.pdf

Referring to data from Met Éireann, the two closest meteorological stations for which there is climate data available are Dublin Airport. We have referred to the data for this station when assessing the data referred to below.

Extreme Temperature

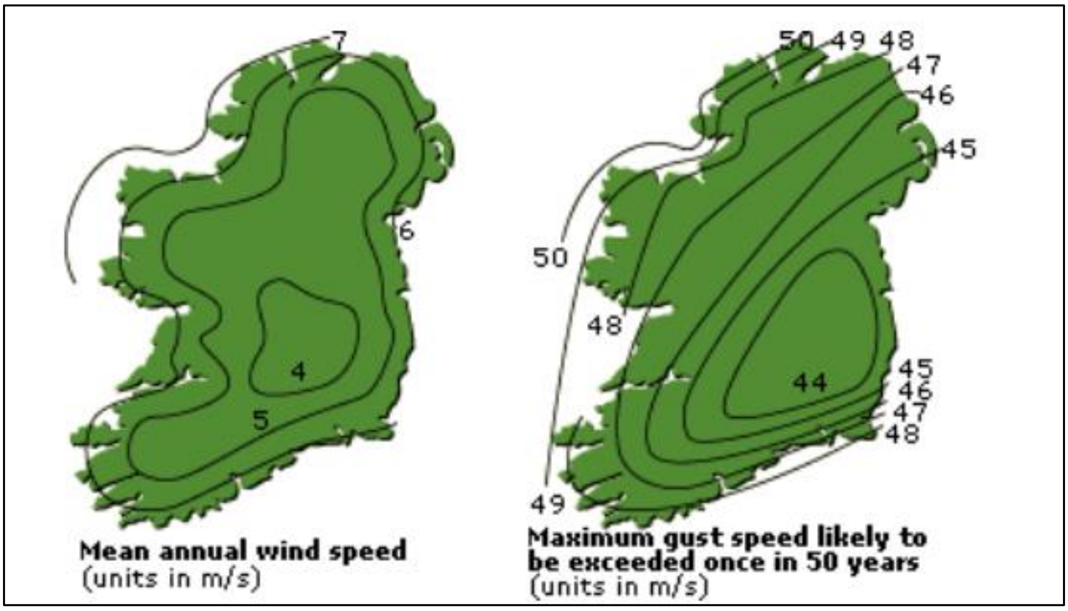
The mean daily maximum temperature recorded at the Dublin Airport weather station over the period from 1981 – 2010 is 13.3°C and the absolute maximum temperature is 28.7°C. There are no scenarios envisioned in which high ambient temperatures could give rise to an accident at the site.

The absolute minimum temperature recorded at Dublin Airport during this period was -12.2°C. Indaver mitigates the risk of accidents on site in freezing conditions by salting the roadways on the site and by imposing a speed limit on movements. The fire-fighting main is protected against water freezing in the line as the main is underground and any chambers for hydrants are insulated and heat traced.

Wind

Met Éireann has produced a map showing the estimated maximum gust speeds for a 50-year return period in Ireland[7]. This is reproduced here as Figure 2-4.

Figure 2-4: Mean and maximum wind speeds (Met Éireann)



Typical maximum gust speeds for Ireland range up to 50 m/s depending on the location of the site. For Duleek, the estimated speed for this return period is c.44 m/s.

The historical data for the Dublin Airport weather station shows the highest 10-minute mean wind speed over the period to be 55 knots (102 km/h), with a maximum gust of 80 knots (148 km/h).

No credible accident scenario resulting from high wind loading was included as an initiating event by the HAZID&RA Team.

[7] https://www.met.ie/climate/what-we-measure/wind

2.4.6 Aircraft impact

The closest airport to the Duleek site is Dublin Airport, which is located at a distance of c.28 km from the site. For this reason, the analysis of the risk of an aircraft impact is based primarily on the risk presented by Dublin Airport.

Environmental Resources Management (ERM) was commissioned in 2005 by the Department of Transport and the Department of the Environment, Heritage and Local Government to undertake a risk investigation to define Public Safety Zones (PSZs) at the three main airports in Ireland, including Dublin Airport. The objective of these PSZs is to protect people on the ground from the risk of aircraft impact by implementing land use planning controls on developments in the vicinity of airports. As part of this study, ERM produced maps showing their proposals for the PSZ around Dublin Airport. The two diagrams shown in Figure 2-5 and Figure 2-6 show the PSZs based on the then current airport configuration and on a proposed configuration incorporating expanded facilities at the airport.

The Duleek site is located comfortably outside of the PSZs for both airport configurations. As such the risk of an aircraft impacting the site is considered to be extremely remote.

Figure 2-5: Proposed Public Safety Zones around Dublin Airport (existing runways) (Source: ERM 2005)

Based on Ordnance Survey Ireland Permit No. 7643. © Ordnance Survey Ireland & Government of Ireland

Figure 2-6: Proposed Public Safety Zones around Dublin Airport including proposed runway 10L/28R (Source: ERM)

Based on Ordnance Survey Ireland Permit No. 7643. © Ordnance Survey Ireland & Government of Ireland

2.4.7 Off-site initiating events

The Indaver Duleek site is located to the northeast of Duleek village.

The maps of the site and surroundings illustrate that there are large separation distances between the installations at the Indaver Duleek site and any neighbouring facilities which could have any potential to act as an initiator for an accident at the site. The R152 runs along the south / east boundary of the site and there are several minor developments along this stretch of road (DSG Stores, Paul Kavanagh VTN, Platin Motor Factors). These closest of these is over 200 m from the production buildings and none of these developments present any risk of initiating an accident at the Duleek plant.

There are no COMAH establishments[8] in the vicinity of the Indaver Duleek site. The closest major industrial development is the Irish Cement Factory Platin. There are large separation distances between the installations at Indaver and at Irish Cement; the closest buildings are over 400 m away from each other.

Prior to the construction of the Indaver site, discussions were held with Irish Cement to determine whether there is any risk to the Duleek site as a result of the blasting activities carried out at the quarry. This is carried out by Irish Cement in a controlled manner, in accordance with the conditions of their licence from the EPA. At the time of these discussions, it was noted that Irish Cement's licence specified a peak particle velocity limit of 12 mm/s for ground-borne vibration at the nearest noise sensitive location. The Indaver site is located at a similar distance from the quarry as the sensitive location identified in the licence and so it was anticipated at the time of construction of the Indaver site that the worst-case vibration levels at the foundations of the buildings would be of the order of 12 mm/s. This assumed that geological ground conditions are consistent between the Irish Cement site and receptor locations around the quarry site. The latest version of the Irish Cement Industrial Emissions Licence retains the 12 mm/s limit, which applies now to three locations around the perimeter of the site.

In addition, to reflect the presence of the quarry in the vicinity, the building foundations at the Indaver site are designed to accommodate this potential seismic activity. On this basis it was anticipated prior to the commencement of construction of the site that there would not be any cosmetic or structural damage at Indaver as a result of the activities at Irish Cement. This has since been borne out and there has been no evidence of any such damage over the years of operation at Duleek.

Based on the above considerations, there is no credible risk that an accident at one of the neighbouring sites could act to initiate a major accident at the Indaver Duleek site.

2.5 Suitability of information used

Due to the range of materials stored at the site, the HAZID&RA Team examined scenarios presenting a variety of hazard types, including scenarios with flammable risks, scenarios with the potential for acute toxic exposure and scenarios involving releases of environmentally hazardous materials.

[8] Establishments to which the Control of Major Accident Hazards Regulations (SI 209 of 2015) apply

When assessing the impacts of accident scenarios to people in the vicinity, a consequence modelling exercise was carried out, using a range of pre-determined endpoints. Some of the endpoints used are also of relevance for emergency response planning.

2.5.1 Consequence modelling – Thermal radiation endpoints

The following thermal radiation endpoints were used for this assessment.

- 4 kW/m^2: Sufficient to cause pain to persons exposed if unable to reach cover within 20 seconds. However, with appropriate protective clothing, emergency response actions lasting several minutes may be undertaken. The distance to this heat flux level is often used by fire responders when determining the limiting distance at which personnel can be deployed.
- 6.3 kW/m^2: This is the heat flux reported by the Chemical Industries Association (CIA)[9] as a maximum level to which an emergency exit should be exposed.
- 8 kW/m^2: This is the threshold value reported in IP19[10] at which protective cooling water may be required to prevent escalation of a fire event to exposed items of plant and equipment.
- 25 kW/m^2: This heat flux is reported in the Green Book[11] as being sufficient to cause Damage Level 2 in steel structures (serious discolouration of surface, peeling off of paints and/or appreciable deformations of structural elements).

2.5.2 Consequence modelling – Explosion overpressures

The following overpressure endpoints were used for this assessment:

- 30 mbar: Glass breakage
- 70 mbar: Glass fragments may be generated as a result of window breakage
- 140 mbar: Doors and windows removed. Some distortion to steel frame buildings and cladding removed. This is also equivalent to exposure to a Dangerous Dose.
- 600 mbar: Significant structural damage to plant and equipment

There is no factoring for exposure time in the case of explosion scenarios as they are effectively instantaneous events.

---

[9] "Guidance for the location and design of occupied buildings on chemical manufacturing sites" 2010 (Chemical Industries Association)

[10] "Model Code of Safe Practice Part 19: Fire precautions at petroleum refineries and bulk storage installations" (Energy Institute)

[11] "Methods for the determination of possible damage to people and objects resulting from releases of hazardous materials (CPR 16E)" (TNO)

2.5.3 Consequence modelling – Acute toxic exposure

For scenarios involving a release of materials classed as acutely toxic to people, the impacts of exposure were calculated by reference to the Probit function, which takes the following form, as set out in the HSA's Land Use Planning guidance document:

$$Probit = a + b \times ln(C^n \times t)$$

Where a, b and n are material-specific values, taken from published data, C is the exposure concentration (the units will depend on the literature source used for determining a, b and n, but will be either mg/m^3 or ppm) and t is the exposure time in minutes.

The Probit function can then be used to directly calculate the risk to people exposed and express them as a probability of lethal impacts in the surrounding area, using the following equation:

$$Probability = \frac{1}{\sqrt{2\pi}} \int_{u=-\infty}^{u=Y-5} exp\left(-\frac{u^2}{2}\right) du$$

Where u is an integration variable.

In the cases of any materials for which Probit data was not available, reference was made to the UK HSE guidance "Assessment of the Dangerous Toxic Load (DTL) for Specified Level of Toxicity (SLOT) and Significant Likelihood of Death (SLOD)". The UK HSE has published data for a wide range of materials on the dose exposure (i.e. the concentration and the exposure time) that would correspond to both the SLOT (1% lethality) and the SLOD (50% lethality).

In addition to consideration of toxic doses, each scenario was also modelled to the AEGL-2 endpoint Acute Exposure Guideline Level), which is used for emergency response purposes. This threshold was determined by the US EPA as the "airborne concentration of a substance above which is it predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape. For any materials for which AEGL endpoint data was not available, then reference was made instead to alternate endpoints, such as the AEGL-2[12] endpoint established by the US EPA and which is widely used for emergency response purposes.

2.5.4 Assessment of impacts – Releases to the aquatic environment

There are a number of materials stored and handled at the site which are classed as dangerous to the environment.

The bunker is used to store large quantities of incoming waste. As the bunker waste is solid, a spill of material (e.g. during a delivery to the site) is not mobile and so would be easily recoverable. Furthermore, in the event of a fire in this area, the bunker would retain the fire-fighting water applied to the waste. The bunker is impermeable and is sized to retain the full volume of water that would be applied in the event of a fire-fighting scenario in this area.

The primary environmental hazard arises not from the bunker material but rather from the residue that is formed at the back end of the process, which can contain elevated concentrations of various heavy metals. We have examined the properties of the waste residue in order to determine the

[12] Acute Exposure Guideline Level 2 – this is defined by the US EPA as the airborne concentration (expressed as ppm or mg/m3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

appropriate hazard classification. The assessment in Appendix 5 shows that the Seveso Regulations do not apply to this waste but nonetheless it is environmentally hazardous.

The other potentially environmentally hazardous materials of note are fuel oil and ammonia:

- Fuel oil: 55 m^3 capacity tank
- Aqueous Ammonia (259%): 62 m^3 capacity tank

These tanks are both of double skinned construction in order to protect against the risk of catastrophic tank failure.

Any spills outside of bunded areas would be collected in the surface drainage systems at the site. The outfall from the site is fitted with an oil water separator to protect against elevated concentrations of oil in the surface water discharge. In the event of a spill of water soluble materials, Indaver can shut down the outfall and divert to a dedicated retention tank. This will be done automatically as there is a TOC, conductivity and pH meter on the line, which will shut down the outfall when necessary. There is also a switch which can be activated by Indaver personnel to manually shut down the outfall, if required.

2.5.5 Weather data for consequence modelling

The range of weather conditions that were examined for the purposes of the consequence modelling work that was conducted in support of the HAZID&RA exercise depended on the type of scenario being considered, as follows:

- Fire scenarios: the consequence modelling exercise for the fire scenarios covered in this report use wind speeds of 5 m/s (to represent the impacts during normal weather conditions) and 10 m/s (to represent the impacts in high wind speeds, which can give rise to flame tilt).
- Explosion scenarios: any scenarios involving the evolution and dispersion of vapour to atmosphere were modelled in D5 weather conditions (5 m/s wind speed and normal levels of atmospheric stability) and F2 weather conditions (2 m/s and calm weather conditions).
- Toxic releases: any scenarios involving the release of toxic materials to atmosphere were modelled in D5 weather conditions (5 m/s wind speed and normal levels of atmospheric stability) and F2 weather conditions (2 m/s wind speed and calm weather conditions).

In each case, the approach was to model the scenario in normal weather conditions, which would be more likely to prevail at the time of an accident, and also in worst case conditions (in other words, low wind speeds and calm atmospheric conditions for toxic releases and high wind speeds for fires).

2.6 Credible Scenario Trail

The approach used to carry out the risk assessment exercise is described in Section 2.1. The resulting HAZID&RA worksheets are included in Appendix 3. These comprise the Accident Scenario sheets (AS), which describe the various end events that were identified for the site, and the Risk Assessment Register (RAR) and Risk Reduction Register (RRR), which identifies the various initiating events which could give rise to an accident and calculates the overall risk associated with each scenario. These worksheets also provide details of the various protection and mitigation measures that will be in place at the site, as well as any additional measures recommended in the course of the HAZID&RA exercise. This exercise covered the full range of accident scenarios identified for each of the areas listed in Section 2.1.2 of this report.

In total, the HAZID&RA covered 144 accident scenarios, many of which were slight variations of other scenarios. Of these, a subset of representative worst case scenarios was identified for further assessment. These scenarios were primarily selected on the basis of their Risk Ratings, but additional consideration was also given to potentially catastrophic events. The scenarios selected for more detailed consideration were as follows:

- Bunker fire, with potential evolution of toxic products of combustion to atmosphere
- Loss of containment of aqueous ammonia from storage tank
- Fire at aqueous waste tank farm
- Fire / explosion at hydrogen generation unit

This sub-set of scenarios was selected on the basis that they represent the credible worst case scenarios of the various categories or types of accident that could arise at the site, as identified by the HAZID&RA Team.

A variety of other scenarios were identified as presenting lower risks, but with the need to conduct consequence modelling to ensure that the impacts of these scenarios were determined.

2.7 Detailed subset of accident scenarios

This section of the report describes the sub-set of accident scenarios that was selected for more detailed analysis. These represent the credible worst case scenarios that could arise at the Duleek site. These scenarios have been selected for detailed discussion as they represent the worst case events at the various locations that were examined.

2.7.1 Bunker Fire

Smoke plume

The risk assessment identified a variety of fire scenarios at the bunker, ranging from a spot fire within the bunker area to a fully developed bunker fire. A fire of this material could have the potential to generate hazardous products of combustion which would be emitted to atmosphere within the smoke plume.

Based on the composition of materials in the bunker, and on previous reviews of similar bunker fire scenarios, the primary hazard associated with the emissions from a fire in the bunker is considered to be the potential formation and emission to atmosphere of dioxins within the smoke plume. There is also the potential for other hazardous products of combustion such as carbon monoxide (CO), hydrogen chloride (HCl) and sulphur dioxide (SO_2).

Based on the analysis of the HAZID&RA Team, there are three categories of bunker fire examined:

- Minor fire – smouldering due to contaminants such as hot ashes in the incoming waste stream. In this scenario, Indaver can respond by using the grab crane to load the portion of smouldering waste to the hopper feeding the furnace. It is conservatively assumed that up to 1 tonne of waste could be burned in the bunker area for this scenario.
- Intermediate fire – this is a larger fire scenario requiring the implementation of Indaver's fire-fighting response to extinguish the fire. It is assumed that up to 50 tonnes of waste could be consumed in this case.

- Fully developed fire – if the initial fire-fighting response fails to deal with the scenario the fire could escalate to become a fully developed scenario. In this case the full inventory of waste in the bunker area (between 4,000 and 6,000 tonnes) is consumed.

A more detailed description of the approach used for the consequence modelling exercise for these potential bunker fire scenarios is included in Appendix 6.

Thermal radiation

In addition to the potentially hazardous effects from the smoke plume arising from a bunker fire, there would also be significant thermal radiation to the surrounding area once the fire became fully developed. The software package that was used for this exercise does not include data on the burning rate and surface emissive power for the waste in the bunker and so a surrogate material was selected. The impacts of this scenario were modelled as a pool fire with a surface area equal to the cross sectional area of the bunker. Decane was selected as a surrogate material, as a longer chain hydrocarbon compound. This is considered to be conservative for the purposes of determining heat fluxes as decane will burn at a higher rate and with a higher intensity than would the material in the bunker.

2.7.2 Loss of containment of aqueous ammonia

There are several loss of containment events associated with the storage and handling of aqueous ammonia. The primary scenarios are as follows:

- Loss of containment of aqueous Ammonia from transfer pipeline. The maximum flow rate in the transfer line is 175 kg/hr. In the event of a major release (i.e. guillotine failure of the transfer line), Indaver personnel would be able to detect the loss of containment and to take the necessary measures to shut down the transfer. For the purposes of this assessment a response time of 15 minutes has been assumed. This is a conservative assumption when calculating the quantity of Ammonia that would be released in this scenario as, if the pipe line was to fail in this manner, the pumps would not be able to maintain the pressure in the line. In order to calculate the total quantity released in this period, we multiplied the flow rate by the response time and applied a factor of 2 to allow for additional material lost due to the reduced resistance against which the pump would be operating and for residual material in the line after the pumping ceased. The total volume spilled in this scenario is calculated to be 87.5 kg.
- Full loss of containment from aqueous Ammonia tank. This is an extremely remote event as the aqueous ammonia tank is a double-skinned vessel. The tank is also protected against impacts by the installation of barriers. However, the HAZID&RA team did not rule out the possibility of the tank being damaged due to mechanical impact. In this scenario the full inventory of the tank could be released (i.e. up to 62 m^3 of aqueous ammonia). If the direction of release was towards the yard area, the smooth surface of the ground would enable the released material to spread out thinly, thereby giving a large surface area for evaporation from the spill surface. The dimensions of the pool in this case would be dictated by the presence of buildings in the vicinity. In the event of a release, the spill would be collected in an ACO drain to a forecourt separator. This is capable of collecting and removing any spilled material at a rate of 3 m^3 per minute. As such it is calculated that the resulting pool would be removed from the area within 21 minutes following the release. Once collected in the surface water network, the spill would be routed to the retention facilities on site.

- Loss of containment during delivery of aqueous ammonia (rupture of transfer hose). This scenario involves a much higher flow rate than a release from a pipeline (40 m^3/hr). However, as the operation is manned locally, there is a much more rapid response time (taken to be 1 to 2 minutes). In this case a factor of 1.5 was also applied to allow for the increase in flow rate following failure of the hose line. The total quantity released in this scenario is 2 m^3.

2.7.3 Fire at Aqueous Waste Tank Farm

The waste tank farm is used for the storage of aqueous mixtures of flammable solvents. Although diluted with water, these mixtures are classed as flammable and so we have examined the impacts of major fire scenarios in this area.

In the event of a major release to the bund, the maximum resulting pool area would be determined by the bund dimensions; 28.86 m length by 10.93 m width. This gives a pool area of 313 m^2.

Referring to the waste data for the site, these waste streams could comprise a variety of flammable solvents. For modelling purposes, we have examined the impacts based on a fire of acetonitrile, which is selected as a surrogate solvent for the mixture. The scenario is modelled as a fire of pure acetonitrile, as a conservative approach.

We also considered the potential for a scenario of catastrophic tank failure to occur. However, the tanks will be fitted with shields around their perimeters, to ensure that in the event of a loss of containment due to tank failure, the released liquid would impact the shielding. This would act to dissipate the energy of the release, thereby protecting against the potential for a release to subsequently overtop the bund wall.

2.7.4 Explosion at Hydrogen Generation Unit

The hydrogen generation unit will operate at a pressure of 350 bar, generating hydrogen at a rate of 162 kg/hr. This will be stored on site in a dedicate tank, which will have a capacity of 100 m^3. We have modelled the impacts for the following scenarios:

- Guillotine failure of 2” hydrogen pipeline
- Rupture of storage vessel

2.8 Consequence Assessment

The consequence modelling results for the scenarios described in Section 2.7 are described in the following sub-sections.

2.8.1 Bunker Fires

Dioxin emissions from bunker fire – human health

The modelling exercise to determine the impacts of the dioxin emissions from a bunker fire is described in Appendix 6. The focus of this aspect of the assessment is to examine the combined dose that could be experienced over the course of the fire event, as follows:

- Initial phase with smouldering waste: this is characterised by lower emission rates but also has a less buoyant smoke plume
- Intermediate phase: this involves a fire in the bunker, but one which is extinguished before it can become fully developed.
- Fully developed fire: this involves a fire in the full inventory in the bunker. It is characterised by higher emission rates but it also has a higher buoyancy smoke plume which helps to reduce ground level impacts.

Each phase is progressively less likely to occur, due to the controls and response plans that Indaver has in place to protect against a fire developing in the bunker, but the combined impacts of all three phases have been examined.

Table 2-5 sets out the findings of the expected maximum contribution to dioxin intake to the closest residence to the site (300 m distance) and at Duleek village (3,000 m distance).

Table 2-5: Impacts of Potential Dioxin Intake (combined risk from all Bunker Fire Scenarios)

	Closest residence	Duleek village
Dist. from Bunker (m)	300 m	3,000 m
Average intake (µg/day)	2.15×10^{-8}	2.7×10^{-9}
Body weight (kg)	70	70
Average Intake (µg/day per kg)	3.07×10^{-10}	3.85×10^{-11}
Average Intake (pg/day per kg)	3.07×10^{-4}	3.85×10^{-5}
Safety Margin compared with TDI	3,253	25,960

This shows that there is a very wide margin of safety between the expected dioxin intake to people at these locations when compared with the WHO's Tolerable Daily Intake (TDI) for lifetime exposure of 1-4 pg/kg/day (taken as 1 pg/kg/day for the purposes of this calculation).

Smoke Plume

The risk assessment team examined a number of different bunker fire scenarios, ranging from a spot fire in the waste bunker area up to a fully developed bunker fire. Although the Seveso Regulations do not apply to the waste material within the bunker, nonetheless a fire in this area could give rise to a variety of potentially hazardous products of combustion. The primary hazard associated with a bunker fire of this type is the potential formation and emission to atmosphere of dioxins in the smoke plume, although there could also be other products of combustion such as CO, HCl and SO_2 in the emission.

The bunker has dimensions of 35 m length, 18 m width and 27. 9 m depth. The waste in the bunker is a mixture of waste streams, with a design calorific value of 9.6 MJ/kg.

Based on the analysis of the HAZID&RA Team, there are three categories of bunker fire examined:

- Minor fire – smouldering due to contaminants such as hot ashes in the incoming waste stream. In this scenario, Indaver can respond by using the grab crane to load the portion of smouldering waste to the hopper feeding the furnace. It is conservatively assumed that up to 1 tonne of waste could be burned in the bunker area for this scenario.

- Intermediate fire – this is a larger fire scenario requiring the implementation of Indaver's fire-fighting response to extinguish the fire. It is assumed that up to 50 tonnes of waste could be consumed in this case.
- Fully developed fire – if the initial fire-fighting response fails to deal with the scenario the fire could escalate to become a fully developed scenario. In this case the full inventory of waste in the bunker area is consumed.

A more detailed description of the approach used for the consequence modelling exercise for these potential bunker fire scenarios is included in Appendix 6.

Thermal Radiation

In addition to the potentially hazardous effects from the smoke plume arising from a bunker fire, there would also be significant thermal radiation to the surrounding area once the fire became fully developed. The software package that was used for this exercise does not include data on the burning rate and surface emissive power for the waste in the bunker and so a surrogate material was selected. The impacts of this scenario were modelled as a pool fire with a surface area equal to the cross sectional area of the bunker. Decane was selected as a surrogate material, as a longer chain hydrocarbon compound. This is considered to be conservative for the purposes of determining heat fluxes as Decane will burn at a higher rate and with a higher intensity than would the material in the bunker.

The consequence modelling results are shown in Table 2-6.

Table 2-6: Consequence modelling of bunker fire (thermal radiation effects)

Parameter	Wind Speed of 5 m/s	Wind Speed of 10 m/s
Distance to 25 kW/m^2	18 m	21 m
Distance to 8 kW/m^2	37 m	35 m
Distance to 6.3 kW/m^2	41 m	38 m
Distance to 4 kW/m^2	49 m	45 m

All distances are expressed as distances from the edge of the bunker. For the purposes of this assessment, the fire is taken to be fully developed and so no shielding effect from the structure of the bunker building is taken into account.

There are no offsite impacts associated with this scenario. In addition, there is little potential risk for this scenario to present any risk to personnel because, aside from the controls that are in place to prevent fire occurring and to respond any fire event initiating in this area, the scenario would take time to develop, allowing Indaver time to evacuate personnel where required.

The primary implications for onsite risk are associated with the exposure of adjacent plant. There is provision in the design of the fire protection systems at the site to cater for this scenario. The bunker is fitted with two cannons which are designed to deluge the bunker area. In addition, there is a deluge system in the feed hopper and a sprinkler system in the crane laydown area. These systems are designed to prevent a fire in one area from escalating to the point where it could escalate to the other areas. However, there is capacity to apply fire-fighting water to all three areas at the same time, if necessary.

2.8.2 Loss of containment of aqueous ammonia

The consequence modelling results for the loss of containment scenarios of aqueous ammonia are shown in Table 2-7.

Table 2-7: Consequence modelling for loss of containment of aqueous ammonia

Parameter	Loss of containment from transfer line		Catastrophic tank failure	
Weather	D5	F2	D5	F2
Pool Area (m^2)	4.4	4.4	1,290	1,290
Distance to AEGL-2	45 m	109 m	629 m	1,500 m
Distance to 1% lethality	5 m	18 m	78 m	285 m
Distance to 50% lethality	-	7 m	35 m	93 m

The 30 minute AEGL-2 concentration for ammonia is 220 ppm (155 mg/m^3). However, in all cases modelled here, the duration of exposure would be significantly lower than 30 minutes. The model calculates an initially high release rate from the surface of the pool, which decreases rapidly as the concentration in the pool decreases.

2.8.3 Fire at aqueous waste tank farm

The consequence modelling results for a bund fire at the aqueous waste tank farm are shown in Table 2-8.

Table 2-8: Consequence modelling of pool fire at waste tank farm

Parameter	Wind Speed of 5 m/s	Wind Speed of 10 m/s
Distance to 25 kW/m^2	4 m	7 m
Distance to 8 kW/m^2	16 m	15 m
Distance to 6.3 kW/m^2	18 m	16 m
Distance to 4 kW/m^2	22 m	19 m

All distances are expressed as distances from the edge of the bund.

2.8.4 Explosion at hydrogen generation unit

The consequence modelling results for the scenarios at the hydrogen generation unit are shown in Table 2-9.

Table 2-9: Consequence modelling of hydrogen scenarios

Parameter	Guillotine failure of pipeline		Rupture of vessel (ideal gas)
Weather	D5	F2	n.a.
Distance to 600 mbar	13 m	14 m	15 m
Distance to 140 mbar	35 m	36 m	33 m
Distance to 70 mbar	61 m	63 m	51 m
Distance to 30 mbar	129 m	134 m	106 m

2.9 Demonstration of ALARP

The risk assessment team examined 144 scenarios at the site, using the methodology described in Section 2.1. Of these, 133 scenarios were found to present credible accident hazards and they were each assigned a Severity Rating and a Frequency Rating.

The distribution of risk ratings, for human health and for the environment, are summarised in Figure 2-7 and Figure 2-8.

Figure 2-7: Accident scenario risk ratings (human health)

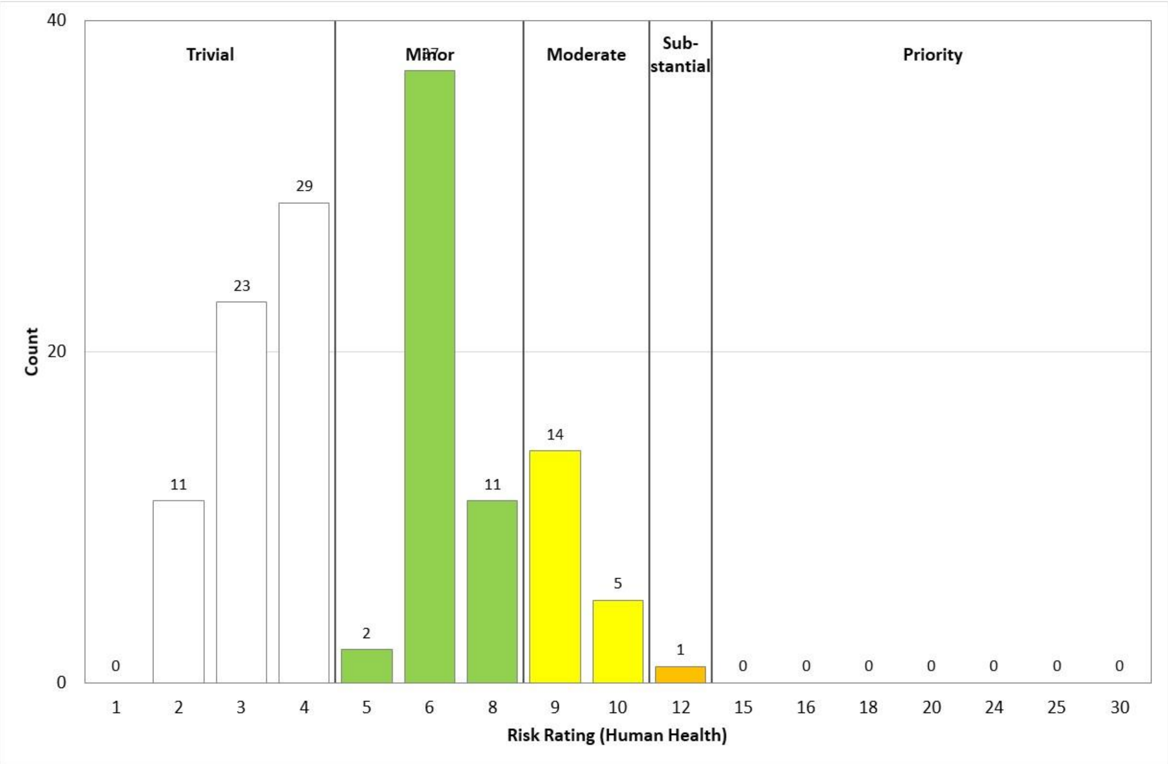
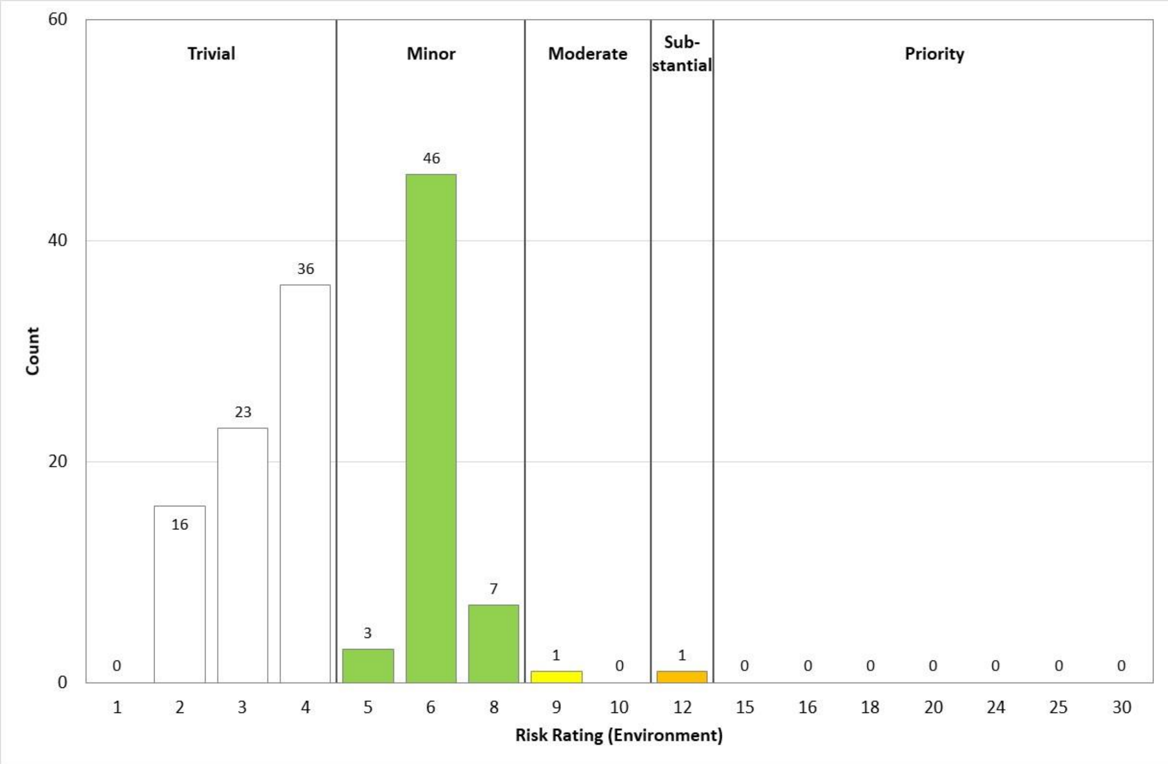


Figure 2-8: Accident scenario risk ratings (environment)



The scenarios identified in the HAZID&RA involve accident scenarios such as fires and loss of containment events involving materials that are hazardous to human health, as listed below:

- Bunker fire
- Loss of containment of aqueous ammonia from storage tank
- Fire at aqueous waste tank farm
- Fire / explosion at hydrogen generation unit.

As such the effects arising from these scenarios could involve direct impacts to human health and/or to the environment. The measures that are in place to protect against these scenarios are set out in the following sub-sections.

Measures to protect against fire at the bunker

- All process activities at the site, including receipt and handling of materials at the bunker, are carried out by trained operators. Indaver has developed standard operating procedures (SOPs) to governing how these activities are carried out.
- Indaver conducts a visual inspection of waste as it is unloaded at the bunker. This inspection is carried out by a trained operator. For new customers, loads are emptied out in the tipping hall area and examined in more detail prior to admittance to the bunker.
- A fire damper is fitted, which will close in the event of a fire initiating at the bunker. This measure ensures that there would be no air supply to the boiler from the bunker area under these circumstances.
- The bunker is a concrete structure and will be compartmentalised (1-hour fire rating). This measure helps to mitigate against the risk of this scenario by limiting the rate at which a fire can develop in this area.

- Fire wrapping is in place on electrical cables at the bunker, to ensure continued function in the event of a fire developing.
- Indaver operates a hot work permitting system at the site, to control ignition sources.
- Where practicable, when maintenance works are required, equipment is taken outside of the bunker for these works.
- The nature of the activity carried out at the site means that there is a quick throughput of material at the bunker. This means that waste is not left to settle within the bunker for a long period of time.
- Indaver operates a Bunker Management Programme. This is carried out once or twice per year, prior to shutdown periods. Indaver lowers the fill level of the bunker to bring the inventory to low level (as far as practicable). This, in conjunction with the quick turnaround of material in the bunker, helps to avoid a situation where a waste batch is allowed to sit in the bunker for a long period of time.
- UV/IR detectors installed in the bunker and at the hopper. These detectors enable early detection in the event of smouldering waste in the bunker. If practicable, and safe to do so, Indaver can load this waste directly to the hopper and then add more waste on top to smother it. This is done at other sites in accordance with a documented procedure.
- Two thermal cameras, one on the north-side of the bunker and one on the south-side of the bunker, are installed to detect hot spots in the waste. If one of the cameras detects temperatures within the waste above 70°C a flashing beacon will alarm in the control room. There are two monitors in the control room that show the temperature profile across the waste and will indicate the location of the hotspots.
- There is a dedicated deluge system above the hopper.
- Indaver has implemented a monitoring programme to study the potential for methane formation due to anaerobic digestion of waste in the bunker. This study has found that the methane levels are very low during operations and rise to levels of up to 400 ppm during shutdowns, when there is no primary air extraction at the bunker. This concentration does not present a fire hazard.
- There are 4 no. fixed water cannons at the bunker, which will provide the facility to douse spot fires. This measure will allow Indaver to respond to a developing fire scenario, allowing the operator the facility to extinguish the event before it becomes fully developed.
- This allows the fire to be extinguished rapidly and with relatively low volumes of water when compared with a fully developed fire.
- There is also a closed dry head fixed sprinkler system in the bunker. This sprinkler system is designed to protect the cranes in case of a bunker fire.
- There is a 250 mm high stop block at the bunker to protect against the risk of a trailer falling into the bunker when unloading waste. In addition, there is an E-Stop located in the tipping hall which stops the cranes in case an operator falls into the bunker.
- The bunker is designed to act as fire water retention facility, to prevent the risk of fire-fighting water that is applied at the bunker subsequently escaping off site as contaminated run-off.
- The tipping hall area is protected by a closed dry head fixed sprinkler system to prevent the risk of fire when waste is tipped out on to the tipping hall floor for inspection.

Measures to protect against loss of containment of aqueous ammonia

- Double skinned aqueous ammonia storage tank.
- Leak detection in place between the two skins on the aqueous ammonia tank, to enable Indaver to rapidly identify if there is a leak in the internal layer, before it could develop into a loss of containment.
- Impact protection in place at the tank.
- Stainless steel pipeline for aqueous ammonia, with welded connection at tank.
- Visual inspection of pipes (daily shift walks)
- Traffic management controls in place, with speed limit on site traffic.
- Barriers to protect against impact to pipelines, with maximum height warning signs at piperack crossovers.
- Preventative maintenance program (tracked on SAP), with permit to work system.
- Drainage system to rapidly collect spills in this area.
- Automatic detection to re-route spill to retention facility on site.
- Inspection of transfer hoses prior to use
- Provision of PPE for delivery drivers
- Overfill protection system on tank, with level gauging and level switch.

Measures to protect against fire at the aqueous waste tank farm

- Tanks will be fully bunded, in accordance with the 110% rule and 25% rule (i.e. bund is large enough to retain at least 110% of the volume of the largest tank and 25% of the total inventory stored at the bund).
- Tanks will be fitted with shielding to protect against the risk of a release outside of the bund due to tank failure.
- Tanks will operate with a nitrogen blanket on the vapour space, to protect against the potential for evolution of flammable vapours from the liquid surface.
- Welded pipelines to minimise the use of flanged connections.
- Preventative maintenance regime to ensure integrity.
- Design to incorporate measure to protect against siphoning of the tank contents in the event of line failure.
- Permit to work system to control potentially invasive works on site.
- Impact protection at tank farm and at tanker loading area.
- Deliveries will be manned activities carried out by trained operators.
- Hoses will be inspected prior to transfers taking place.
- Visual inspection of tankers prior to acceptance on site.
- Overfill protection system on tanks (level gauges, level switches).
- Personnel protective equipment (PPE) for operators involved in carrying out deliveries, as required.

- Contents of the aqueous waste tank are dilute (>90% water), thereby reducing the fire hazard.

Measures to protect against fire at the hydrogen generation unit

- Interlocks on system, to enable a leaking section of line to be isolated, reducing the potential quantity released to atmosphere.
- Pressure reduction at connection for vehicle fuelling.
- Siting of facility and separation distances to other plant, equipment, buildings, etc. in accordance with NFPA 55.
- Preventative maintenance system on plant and equipment, to ensure integrity and fitness for purpose.
- Forced ventilation at indoor area of plant, to prevent risk of hydrogen accumulation at ceiling level.
- Impact protection on hydrogen plant.
- Speed limit in place on site.
- Road tanker movements supervised by trained Indaver operator.
- Visual inspection of road tankers prior to acceptance on site.
- Transfer hoses inspected prior to use.
- ATEX zoning, with control of ignition sources.

These include measures to reduce the probability of an accident scenario developing (risk prevention) and measures to reduce the consequences if an accident did occur (risk mitigation). The measures protect against the conditions arising under which an accident could occur, they enable rapid detection and response and protect against the risk of environmental contamination.

With these measures in place, the HAZID&RA found that Indaver would have all necessary measures to in place at the bunker, throughout all phases of the operation. As such the risks associated with this scenario were considered to be ALARP (as low as reasonably practicable).

Major Accident Scenario Sheet

ID	Area	Date	Rev	Completed By	End Event Ref.	Generic Category of End Event	Details of End Event	Consequence Description	Env. Receptor	Severity: Human Health	Severity: Environment	ID & Description
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.01	Fire (combustible solids)	Spot Fire in waste bunker area	Spot smoking - in Bunker, HCl, smoke, some dioxins may be formed. Sucked into boiler as combustion air.	Air	2	1	01.01 - Spot Fire in waste bunker area
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.02	Fire (combustible solids)	Escalation of spot fire to larger scale (intermediate bunker fire)	As above, but with greater emission of potentially toxic combustion products	Air	2	2	01.02 - Escalation of spot fire to larger scale (intermediate bunker fire)
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.03	Fire (combustible solids)	Fully developed Bunker Fire	As above, but with greater emission of potentially toxic combustion products Potential escalation / knock on effects to other areas of site.	Air	3	3	01.03 - Fully developed Bunker Fire
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.04	Fire (combustible solids)	Fire in Hopper	Similar consequences to 2-1 above. Possibility of spreading back to bunker	Air	2	1	01.04 - Fire in Hopper
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.05	Fire (combustible solids)	Explosion at Hopper	LPG cylinders makes it through to waste pusher where it is crushed. Explosion resulting in waste being blown back out of hopper. Damage to furnace.	Air	2	2	01.05 - Explosion at Hopper
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.01	Explosion (flammable substance)	Explosion in furnace	Overpressure leading to explosion. Refractory damage	Air	2	2	02.01 - Explosion in furnace
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.02	Gaseous (toxic) release	Flue gases back into boiler house building	Potential for inhalation of flue gases if someone is in vicinity at the time (elevated SO2	Air	2	2	02.02 - Flue gases back into boiler house building
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.03	Liquid (toxic) release	Loss of containment from gas oil Supply at Furnace Start up	Spill to building. Contained within building	Surface water	1	2	02.03 - Loss of containment from gas oil Supply at Furnace Start up
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.04	Fire (flammable liquid / gas)	Loss of containment from gas oil Supply at Furnace Start up - with ignition - not credible (high flash point liquid)	Loss of containment without ignition - scenario is described in 02.03 above.	None	0	0	02.04 - Loss of containment from gas oil Supply at Furnace Start up - with ignition - not credible (high flash point liquid)
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.05	Liquid (toxic) release	Loss of containment from liquid waste supply to furnace	Spill to building. Contained within building	Surface Water (SW)	1	2	02.05 - Loss of containment from liquid waste supply to furnace

Major Accident Scenario Sheet

ID	Area	Date	Rev	Completed By	End Event Ref.	Generic Category of End Event	Details of End Event	Consequence Description	Env. Receptor	Severity: Human Health	Severity: Environment	ID & Description
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.06	Liquid (toxic) release	Loss of containment from liquid waste supply to furnace (low cal waste high water content) - with ignition not credible FP >55C	Loss of containment without ignition - scenario is described in 02.05 above.	Surface Water, Air	1	2	02.06 - Loss of containment from liquid waste supply to furnace (low cal waste high water content) - with ignition not credible FP >55C
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.07	Fire (gas)	Loss of containment from LPG supply to burners	Release of flammable gas - evolution of flammable atmosphere to surrounding area	Air (A)	1	1	02.07 - Loss of containment from LPG supply to burners
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.08	Fire (gas)	Loss of containment from LPG supply to burners - with ignition	Release of flammable gas - with ignition	Air (A)	3	1	02.08 - Loss of containment from LPG supply to burners - with ignition
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.09	Fire (gas)	Loss of containment from LPG supply to burners - with ignition	Release of flammable gas - with ignition - operator in vicinity	Air (A)	4	1	02.09 - Loss of containment from LPG supply to burners - with ignition
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.10	Explosion (flammable substance)	Explosion in deslagger, with release of hot ash into boiler house	Release of hot ash to unoccupied area - retained in situ	Surface Water (SW)	1	1	02.10 - Explosion in deslagger, with release of hot ash into boiler house
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.11	Explosion (flammable substance)	Explosion in deslagger, with release of hot ash into boiler house	Injury to operator if in vicinity at the time	Surface Water (SW)	2	1	02.11 - Explosion in deslagger, with release of hot ash into boiler house
03	03 Boiler	02-Oct-19	1.0	HAZID team	03.01	Liquid (toxic) release	Leak of oil at flanged connection to burner	Spill of oil to drip tray inside building	Surface Water (SW)	1	1	03.01 - Leak of oil at flanged connection to burner
03	03 Boiler	02-Oct-19	1.0	HAZID team	03.02	Fire	Leak of oil at flanged connection to burner - with ignition	Small pool fire within drip tray	Air (A)	2	2	03.02 - Leak of oil at flanged connection to burner - with ignition
03	03 Boiler	02-Oct-19	1.0	HAZID team	03.03	Liquid (toxic) release	Complete failure at flange connection, spill of oil	Spill to ground. Retained within building.	Groundwater (GW)	1	2	03.03 - Complete failure at flange connection, spill of oil
03	03 Boiler	02-Oct-19	1.0	HAZID team	03.04	Other	Release of hot water or steam due to leak from boiler	Risk of injury to operator, if operator is on adjacent pathway at time	Air (A)	3	1	03.04 - Release of hot water or steam due to leak from boiler
04	04 Spray Dryer	02-Oct-19	1.0	HAZID team	04.01		No MAH identified in this area. Flue gas in chamber - water & lime	n.a.	None	0	0	04.01 - No MAH identified in this area. Flue gas in chamber - water & lime
05	05 Raw material bulk storage (Expanded Clay / Activated carbon / Quick lime and hydrated lime)	02-Oct-19	1.0	HAZID team	05.01		No MAH identified in this area.	n.a.	None	0	0	05.01 - No MAH identified in this area.
06	06 Bag House	02-Oct-19	1.0	HAZID team	06.01	Solid (toxic) release	Release of ash residue from bag filters	Accumulation of residue on floor Release of residue dust cloud through vents/open doorways	Groundwater, surface water	2	1	06.01 - Release of ash residue from bag filters

Major Accident Scenario Sheet

ID	Area	Date	Rev	Completed By	End Event Ref.	Generic Category of End Event	Details of End Event	Consequence Description	Env. Receptor	Severity: Human Health	Severity: Environment	ID & Description
07	07 Flue gas residue and boiler ash storage and treatment	02-Oct-19	1.0	HAZID team	07.01	Solid (toxic) release	Release of ash residue from storage silos (2 No. silos - with a capacity of between 360m3 and 540m3)	Accumulation of residue on floor Release of residue dust cloud through vents/open doorways	Groundwater, surface water	1	2	07.01 - Release of ash residue from storage silos (2 No. silos - with a capacity of between 360m3 and 540m3)
08	08 Chemstore units	02-Oct-19	1.0	HAZID team	08.01	Toxic (liquid)	Loss of containment from packaged container when being placed in or removed from Chemstore	Spill to ground, evolution of vapours to atmosphere with spill collected in surface drainage system	Surface Water (SW)	2	2	08.01 - Loss of containment from packaged container when being placed in or removed from Chemstore
08	08 Chemstore units	02-Oct-19	1.0	HAZID team	08.02	Fire (liquid)	Loss of containment from packaged container when being placed in or removed from Chemstore - with ignition	Pool fire Radiant heat Products of combustion to atmosphere Firewater	Air (A)	2	2	08.02 - Loss of containment from packaged container when being placed in or removed from Chemstore - with ignition
08	08 Chemstore units	02-Oct-19	1.0	HAZID team	08.03	Toxic (liquid)	Loss of containment within chemstore	Spill collected in bunded unit. Clean up / recovery of spilled	Surface Water (SW)	1	1	08.03 - Loss of containment within chemstore
08	08 Chemstore units	02-Oct-19	1.0	HAZID team	08.04	Fire (liquid)	Loss of containment within chemstore - with ignition	Spill collected in bunded unit. Engulfment of other containers within the unit. Fire water	Surface Water (SW)	2	2	08.04 - Loss of containment within chemstore - with ignition
09	09 ID fan	02-Oct-19	1.0	HAZID team	09.01		No MAH identified in this area.	n.a.	None	0	0	09.01 - No MAH identified in this area.
10	10 Stack	02-Oct-19	1.0	HAZID team	10.01		No MAH identified in this area.	n.a.	None	0	0	10.01 - No MAH identified in this area.
11	11 HCl storage	02-Oct-19	1.0	HAZID team	11.01	Liquid (toxic) release	Loss of containment from IBC to bund tray	Spill to ground. Held within bund. Evolution of toxic vapour to atmosphere	Surface Water, Air	2	2	11.01 - Loss of containment from IBC to bund tray
11	11 HCl storage	02-Oct-19	1.0	HAZID team	11.02	Liquid (toxic) release	Rupture of IBC and release to outside bund	Spill to ground. Collected in internal drainage system (leading to dirty water pit). Evolution of toxic vapour to atmosphere	Surface Water, Air	3	2	11.02 - Rupture of IBC and release to outside bund
11	11 HCl storage	02-Oct-19	1.0	HAZID team	11.03	Liquid (toxic) release	Loss of containment during IBC delivery	Loss of containment of 1m3 of HCl (30%) to unbunded area.	Surface Water, Air	3	2	11.03 - Loss of containment during IBC delivery
12	12 Piperacks	02-Oct-19	1.0	HAZID team	12.01	Liquid (toxic) release	Leak of fuel oil from pipeline	Release of oil to ground collected in surface water drainage system. May be diverted to surface/firewater retention tank	Surface water, groundwater	1	1	12.01 - Leak of fuel oil from pipeline
12	12 Piperacks	02-Oct-19	1.0	HAZID team	12.02	Liquid (toxic) release	Rupture of fuel oil pipeline	Release of oil to ground collected in surface water drainage system. Diverted to surface/firewater retention tank	Surface water, groundwater	1	2	12.02 - Rupture of fuel oil pipeline

Major Accident Scenario Sheet

ID	Area	Date	Rev	Completed By	End Event Ref.	Generic Category of End Event	Details of End Event	Consequence Description	Env. Receptor	Severity		ID & Description
										Human Health	Environment	
12	12 Piperacks	02-Oct-19	1.0	HAZID team	12.03	Liquid (toxic) release	Leak of ammonia solution from pipeline	Release of ammonia to ground collected in surface water drainage system. May be diverted to surface/firewater retention tank	Surface water, groundwater	2	2	12.03 - Leak of ammonia solution from pipeline
12	12 Piperacks	02-Oct-19	1.0	HAZID team	12.04	Liquid (toxic) release	Rupture of ammonia solution pipeline	Release of ammonia to ground collected in surface water drainage system. Diverted to surface/firewater retention tank	Surface water, groundwater	3	2	12.04 - Rupture of ammonia solution pipeline
12	12 Piperacks	02-Oct-19	1.0	HAZID team	12.05	Fire (flammable liquid / gas)	Leak of aqueous waste from pipeline	Spill giving rise to pool fire. Spill collected in surface water drainage along with fire fighting water	Surface water, groundwater	1	1	12.05 - Leak of aqueous waste from pipeline
12	12 Piperacks	02-Oct-19	1.0	HAZID team	12.06	Fire (flammable liquid / gas)	Rupture of aqueous waste pipeline	Spill giving rise to pool fire. Spill collected in surface water drainage along with fire fighting water	Surface water, groundwater	2	2	12.06 - Rupture of aqueous waste pipeline
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.01	Liquid (toxic) release	Loss of containment from fuel oil tank connection (pipeline)	Spill of fuel to ground. Collected in drainage system.	Surface water	1	2	13.01 - Loss of containment from fuel oil tank connection (pipeline)
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.02	Liquid (toxic) release	Rupture of fuel oil tank	Loss of full tank contents to bund	Surface water	1	2	13.02 - Rupture of fuel oil tank
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.03	Liquid (toxic) release	Loss of containment of fuel oil tank during road tanker delivery	Spill of fuel to ground. Collected in drainage system.	Surface water	1	2	13.03 - Loss of containment of fuel oil tank during road tanker delivery
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.04	Liquid (toxic) release	Loss of containment from aqueous Ammonia tank connection (pipeline)	Spill to ground. Collected in drainage system. Evolution of toxic vapour to atmosphere	Surface Water, Air	2	2	13.04 - Loss of containment from aqueous Ammonia tank connection (pipeline)
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.05	Liquid (toxic) release	Rupture of aqueous Ammonia tank	Loss of full tank contents to ground. Evolution of toxic vapour to atmosphere. Potential risk to operator if in vicinity. Potential emergency response	Surface Water, Air	5	3	13.05 - Rupture of aqueous Ammonia tank
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.06	Liquid (toxic) release	Loss of containment of aqueous ammonia during road tanker delivery	Loss of containment of Ammonia to unbunded area delivery rate of 40m3/hr). Operator responds and shuts down transfer within 1-2 minutes	Surface Water, Air	3	2	13.06 - Loss of containment of aqueous ammonia during road tanker delivery
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.07	Liquid (toxic) release	Loss of containment from aqueous waste tank connection (pipeline)	Loss of containment of dilute solution to ground - collected in surface drainage system	Surface water	1	2	13.07 - Loss of containment from aqueous waste tank connection (pipeline)

Major Accident Scenario Sheet

ID	Area	Date	Rev	Completed By	End Event Ref.	Generic Category of End Event	Details of End Event	Consequence Description	Env. Receptor	Severity		ID & Description
										Human Health	Environment	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.08	Fire (flammable liquid / gas)	Loss of containment from aqueous waste tank connection (pipeline) - with ignition	Spill giving rise to pool fire. Spill collected in surface water drainage along with fire fighting water	Surface water	2	2	13.08 - Loss of containment from aqueous waste tank connection (pipeline) - with ignition
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.09	Liquid (toxic) release	Rupture of aqueous waste tank	Spill of fuel to ground. Collected in drainage system.	Surface water	1	2	13.09 - Rupture of aqueous waste tank
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.10	Fire (flammable liquid / gas)	Rupture of aqueous waste tank - with ignition	Spill giving rise to pool fire. Spill collected in surface water drainage along with fire fighting water	Surface water	3	2	13.10 - Rupture of aqueous waste tank - with ignition
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.11	Fire (flammable liquid / gas)	Loss of containment of aqueous waste during road tanker delivery	Spill giving rise to pool fire. Spill collected in surface water drainage along with fire fighting water	Surface water	1	2	13.11 - Loss of containment of aqueous waste during road tanker delivery
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.12	Fire (flammable liquid / gas)	Loss of containment of aqueous waste during road tanker delivery - with ignition	Spill giving rise to pool fire. Spill collected in surface water drainage along with fire fighting water	Surface water	2	2	13.12 - Loss of containment of aqueous waste during road tanker delivery - with ignition
14	14 Nitric Acid Storage	02-Oct-19	1.0	HAZID team	14.01	Liquid (toxic) release	Loss of containment from nitric acid IBC	Loss of contents of IBC to concreted area, collected in drainage system	Surface water	2	1	14.01 - Loss of containment from nitric acid IBC
14	14 Nitric Acid Storage	02-Oct-19	1.0	HAZID team	14.02	Liquid (toxic) release	Loss of containment from nitric acid storage tank	Release of up to 2m3 to concreted area, collected in drainage system	Surface water	2	1	14.02 - Loss of containment from nitric acid storage tank
15	15 Warehouse / Workshop	02-Oct-19	1.0	HAZID team	15.01	Fire (flammable liquid / gas)	Loss of containment of packaged flammable material, release of aerosol into warehouse	Potential for flammable atmosphere within building	Air (A)	1	1	15.01 - Loss of containment of packaged flammable material, release of aerosol into warehouse
15	15 Warehouse / Workshop	02-Oct-19	1.0	HAZID team	15.02	Fire (flammable liquid / gas)	Loss of containment of packaged flammable material, release of aerosol into warehouse - with ignition	Flash fire over small area - potential for container to rocket within caged area	Air (A)	2	1	15.02 - Loss of containment of packaged flammable material, release of aerosol into warehouse - with ignition
15	15 Warehouse / Workshop	02-Oct-19	1.0	HAZID team	15.03	Fire (flammable liquid / gas)	Fire following loss of containment from multiple aerosol containers	Fire with thermal radiation to surroundings. Rocketing containers within caged area.	Air (A)	3	2	15.03 - Fire following loss of containment from multiple aerosol containers
16	16 ACC (Air Cooled Condenser)	02-Oct-19	1.0	HAZID team	16.01		No MAH - no dangerous substances; low pressure, low temperature steam after the turbine (40C)	n.a.	None	0	0	16.01 - No MAH - no dangerous substances; low pressure, low temperature steam after the turbine (40C)
17	17 Roads (onsite)	02-Oct-19	1.0	HAZID team	17.01	Toxic (liquid)	Loss of containment from gas oil tanker	Spill collected in drainage system; potential risk to aquatic environment if material escapes off site	Surface Water (SW)	1	4	17.01 - Loss of containment from gas oil tanker

Major Accident Scenario Sheet

ID	Area	Date	Rev	Completed By	End Event Ref.	Generic Category of End Event	Details of End Event	Consequence Description	Env. Receptor	Severity Human Health	Severity Environment	ID & Description
17	17 Roads (onsite)	02-Oct-19	1.0	HAZID team	17.02	Toxic (liquid)	Loss of containment of aqueous ammonia from bulk tanker	Spill collected in drainage system; potential risk to aquatic environment if material escapes off site. Evolution of gas to atmosphere	Surface Water (SW)	3	3	17.02 - Loss of containment of aqueous ammonia from bulk tanker
17	17 Roads (onsite)	02-Oct-19	1.0	HAZID team	17.03	Fire (liquid)	Loss of containment of aqueous solvent waste mixture, with ignition	Thermal radiation to surrounding area. Risk to operator	Surface Water (SW)	4	2	17.03 - Loss of containment of aqueous solvent waste mixture, with ignition
17	17 Roads (onsite)	02-Oct-19	1.0	HAZID team	17.04	Toxic (liquid)	Loss of containment from IBC of nitric acid	Spill collected in drainage system; potential risk to aquatic environment if material escapes off site. Evolution of gas to atmosphere	Surface Water (SW)	2	2	17.04 - Loss of containment from IBC of nitric acid
18	18 Bottom Ash Storage Building	02-Oct-19	1.0	HAZID team	18.01		Hydrogen generation from ash - extracted at ceiling level with forced ventilation	caused by presence of Al in ash... low rate of generation with no potential for major accident hazards	None	0	0	18.01 - Hydrogen generation from ash - extracted at ceiling level with forced ventilation
19	19 Hydrogen Generation unit	02-Oct-19	1.0	HAZID team	19.01		Loss of containment of H2 from low pressure stage (electrolysis step)	caused by presence of Al in ash... low rate of generation with no potential for major accident	None	0	0	19.01 - Loss of containment of H2 from low pressure stage (electrolysis step)
19	19 Hydrogen Generation unit	02-Oct-19	1.0	HAZID team	19.02	Fire (gas)	Rupture of compressor on high pressure side loss of containment of H2 at 350bar - flare / jet fire	Flare / jet fire. Potential damage to adjacent plant or equipment	Air (A)	3	1	19.02 - Rupture of compressor on high pressure side loss of containment of H2 at 350bar - flare / jet fire
19	19 Hydrogen Generation unit	02-Oct-19	1.0	HAZID team	19.03	Explosion (gas)	Rupture of compressor on high pressure side loss of containment of H2 at 350bar - flash fire / VCE	Delayed ignition, with development of flammable gas atmosphere - ignition to give flash fire or VCE.	Air (A)	4	1	19.03 - Rupture of compressor on high pressure side loss of containment of H2 at 350bar - flash fire / VCE
19	19 Hydrogen Generation unit	02-Oct-19	1.0	HAZID team	19.04	Explosion (gas)	Rupture of storage tank (2 tonnes) - overpressure to	Overpressure resulting in damage to adjacent plant and equipment, missiles	Air (A)	5	1	19.04 - Rupture of storage tank (2 tonnes) - overpressure to surrounding area
19	19 Hydrogen Generation unit	02-Oct-19	1.0	HAZID team	19.05	Fire (gas)	Loss of containment from road tanker - jet fire	Flare / jet fire. Potential damage to adjacent plant or equipment	Air (A)	3	1	19.05 - Loss of containment from road tanker - jet fire
19	19 Hydrogen Generation unit	02-Oct-19	1.0	HAZID team	19.06	Explosion (gas)	Loss of containment from road tanker - flash fire or VCE	Delayed ignition, with development of flammable gas atmosphere - ignition to give flash	Air (A)	4	1	19.06 - Loss of containment from road tanker - flash fire or VCE
19	19 Hydrogen Generation unit	02-Oct-19	1.0	HAZID team	19.07	Explosion (gas)	Rupture of road tanker (200kg) - overpressure to surrounding area	Overpressure resulting in damage to adjacent plant and equipment, missiles	Air (A)	4	1	19.07 - Rupture of road tanker (200kg) - overpressure to surrounding area

Major Accident Scenario Sheet

ID	Area	Date	Rev	Completed By	End Event Ref.	Generic Category of End Event	Details of End Event	Consequence Description	Env. Receptor	Severity		ID & Description
										Human Health	Environment	
20	20 Turbine	02-Oct-19	1.0	HAZID team	**20.01**	Explosion (gas)	Failure of turbine, resulting in vessel rupture and overpressure to surroundings	Not a MAH as scenario involves failure of steam turbine; however, impacts are no different than if a dangerous substance was involved. Overpressure resulting in damage to adjacent plant and equipment, missiles	Air (A)	4	1	20.01 - Failure of turbine, resulting in vessel rupture and overpressure to surroundings

Risk Assessment Register (RAR)

ID	Area	Date	Rev	Completed By	End Event	Initiating Event (Scenario) Ref.	Initiating Event (Scenario) Description	Activity	Frequency	Severity / Harm Human Health	Severity / Harm Environ-ment	Risk Rating Human Health	Risk Rating Environ-ment	Measures Existing	Measures Additional
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.01 - Spot Fire in waste bunker area -	01.01.01	Waste arrives on site smouldering in truck (e.g., hot ash), escalating into fire event when placed in bunker	Waste receipt	4	2	1	8	4	If fire is detected in bunker, the primary air damper will close and air to the furnace will be taken from elsewhere. Bunker is concrete structure and is compartmentalised (1 hr fire rating). Visual inspection of waste as it is unloaded. Fire wrapping of cables to ensure continued function of cranes during fire event. Fire protection systems in Bunker (UVIR, smoke detection and thermal cameras on bunker). Water cannons and fixed sprinkler system - systems designed, installed and maintained to FM HPR standards	
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.01 - Spot Fire in waste bunker area -	01.01.02	Ignition due to hot works or similar activities in area	Maintenance	3	2	1	6	3	Hot work permitting system with extended fire watch in bunker area. Trained operators. Where practicable, equipment is taken outside of the bunker for maintenance works.	
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.01 - Spot Fire in waste bunker area -	01.01.03	Heating due to self-combustion of organic fraction in the waste	Waste receipt	5	2	1	10	5	Relatively quick throughput, waste is not left to settle for long period of time in the bunker. Bunker Management Programme - once per year, prior to shutdown periods, the bunker inventory is brought to low level (as far as practicable) to avoid situation where a waste batch is allowed sit for long period of time. Would be evident due to smoke formation as well as UV/IR detectors and thermal cameras in the bunker. If smouldering waste is detected it is loaded directly to hopper and more waste is then dumped on top to smother it. 4 x Fixed water cannons in place to douse spot fires. Sprinkler system on hopper, the crane laydown areas, crane cable areas and at window of control room	
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.01 - Spot Fire in waste bunker area -	01.01.04	Trailer falls into bunker. Loss of containment of high temperature fuel, with ignition	Waste receipt	2	2	1	4	2	250mm precast concrete kerb. Induction for drivers. Supervision by tipping hall operator. SOP and operational risk assessment for this activity	
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.01 - Spot Fire in waste bunker area -	01.01.04	Container of flammable material in bunker, damaged by grab when collecting from bunker	Waste receipt	4	2	1	8	4	Visual inspection of waste in tipping hall. LEL detector in bunker. Fire protection systems in place (ref. 01.01.01)	
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.01 - Spot Fire in waste bunker area -	01.01.05	Methane formation due to anaerobic digestion in waste - with ignition	Waste receipt	3	2	1	6	3	LEL detector in bunker. High turnover of waste in bunker. Indaver study of bunker conditions and CH4 formation in the banker indicates that it is present in low concentrations, less than OEL	

Risk Assessment Register (RAR)

ID	Area	Date	Rev	Completed By	End Event	Initiating Event (Scenario) Ref.	Initiating Event (Scenario) Description	Activity	Frequency	Severity / Harm Human Health	Severity / Harm Environment	Risk Rating Human Health	Risk Rating Environment	Measures Existing	Measures Additional
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.02 - Escalation of spot fire to larger scale (intermediate bunker fire)	01.02.01	Waste arrives on site smouldering in truck	Waste receipt	3	2	2	6	6	If fire is detected in bunker, the fire damper will close and air to boiler will be taken from elsewhere. Bunker is concrete structure and is compartmentalised (1 hr fire rating).. Visual inspection of waste as it is unloaded. Fire wrapping of cables to ensure continued function during fire event. Fire protection systems in Bunker.	
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.02 - Escalation of spot fire to larger scale (intermediate bunker fire)	01.02.02	Ignition due to hot works or similar activities in area	Maintenance	2	2	2	4	4	Hot work permitting system. Trained operators. Where practicable, equipment is taken outside of the bunker for maintenance works.	
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.02 - Escalation of spot fire to larger scale (intermediate bunker fire)	01.02.03	Heating due to self-combustion of organic fraction in the waste	Waste receipt	4	2	2	8	8	Relatively quick throughput, waste is not left to settle for long period of time. Bunker Management Programme - once or twice per year, prior to shutdown periods, the bunker inventory is brought to low level (as far as practicable) to avoid situation where a waste batch is allowed sit for long period of time. Would be evident due to smoke formation as well as UV/IR detectors in the bunker. If smouldering waste is detected it is loaded directly to hopper and more waste is then dumped on top to smother it. 4 x Fixed water cannons in place to douse spot fires. Sprinkler system on roof as back up.	
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.02 - Escalation of spot fire to larger scale (intermediate bunker fire)	01.02.04	Trailer falls into bunker. Loss of containment of high temperature fuel, with ignition	Waste receipt	2	2	2	4	4	Barrier in place. SOP	
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.02 - Escalation of spot fire to larger scale (intermediate bunker fire)	01.02.05	Container of flammable material in bunker, damaged by grab when collecting from bunker	Waste receipt	2	2	2	4	4	Visual inspection of waste in tipping hall. LEL detector in bunker	
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.02 - Escalation of spot fire to larger scale (intermediate bunker fire)	01.02.06	Methane formation due to anaerobic digestion in waste	Waste receipt	2	2	2	4	4	LEL detector in bunker	Indaver are conducting an investigation of the atmospheric conditions in the bunker in Meath to see if there is any CH4 formation - in particular when process is stopped.
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.03 - Fully developed Bunker Fire	01.03.01	Waste arrives on site smouldering in truck	Waste receipt	3	3	3	9	9	If fire is detected in bunker, the fire damper will close and air to boiler will be taken from elsewhere. Bunker is concrete structure and is compartmentalised (1 hr fire rating).. Visual inspection of waste as it is unloaded. Fire wrapping of cables to ensure continued function during fire event. Fire protection systems in Bunker.	FWR study to be conducted to confirm that bunker has capacity to retain the fire fighting water applied in this scenario

Risk Assessment Register (RAR)

ID	Area	Date	Rev	Completed By	End Event	Initiating Event (Scenario) Ref.	Initiating Event (Scenario) Description	Activity	Frequency	Severity / Harm: Human Health	Severity / Harm: Environ-ment	Risk Rating: Human Health	Risk Rating: Environ-ment	Measures: Existing	Measures: Additional
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.03 - Fully developed Bunker Fire	01.03.02	Ignition due to hot works or similar activities in area	Maintenance	2	3	3	6	6	Hot work permitting system. Trained operators. Where practicable, equipment is taken outside of the bunker for maintenance works.	
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.03 - Fully developed Bunker Fire	01.03.03	Heating due to self-combustion of organic fraction in the waste	Waste receipt	4	3	3	12	12	Relatively quick throughput, waste is not left to settle for long period of time. Bunker Management Programme - once or twice per year, prior to shutdown periods, the bunker inventory is brought to low level (as far as practicable) to avoid situation where a waste batch is allowed sit for long period of time. Would be evident due to smoke formation as well as UV/IR detectors in the bunker. If smouldering waste is detected it is loaded directly to hopper and more waste is then dumped on top to smother it. 4 x Fixed water cannons in place to douse spot fires. Sprinkler system on roof as back up.	FWR study to be conducted to confirm that bunker has capacity to retain the fire fighting water applied in this scenario
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.03 - Fully developed Bunker Fire	01.03.04	Trailer falls into bunker. Loss of containment of high temperature fuel, with ignition	Waste receipt	2	3	3	6	6	Barrier in place. SOP	
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.03 - Fully developed Bunker Fire	01.03.05	Container of flammable material in bunker, damaged by grab when collecting from bunker	Waste receipt	2	3	3	6	6	Visual inspection of waste in tipping hall. LEL detector in bunker	
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.03 - Fully developed Bunker Fire	01.03.06	Methane formation due to anaerobic digestion in waste	Waste receipt	2	3	3	6	6	LEL detector in bunker	
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.04 - Fire in Hopper	01.04.01	Smouldering material dumped into hopper in error	Waste processing	3	2	1	6	3	As above (inspections) UV/IR at hopper. Dedicated deluge system above hopper. Trained operators. Documented emergency procedure in place to respond to this scenario by smothering the smouldering material with more waste.	
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.04 - Fire in Hopper	01.04.02	Backfire from furnace via waste chute to hopper	Waste processing	5	2	1	10	5	During normal operations, the waste is continuously being fed through and so there is no mechanism for a back fire. For planned shutdowns, waste feeding is stopped and levels run down prior to shutdown. For quick shutdowns, hopper is monitored for any signs of initiation of fire. Fire detection and protection measures as described above	

Risk Assessment Register (RAR)

ID	Area	Date	Rev	Completed By	End Event	Initiating Event (Scenario) Ref.	Initiating Event (Scenario) Description	Activity	Frequency	Severity / Harm Human Health	Severity / Harm Environment	Risk Rating Human Health	Risk Rating Environment	Measures Existing	Measures Additional
01	01 Bunker and tipping hall	02-Oct-19	1.0	HAZID team	01.05 - Explosion at Hopper	01.05.01	LPG cylinder in waste stream. Dropped into hopper and then crushed by the waste pusher	Waste processing	3	2	2	6	6	Customer segregation at source. Visual inspection prior to acceptance. Periodically, load is dumped on floor in receipt area and examined in more detail before admitting into the bunker Robust construction of hopper, chute, pushers and furnace entry. Any impact would be mitigated by c.25 tonnes of waste on top of point where pusher activates Control of operations - operator would notify the control room in the event that they had to work at the hopper.	
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.01 - Explosion in furnace	02.01.01	LPG cylinder in waste stream. Makes its way to furnace and ruptures due to high temperatures	Waste processing	3	2	2	6	6	Waste acceptance criteria and inspection as described above System designed in accordance with EN 12952. Observations at similar sites indicate that the system can withstand this scenario without sustaining damage - operational experience here also.	
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.01 - Explosion in furnace	02.01.02	Emergency shutdown, combustion on grate, continues to emit CO. Or waste smouldering to generate CO. Not credible as MAH as there is a continuous air movement by natural draft even in shutdown	Waste processing	0	2	2	0	0	Interlocks on O2 level to ensure excess oxygen. Monitoring for CO at stack.	
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.02 - Flue gases back into boiler house building	02.02.01	Control loop pressure transmitter (set point -2mbar) goes out of action. Overpressure leading to induced draft fan failure, combustion continues. Flue gases back into building	Waste processing	3	2	2	6	6	Preventative Maintenance on ID fan. Vibration detection Majority of air would still flow through stack even in this shutdown event	
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.02 - Flue gases back into boiler house building	02.02.02	Slag accumulation on furnace walls - drops off and impacts grate. Sudden impact of hot slag on water lock gives rise to overpressure with release flue of gases - not credible due to appropriate material selection to prevent slag accumulation in the first place	Waste processing	0	2	2	0	0	Engineer hazard out: appropriate selection of materials for wall to protect against risk of slag accumulation. Cleaning once per year.	
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.03 - Loss of containment from Fuel Oil Supply at Furnace Start up	02.03.01	Oil to furnace without burners activated. Oil passes through grate and is collected inside building	Combustion	3	1	2	3	6	Purge step is carried out on start up of burners. Interlocks to prevent oil flow when burners are not firing. Contained building to retain spills. UV/IR and sprinkler system at burners. Flame scanners on system - would also activate shutdown if burners do not fire within timeframe	

Risk Assessment Register (RAR)

ID	Area	Date	Rev	Completed By	End Event	Initiating Event (Scenario) Ref.	Initiating Event (Scenario) Description	Activity	Frequency	Severity / Harm Human Health	Severity / Harm Environ-ment	Risk Rating Human Health	Risk Rating Environ-ment	Measures Existing	Measures Additional
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.03 - Loss of containment from Fuel Oil Supply at Furnace Start up	02.03.02	Failure of pipeline resulting in leak. Spill is collected inside building or in surface water drains	Combustion	3	1	2	3	6	Oil water separator on drains. PM programme. Pressure gauge at burner would detect major loss of containment and activate interlocks Emergency response plan and ERT in place	
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.04 - Loss of containment from Fuel Oil Supply at Furnace Start up - with ignition - not credible (high flash point liquid)	02.04.01	n.a.	-	0	0	0	0	0	n.a.	
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.05 - Loss of containment from liquid waste supply to furnace	02.05.01	Aqueous waste to furnace without burners activated. Aqueous waste passes through grate and is collected inside building	Combustion	3	1	2	3	6	Spill kits. Drainage / bund tray to restrict size of spill.	
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.05 - Loss of containment from liquid waste supply to furnace	02.05.02	Failure of pipeline resulting in leak. Spill is collected inside building or in surface water drains	Combustion	3	1	2	3	6	Welded pipe with flanged connection at entry to furnace	
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.06 - Loss of containment from liquid waste supply to furnace - with ignition	02.06.01	Failure of pipeline resulting in leak. Spill is collected inside building or in surface water drains	Combustion	3	1	2	3	6	ATEX Zoning. Furnace is insulated with cladding, no external ignition source. Fire fighting system - hoses, extinguishers.	
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.07 - Loss of containment from LPG supply to burners	02.07.01	Mechanical failure of line	Combustion	4	1	1	4	4	LPG used at startup 2 no., one on duty and one on standby. LPG manifold located outdoors. Trained operators to connect up cylinders at manifold. Preventative maintenance programme in place	
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.07 - Loss of containment from LPG supply to burners	02.07.02	Loss of containment at cylinder connection	Combustion	4	1	1	4	4		
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.08 - Loss of containment from LPG supply to burners - with ignition	02.08.01	Mechanical failure of line - with ignition	Combustion	3	3	1	9	3	Controls to protect against loss of containment as described in 02.07. Control of ignition sources in accordance with ATEX.	
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.08 - Loss of containment from LPG supply to burners - with ignition	02.08.02	Loss of containment at cylinder connection - with ignition	Combustion	3	3	1	9	3	Controls to protect against loss of containment as described in 02.07. Control of ignition sources in accordance with ATEX.	
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.09 - Loss of containment from LPG supply to burners - with ignition	02.09.01	Mechanical failure of line with operator in vicinity - with ignition	Combustion	2	4	1	8	2	Trained operators. Area not normally staffed, low potential for exposure	
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.09 - Loss of containment from LPG supply to burners - with ignition	02.09.02	Loss of containment at cylinder connection with operator in vicinity - with ignition	Combustion	2	4	1	8	2	Trained operators. Area not normally staffed, low potential for exposure. Emergency response.	

Risk Assessment Register (RAR)

ID	Area	Date	Rev	Completed By	End Event	Initiating Event (Scenario) Ref.	Initiating Event (Scenario) Description	Activity	Frequency	Severity / Harm Human Health	Severity / Harm Environ-ment	Risk Rating Human Health	Risk Rating Environ-ment	Measures Existing	Measures Additional
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.10 - Explosion in deslagger, with release of hot ash into boiler house	02.10.01	Slag accumulation on furnace walls - drops off and impacts grate. Sudden impact of hot slag on water lock gives rise to overpressure with release of steam and hot ash into boiler house	Combustion	5	1	1	5	5	Material selection - silicon carbide refractory to reduce potential for accumulation to occur. Protective structure to mitigate impacts of any release. PTW for works carried out in this area. SOP will be activated to stop extracting the ash and to drain water, to protect against this occurring while works are carried out	
02	02 Furnace	02-Oct-19	1.0	HAZID team	02.11 - Explosion in deslagger, with release of hot ash into boiler house	02.11.01	Slag accumulation on furnace walls - drops off and impacts grate. Sudden impact of hot slag on water lock gives rise to overpressure with release of steam and hot ash into boiler house - with operator in vicinity	Combustion	4	2	1	8	4	Controls to protect against occurrence as described in 02.10. Area not normally staffed.	
03	03 Boiler	02-Oct-19	1.0	HAZID team	03.01 - Leak of oil at flanged connection to burner	03.01.01	Operator error - not securing flange connection following maintenance works	Post combustion process	4	1	1	4	4	Trained fitters	
03	03 Boiler	02-Oct-19	1.0	HAZID team	03.01 - Leak of oil at flanged connection to burner	03.01.02	Mechanical failure of flange	Post combustion process	3	1	1	3	3	Piping designed to recognised standard/specification Visual inspection of pipes (daily shift walks) Preventative maintenance program (SAP)	
03	03 Boiler	02-Oct-19	1.0	HAZID team	03.02 - Leak of oil at flanged connection to burner - with ignition	03.02.01	Operator error - not securing flange connection following maintenance works	Post combustion process	3	2	2	6	6	see 03.04 for controls to prevent loss of containment	
03	03 Boiler	02-Oct-19	1.0	HAZID team	03.02 - Leak of oil at flanged connection to burner - with ignition	03.02.02	Mechanical failure of flange	Post combustion process	2	2	2	4	4	Fire detection system Control of ignition sources Fire protection Sprinkler system	
03	03 Boiler	02-Oct-19	1.0	HAZID team	03.03 - Complete failure at flange connection, spill of oil	03.03.01	Operator error - not securing flange connection following maintenance works	Post combustion process	4	1	2	4	8	Lock out, tag out procedure. Permit to work sign off by authorised party Trained fitters	
03	03 Boiler	02-Oct-19	1.0	HAZID team	03.03 - Complete failure at flange connection, spill of oil	03.03.02	Mechanical failure of flange	Post combustion process	3	1	2	3	6	Piping designed to recognised standard/specification Visual inspection of pipes (daily shift walks) Preventative maintenance program (SAP)	
03	03 Boiler	02-Oct-19	1.0	HAZID team	03.04 - Release of hot water or steam due to leak from boiler	03.04.01	Leak at boiler due to corrosion / erosion / wear and tear	Post combustion process	3	3	1	9	3	PM on boiler. Leak detection on boiler - measuring water in and steam out (DCS alarm) Area in vicinity of boiler is generally not populated	
#N/A	04 Flue gas cooling section water quench	02-Oct-19	1.0	HAZID team	04.01 - No MAH identified in this area. Flue gas in chamber - water & lime	04.01.01	n.a.	-	0	0	0	0	0	n.a.	
#N/A	05 Activated carbon silo	02-Oct-19	1.0	HAZID team	05.01 - No MAH identified in this area.	05.01.01	n.a.	-	0	0	0	0	0	n.a.	

Risk Assessment Register (RAR)

ID	Area	Date	Rev	Completed By	End Event	Initiating Event (Scenario) Ref.	Initiating Event (Scenario) Description	Activity	Frequency	Severity / Harm Human Health	Severity / Harm Environ-ment	Risk Rating Human Health	Risk Rating Environ-ment	Measures Existing	Measures Additional
06	06 Bag House	02-Oct-19	1.0	HAZID team	06.01 - Release of ash residue from bag filters	06.01.01	Major mechanical damage to bag house due to impact	Operation of filter	3	2	1	6	3	Baghouse at elevated level - not at risk from impact Inside a building, release would be contained Restricted vehicle access Trained operators Process controls to detect pressure drops. Alarms.	
06	06 Bag House	02-Oct-19	1.0	HAZID team	06.01 - Release of ash residue from bag filters	06.01.02	Operator error - opens hopper for inspection, resulting in release of residue to ground	Maintenance	3	2	1	6	3	Trained operators. Operational risk assessment with method statement. PPE.	
06	06 Bag House	02-Oct-19	1.0	HAZID team	06.01 - Release of ash residue from bag filters	06.01.03	Loss of containment due to corrosion of hopper, e.g. due to cold spots on flue gas path	Operation of filter	3	2	1	6	3	PM programme with inspections. Thermal imaging. OEM inspections	
#N/A	07 Flue gas residue storage	02-Oct-19	1.0	HAZID team	07.01 - Release of ash residue from storage silos (2 No. silos - with a capacity of between 360m3 and 540m3)	07.01.01	Major mechanical damage to silo(s) due to impact	Storage of residue	3	1	2	3	6	Impact protection Inside a building Restricted vehicle access Trained operators Process controls - temperature/weight detection	
#N/A	07 Flue gas residue storage	02-Oct-19	1.0	HAZID team	07.01 - Release of ash residue from storage silos (2 No. silos - with a capacity of between 360m3 and 540m3)	07.01.02	Catastrophic failure of silo	Storage of residue	2	1	2	2	4	Silos designed to recognised standard/specification (designed for external use, housed internally) Visual inspection of silos (daily shift walks) Preventative maintenance program (SAP)	
08	08 Chemstore units	02-Oct-19	1.0	HAZID team	08.01 - Loss of containment from packaged container when being placed in or removed from Chemstore	08.01.01	Manual handling error, resulting in loss of containment from packaged container	Transferring material to/from chemstore	4	2	2	8	8	Operator training on site. Chemical awareness and ADR training UN rated packages (drop testing). Bunded and tested chemical storage units. Spill response procedure. Emergency response plan and ERT in place	
08	08 Chemstore units	02-Oct-19	1.0	HAZID team	08.02 - Loss of containment from packaged container when being placed in or removed from Chemstore - with ignition	08.02.01	Manual handling error, resulting in loss of containment from packaged container - with ignition	Transferring material to/from chemstore	3	2	2	6	6	Operator training on site. Chemical awareness and ADR training UN rated packages (drop testing). Bunded and tested chemical storage units. Spill response procedure. Emergency response plan and ERT in place	
08	08 Chemstore units	02-Oct-19	1.0	HAZID team	08.03 - Loss of containment within chemstore	08.03.01	Corrosion of container	Drum handling and storage	4	1	1	4	4	Documented visual inspection on acceptance. Documented periodic visual inspection of containers, by trained operators. UN approved drums. Bunded and tested chemical storage units. Spill response procedure. Emergency response plan and ERT in place	

Risk Assessment Register (RAR)

ID	Area	Date	Rev	Completed By	End Event	Initiating Event (Scenario) Ref.	Initiating Event (Scenario) Description	Activity	Frequency	Severity / Harm Human Health	Severity / Harm Environ-ment	Risk Rating Human Health	Risk Rating Environ-ment	Measures Existing	Measures Additional
08	08 Chemstore units	02-Oct-19	1.0	HAZID team	08.03 - Loss of containment within chemstore	08.03.02	Manual handling error, resulting in loss of containment from packaged container	Drum handling and storage	4	1	1	4	4	Operator training on site. Chemical awareness and ADR training UN rated packages (drop testing). Bunded and tested chemical storage units. Spill response procedure. Emergency response plan and ERT in place	
08	08 Chemstore units	02-Oct-19	1.0	HAZID team	08.04 - Loss of containment within chemstore - with ignition	08.04.01	Corrosion of container - with ignition	Drum handling and storage	3	2	2	6	6	Documented visual inspection on acceptance. Documented periodic visual inspection of containers, by trained operators. UN approved drums. Bunded and tested chemical storage units. Spill response procedure. Emergency response plan and ERT in place	
08	08 Chemstore units	02-Oct-19	1.0	HAZID team	08.04 - Loss of containment within chemstore - with ignition	08.04.02	Manual handling error, resulting in loss of containment from packaged container - with ignition	Drum handling and storage	3	2	2	6	6	Operator training on site. Chemical awareness and ADR training UN rated packages (drop testing). Bunded and tested chemical storage units. Spill response procedure. Emergency response plan and ERT in place	
09	09 ID fan	02-Oct-19	1.0	HAZID team	09.01 - No MAH identified in this area.	09.01.01	n.a.	-	0	0	0	0	0	n.a.	
10	10 Stack	02-Oct-19	1.0	HAZID team	10.01 - No MAH identified in this area.	10.01.01	n.a.	-	0	0	0	0	0	n.a.	
11	11 HCl storage	02-Oct-19	1.0	HAZID team	11.01 - Loss of containment from IBC to bund tray	11.01.01	Corrosive/wear & tear causing leak	HCl storage	2	2	2	4	4	UN approved containers / packaging for materials. Bunded IBCs Regular site inspection (as above) Screening / assessing deliveries to site Investigations / follow up if supplier provides faulty IBC	
11	11 HCl storage	02-Oct-19	1.0	HAZID team	11.01 - Loss of containment from IBC to bund tray	11.01.02	Leak at outlet/tap	HCl storage	3	2	2	6	6	as above	
11	11 HCl storage	02-Oct-19	1.0	HAZID team	11.01 - Loss of containment from IBC to bund tray	11.01.03	Mechanical impact	HCl storage	3	2	2	6	6	Speed limit / traffic management controls on site. Trained operators Permit to work system Caged IBCs	
11	11 HCl storage	02-Oct-19	1.0	HAZID team	11.02 - Rupture of IBC and release to outside bund	11.02.01	Mechanical impact	HCl storage	3	3	2	9	6	Speed limit / traffic management controls on site. Trained operators Permit to work system Caged IBCs	
11	11 HCl storage	02-Oct-19	1.0	HAZID team	11.02 - Rupture of IBC and release to outside bund	11.02.02	Catastrophic failure	HCl storage	2	3	2	6	4	UN approved containers / packaging for materials. Bunded IBCs Regular site inspection (as above) Screening / assessing deliveries to site Investigations / follow up if supplier provides faulty IBC	

Risk Assessment Register (RAR)

ID	Area	Date	Rev	Completed By	End Event	Initiating Event (Scenario) Ref.	Initiating Event (Scenario) Description	Activity	Frequency	Severity / Harm Human Health	Severity / Harm Environ-ment	Risk Rating Human Health	Risk Rating Environ-ment	Measures Existing	Measures Additional
11	11 HCl storage	02-Oct-19	1.0	HAZID team	11.03 - Loss of containment during IBC delivery	11.03.01	Mechanical impact	HCl delivery	3	3	2	9	6	Speed limit / traffic management controls on site. Trained operators Caged IBCs	
11	11 HCl storage	02-Oct-19	1.0	HAZID team	11.03 - Loss of containment during IBC delivery	11.03.02	Operator drops IBC	HCl delivery	2	3	2	6	4	Speed limit / traffic management controls on site. Trained operators Caged IBCs	
12	12 Piperacks	02-Oct-19	1.0	HAZID team	12.01 - Leak of fuel oil from pipeline	12.01.01	Wear & tear / corrosive	Transfer of fuel oil by pipeline	3	1	1	3	3	Piping designed to recognised standard/specification (piperacks welded / flanged at end) Visual inspection of pipes (daily shift walks) Preventative maintenance program (SAP)	
12	12 Piperacks	02-Oct-19	1.0	HAZID team	12.01 - Leak of fuel oil from pipeline	12.01.02	Mechanical Impact	Transfer of fuel oil by pipeline	3	1	1	3	3	Speed limit / traffic management controls on site. Trained operators Protection barriers Maximum height warning signs at piperack crossovers	
12	12 Piperacks	02-Oct-19	1.0	HAZID team	12.01 - Leak of fuel oil from pipeline	12.01.03	Overpressure due to blockage in line	Transfer of fuel oil by pipeline	2	1	1	2	2	Pressure relief valve at pump Pipe lines pressure tested to 1.5 times operating pressure	
12	12 Piperacks	02-Oct-19	1.0	HAZID team	12.02 - Rupture of fuel oil pipeline	12.02.01	Mechanical Impact	Transfer of fuel oil by pipeline	3	1	2	3	6	Speed limit / traffic management controls on site. Trained operators Protection barriers Maximum height warning signs at piperack crossovers	
12	12 Piperacks	02-Oct-19	1.0	HAZID team	12.02 - Rupture of fuel oil pipeline	12.02.02	Catastrophic failure	Transfer of fuel oil by pipeline	3	1	2	3	6	Piping designed to recognised standard/specification (piperacks welded / flanged at end) Visual inspection of pipes (daily shift walks) Preventative maintenance program (SAP)	
12	12 Piperacks	02-Oct-19	1.0	HAZID team	12.03 - Leak of ammonia solution from pipeline	12.03.01	Wear & tear / corrosive	Transfer of ammonia by pipeline	3	2	2	6	6	Piping designed to recognised standard/specification (piperacks welded / flanged at end, stainless steel pipeline for ammonia) Visual inspection of pipes (daily shift walks)	
12	12 Piperacks	02-Oct-19	1.0	HAZID team	12.03 - Leak of ammonia solution from pipeline	12.03.02	Mechanical Impact	Transfer of ammonia by pipeline	3	2	2	6	6	Speed limit / traffic management controls on site. Trained operators Protection barriers Maximum height warning signs at piperack crossovers	
12	12 Piperacks	02-Oct-19	1.0	HAZID team	12.03 - Leak of ammonia solution from pipeline	12.03.03	Overpressure due to blockage in line	Transfer of ammonia by pipeline	2	2	2	4	4	Pressure relief valve at pump Pipe lines pressure tested to 1.5 times operating pressure	

Risk Assessment Register (RAR)

ID	Area	Date	Rev	Completed By	End Event	Initiating Event (Scenario) Ref.	Initiating Event (Scenario) Description	Activity	Frequency	Severity / Harm Human Health	Severity / Harm Environment	Risk Rating Human Health	Risk Rating Environment	Measures Existing	Measures Additional
12	12 Piperacks	02-Oct-19	1.0	HAZID team	12.04 - Rupture of ammonia solution pipeline	12.04.01	Mechanical Impact	Transfer of ammonia by pipeline	3	3	2	9	6	Speed limit / traffic management controls on site. Trained operators Protection barriers Maximum height warning signs at piperack crossovers	
12	12 Piperacks	02-Oct-19	1.0	HAZID team	12.04 - Rupture of ammonia solution pipeline	12.04.02	Catastrophic failure	Transfer of ammonia by pipeline	3	3	2	9	6	Piping designed to recognised standard/specification (piperacks welded / flanged at end) Visual inspection of pipes (daily shift walks) Preventative maintenance program (SAP)	
12	12 Piperacks	02-Oct-19	1.0	HAZID team	12.05 - Leak of aqueous waste from pipeline	12.05.01	Wear & tear / corrosive	Transfer of aqueous waste by pipeline	2	1	1	2	2	Controls to prevent loss of containment as per 12-03 Control on ignition sources (Permit to Work) Fire fighting systems / water main Spill kits ERT team	
12	12 Piperacks	02-Oct-19	1.0	HAZID team	12.05 - Leak of aqueous waste from pipeline	12.05.02	Mechanical Impact	Transfer of aqueous waste by pipeline	2	1	1	2	2	as above	
12	12 Piperacks	02-Oct-19	1.0	HAZID team	12.05 - Leak of aqueous waste from pipeline	12.05.03	Overpressure due to blockage in line	Transfer of aqueous waste by pipeline	2	1	1	2	2	as above	
12	12 Piperacks	02-Oct-19	1.0	HAZID team	12.06 - Rupture of aqueous waste pipeline	12.06.01	Mechanical Impact	Transfer of aqueous waste by pipeline	2	2	2	4	4	Controls to prevent loss of containment as per 102-4 Control on ignition sources (Permit to Work) Fire fighting systems / water main Spill kits ERT team	
12	12 Piperacks	02-Oct-19	1.0	HAZID team	12.06 - Rupture of aqueous waste pipeline	12.06.02	Catastrophic failure	Transfer of aqueous waste by pipeline	2	2	2	4	4	as above	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.01 - Loss of containment from fuel oil tank connection (pipeline)	13.01.01	Impact to line	Fuel oil supply to furnace	4	1	2	4	8	CE certified equipment.	Design to incorporate measure to protect against siphoning of the tank contents (e.g. a hole in pipeline at top point on tank outlet or a check valve) in the event of line failure.
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.01 - Loss of containment from fuel oil tank connection (pipeline)	13.01.02	Corrosion /erosion of line	Fuel oil supply to furnace	3	1	2	3	6	No flange connections, all welded. Carbon steel line. PM regime on site.	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.01 - Loss of containment from fuel oil tank connection (pipeline)	13.01.03	Maintenance error, line breaking	Fuel oil supply to furnace	3	1	2	3	6	Permit to work system for maintenance. Trained operators	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.02 - Rupture of fuel oil tank	13.02.01	Mechanical Impact	Fuel oil storage	2	1	2	2	4	Impact protection. Speed limit on site. Trained operators.	

Risk Assessment Register (RAR)

ID	Area	Date	Rev	Completed By	End Event	Initiating Event (Scenario) Ref.	Initiating Event (Scenario) Description	Activity	Frequency	Severity / Harm Human Health	Severity / Harm Environ-ment	Risk Rating Human Health	Risk Rating Environ-ment	Measures Existing	Measures Additional
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.02 - Rupture of fuel oil tank	13.02.02	Catastrophic failure	Fuel oil storage	3	1	2	3	6	PM regime. Double skinned tank with leak detection.	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.03 - Loss of containment of fuel oil tank during road tanker delivery	13.03.01	Failure of transfer hose	Fuel oil delivery	3	1	2	3	6	Trained operators. Manned activity. Hose inspection prior to use	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.03 - Loss of containment of fuel oil tank during road tanker delivery	13.03.02	Road tanker in poor condition - corrosion	Fuel oil delivery	2	1	2	2	4	Visual inspection of tankers prior to acceptance on site	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.03 - Loss of containment of fuel oil tank during road tanker delivery	13.03.03	Overfilling of tank	Fuel oil delivery	3	1	2	3	6	Overfill protection systems in place (gauging, level switches etc.)	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.04 - Loss of containment from aqueous Ammonia tank connection (pipeline)	13.04.01	Impact to line	Ammonia to SNCR for scrubbing	4	2	2	8	8	CE certified equipment.	Design to incorporate measure to protect against siphoning of the tank contents (e.g. a hole in pipeline at top point on tank outlet or a check valve) in the event of line failure.
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.04 - Loss of containment from aqueous Ammonia tank connection (pipeline)	13.04.02	Corrosion /erosion of line	Ammonia to SNCR for scrubbing	3	2	2	6	6	No flange connections, all welded. Stainless steel line. PM regime on site.	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.04 - Loss of containment from aqueous Ammonia tank connection (pipeline)	13.04.03	Maintenance error, line breaking	Ammonia to SNCR for scrubbing	3	2	2	6	6	Permit to work system for maintenance. Trained operators	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.05 - Rupture of aqueous Ammonia tank	13.05.01	Mechanical impact to tank	Ammonia storage	2	5	3	10	6	Impact protection. Speed limit on site. Trained operators.	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.05 - Rupture of aqueous Ammonia tank	13.05.02	Catastrophic failure of tank	Ammonia storage	1	5	3	5	3	PM regime Double skinned tank Leak detection between skins on all double skinned tanks	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.06 - Loss of containment of aqueous ammonia during road tanker delivery	13.06.01	Failure of transfer hose	Ammonia delivery	3	3	2	9	6	Trained operators. Manned activity. Hose inspection prior to use	PPE for delivery drivers
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.06 - Loss of containment of aqueous ammonia during road tanker delivery	13.06.02	Road tanker in poor condition - corrosion	Ammonia delivery	2	3	2	6	4	Visual inspection of tankers prior to acceptance on site	

Risk Assessment Register (RAR)

ID	Area	Date	Rev	Completed By	End Event	Initiating Event (Scenario)		Activity	Frequency	Severity / Harm		Risk Rating		Measures	
						Ref.	Description			Human Health	Environ-ment	Human Health	Environ-ment	Existing	Additional
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.06 - Loss of containment of aqueous ammonia during road tanker delivery	13.06.03	Overfilling of tank	Ammonia delivery	3	3	2	9	6	Overfill protection systems (gauging, level switches etc)	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.07 - Loss of containment from aqueous waste tank connection (pipeline)	13.07.01	Impact to line	Operation of aqueous waste tank	4	1	2	4	8	CE certified equipment.	Design to incorporate measure to protect against siphoning of the tank contents (e.g. a hole in pipeline at top point on tank outlet or a check valve) in the event of line failure.
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.07 - Loss of containment from aqueous waste tank connection (pipeline)	13.07.02	Corrosion /erosion of line	Operation of aqueous waste tank	3	1	2	3	6	No flange connections, all welded. Stainless steel line. PM regime on site.	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.07 - Loss of containment from aqueous waste tank connection (pipeline)	13.07.03	Maintenance error, line breaking	Operation of aqueous waste tank	3	1	2	3	6	Permit to work system for maintenance. Trained operators	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.08 - Loss of containment from aqueous waste tank connection (pipeline) - with ignition	13.08.01	Impact to line	Operation of aqueous waste tank	3	2	2	6	6	Controls to protect against loss of containment, as described in 13.07. Dilute waste stream (>70% water), which reduces fire hazard. Fire fighting / fire protection systems on site.	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.08 - Loss of containment from aqueous waste tank connection (pipeline) - with ignition	13.08.02	Corrosion /erosion of line	Operation of aqueous waste tank	2	2	2	4	4	No flange connections, all welded. Stainless steel line. PM regime on site.	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.08 - Loss of containment from aqueous waste tank connection (pipeline) - with ignition	13.08.03	Maintenance error, line breaking	Operation of aqueous waste tank	2	2	2	4	4	Permit to work system for maintenance. Trained operators	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.09 - Rupture of aqueous waste tank	13.09.01	Mechanical impact to tank	Operation of aqueous waste tank	2	1	2	2	4	Impact protection. Speed limit on site. Trained operators.	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.09 - Rupture of aqueous waste tank	13.09.02	Catastrophic failure of tank with overtopping of bund	Operation of aqueous waste tank	2	1	2	2	4	PM regime Baffle walls between tanks and bund walls Bunded tank farm	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.10 - Rupture of aqueous waste tank - with ignition	13.10.01	Mechanical impact to tank	Operation of aqueous waste tank	2	3	2	6	4	Controls to protect against loss of containment, as described above. Dilute waste stream (>70% water), which reduces fire hazard. Fire fighting / fire protection systems on site.	

Risk Assessment Register (RAR)

ID	Area	Date	Rev	Completed By	End Event	Initiating Event (Scenario) Ref.	Initiating Event (Scenario) Description	Activity	Frequency	Severity / Harm Human Health	Severity / Harm Environ-ment	Risk Rating Human Health	Risk Rating Environ-ment	Measures Existing	Measures Additional
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.10 - Rupture of aqueous waste tank - with ignition	13.10.02	Catastrophic failure of tank with overtopping of bund	Operation of aqueous waste tank	1	3	2	3	2	Controls to protect against loss of containment, as described above. Dilute waste stream (>70% water), which reduces fire hazard. Fire fighting / fire protection systems on site.	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.11 - Loss of containment of aqueous waste during road tanker delivery	13.11.01	Wear & tear / corrosive	Operation of aqueous waste tank	3	1	2	3	6	Trained operators. Manned activity. Hose inspection prior to use	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.11 - Loss of containment of aqueous waste during road tanker delivery	13.11.02	Mechanical Impact	Operation of aqueous waste tank	3	1	2	3	6	Visual inspection of tankers prior to acceptance on site	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.11 - Loss of containment of aqueous waste during road tanker delivery	13.11.03	Overpressure due to blockage in line	Operation of aqueous waste tank	2	1	2	2	4	Overfill protection systems (gauging, level switches etc)	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.12 - Loss of containment of aqueous waste during road tanker delivery - with ignition	13.12.01	Wear & tear / corrosive	Operation of aqueous waste tank	2	2	2	4	4	Controls to protect against loss of containment, as described in 104-11. Dilute waste stream (>70% water), which reduces fire hazard. Fire fighting / fire protection systems on site.	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.12 - Loss of containment of aqueous waste during road tanker delivery - with ignition	13.12.02	Mechanical Impact	Operation of aqueous waste tank	2	2	2	4	4	Visual inspection of tankers prior to acceptance on site	
13	13 Bulk liquid storage areas	02-Oct-19	1.0	HAZID team	13.12 - Loss of containment of aqueous waste during road tanker delivery - with ignition	13.12.03	Overpressure due to blockage in line	Operation of aqueous waste tank	2	2	2	4	4	Overfill protection systems (gauging, level switches etc)	
14	14 Nitric Acid Storage	02-Oct-19	1.0	HAZID team	14.01 - Loss of containment from nitric acid IBC	14.01.01	Corrosion, erosion of IBC	Nitric acid storage	2	2	1	4	2	Approved supplier. IBCs handled on site by trained indaver operator. Marking system on IBCs showing expiry date for container. PPE for operators. Spills collected in drainage system and routed to dirty water pit.	
14	14 Nitric Acid Storage	02-Oct-19	1.0	HAZID team	14.01 - Loss of containment from nitric acid IBC	14.01.02	Mechanical impact	Nitric acid storage	3	2	1	6	3	Trained operators. Speed limit on site. Caged IBCs	
14	14 Nitric Acid Storage	02-Oct-19	1.0	HAZID team	14.01 - Loss of containment from nitric acid IBC	14.01.03	Operator error, resulting in release from IBC	Nitric acid storage	3	2	1	6	3	Trained operator. SOP for transferring contents from IBC to tank. Risk assessment and method statement for transferred from IBC to tank	

Risk Assessment Register (RAR)

ID	Area	Date	Rev	Completed By	End Event	Initiating Event (Scenario) Ref.	Initiating Event (Scenario) Description	Activity	Frequency	Severity / Harm Human Health	Severity / Harm Environ-ment	Risk Rating Human Health	Risk Rating Environ-ment	Measures Existing	Measures Additional
14	14 Nitric Acid Storage	02-Oct-19	1.0	HAZID team	14.02 - Loss of containment from nitric acid storage tank	14.02.01	Corrosion of tank	Nitric acid storage	2	2	1	4	2	Materials of construction - tank is plastic and rated to hold nitric acid. Double containment tank. Inspection programme - includes test of the internal space as part of the bund register	
14	14 Nitric Acid Storage	02-Oct-19	1.0	HAZID team	14.02 - Loss of containment from nitric acid storage tank	14.02.02	Mechanical impact	Nitric acid storage	3	2	1	6	3	Trained operators. Speed limit on site.	
14	14 Nitric Acid Storage	02-Oct-19	1.0	HAZID team	14.02 - Loss of containment from nitric acid storage tank	14.02.03	Failure of tank fixture / fitting	Nitric acid storage	3	2	1	6	3	PM programme Spill collection as described under 14.01	
15	15 Warehouse / Workshop	02-Oct-19	1.0	HAZID team	15.01 - Loss of containment of packaged flammable material, release of aerosol into warehouse	15.01.01	Damage to container due to impact from forklift	Storage and handling of packaged flammable materials	4	1	1	4	4	Trained operators. Speed limit on site for vehicle movements. Caged area for storage of aerosols - restricts access.	
15	15 Warehouse / Workshop	02-Oct-19	1.0	HAZID team	15.01 - Loss of containment of packaged flammable material, release of aerosol into warehouse	15.01.02	Damage to container due to being dropped from height	Storage and handling of packaged flammable materials	4	1	1	4	4	Trained operators. Caged area for storage of aerosols - restricts access.	
15	15 Warehouse / Workshop	02-Oct-19	1.0	HAZID team	15.01 - Loss of containment of packaged flammable material, release of aerosol into warehouse	15.01.03	Leak due to corrosion, wear-and-tear of container in storage	Storage and handling of packaged flammable materials	3	1	1	3	3	Visual inspection of containers arriving on site. Periodic inspection of materials in storage	
15	15 Warehouse / Workshop	02-Oct-19	1.0	HAZID team	15.02 - Loss of containment of packaged flammable material, release of aerosol into warehouse - with ignition	15.02.01	Damage to container due to impact from forklift - with ignition	Storage and handling of packaged flammable materials	3	2	1	6	3	Controls to protect against loss of containment, as described in 15.01. Emergency response plan and ERT in place. Caged storage of aerosols helps to retain rocketing containers.	
15	15 Warehouse / Workshop	02-Oct-19	1.0	HAZID team	15.02 - Loss of containment of packaged flammable material, release of aerosol into warehouse - with ignition	15.02.02	Damage to container due to being dropped from height - with ignition	Storage and handling of packaged flammable materials	3	2	1	6	3	Controls to protect against loss of containment, as described in 15.01. Emergency response plan and ERT in place. Caged storage of aerosols helps to retain rocketing containers.	

Risk Assessment Register (RAR)

ID	Area	Date	Rev	Completed By	End Event	Initiating Event (Scenario) Ref.	Initiating Event (Scenario) Description	Activity	Frequency	Severity / Harm Human Health	Severity / Harm Environ-ment	Risk Rating Human Health	Risk Rating Environ-ment	Measures Existing	Measures Additional
15	15 Warehouse / Workshop	02-Oct-19	1.0	HAZID team	15.02 - Loss of containment of packaged flammable material, release of aerosol into warehouse - with ignition	15.02.03	Leak due to corrosion, wear-and-tear of container in storage - with ignition	Storage and handling of packaged flammable materials	2	2	1	4	2	Controls to protect against loss of containment, as described in 15.01. Emergency response plan and ERT in place. Caged storage of aerosols helps to retain rocketing containers.	
15	15 Warehouse / Workshop	02-Oct-19	1.0	HAZID team	15.03 - Fire following loss of containment from multiple aerosol containers	15.03.01	Fire in area (15.02) with escalation resulting in damage to multiple aerosol containers	Storage and handling of packaged flammable materials	3	3	2	9	6	Controls to protect against loss of containment, as described in 15.01. Emergency response plan and ERT in place. Caged storage of aerosols helps to retain rocketing containers.	
16	16 ACC (Air Cooled Condenser)	02-Oct-19	1.0	HAZID team	16.01 - No MAH identified in this area	16.01.01	n.a.	-	0	0	0	0	0	n.a.	
17	17 Roads (onsite)	02-Oct-19	1.0	HAZID team	17.01 - Loss of containment from gas oil tanker	17.01.01	Loss of containment from tanker while vehicle is travelling on site	Oil delivery to site	2	1	4	2	8	Speed limit (kph) Traffic management system with one way flow. Signs and road markings. Induction training of drivers. ADR driver training, where applicable Spill on roadways - collected in drainage system (pH, TOC, conductivity). Diverted to FWR tank if not in compliance	
17	17 Roads (onsite)	02-Oct-19	1.0	HAZID team	17.02 - Loss of containment of aqueous ammonia from bulk tanker	17.02.01	Loss of containment from tanker while vehicle is travelling on site	Aqueous ammonia delivery to site	2	3	3	6	6	Speed limit (kph) Traffic management system with one way flow. Signs and road markings. Induction training of drivers. ADR driver training, where applicable Spill on roadways - collected in drainage system (pH, TOC, conductivity). Diverted to FWR tank if not in compliance	
17	17 Roads (onsite)	02-Oct-19	1.0	HAZID team	17.03 - Loss of containment of aqueous solvent waste mixture, with ignition	17.03.01	Loss of containment from tanker while vehicle is travelling on site	Aqueous solvent waste delivery to site	2	4	2	8	4	Speed limit (kph) Traffic management system with one way flow. Signs and road markings. Induction training of drivers. ADR driver training, where applicable Spill on roadways - collected in drainage system (pH, TOC, conductivity). Diverted to FWR tank if not in compliance Low solvent content, low calorific value waste stream.	
17	17 Roads (onsite)	02-Oct-19	1.0	HAZID team	17.04 - Loss of containment from IBC of nitric acid	17.04.01	Loss of containment from IBC when delivery of nitric acid is being made to the site	Nitric acid delivery	2	2	2	4	4	Speed limit (kph) Traffic management system with one way flow. Signs and road markings. Induction training of drivers. ADR driver training, where applicable Spill on roadways - collected in drainage system (pH, TOC, conductivity). Diverted to FWR tank if not in compliance	

Risk Assessment Register (RAR)

ID	Area	Date	Rev	Completed By	End Event	Initiating Event (Scenario) Ref.	Initiating Event (Scenario) Description	Activity	Frequency	Severity / Harm Human Health	Severity / Harm Environment	Risk Rating Human Health	Risk Rating Environment	Measures Existing	Measures Additional
18	18 Bottom Ash Storage Building	02-Oct-19	1.0	HAZID team	18.01 - No MAH identified in this area.		n.a.	Ash storage	0	0	0	0	0	n.a.	
19	19 Hydrogen Generation unit	02-Oct-19	1.0	HAZID team	19.01 - Loss of containment of H2 from low pressure stage (electrolysis step)	19.01.01	Evolution of H2 - no potential for explosive atmosphere to form, no MAH	Hydrogen generation	0	0	0	0	0	Low pressure H2 - indoors. Forced ventilation to protect against accumulation of H2 at ceiling	
19	19 Hydrogen Generation unit	02-Oct-19	1.0	HAZID team	19.02 - Rupture of compressor on high pressure side loss of containment of H2 at 350bar - flare / jet fire	19.02.01	Mechanical failure of compressor resulting in loss of containment, with ignition	Hydrogen generation	3	3	1	9	3	High pressure system to be designed and installed in accordance with good practice. Preventative maintenance programme. Control on ignition sources. Area not normally manned, low exposure to personnel (maintenance checks etc once per week).	Indaver to review details of supplier recommendations and controls for the high pressure H2 system prior to installations
19	19 Hydrogen Generation unit	02-Oct-19	1.0	HAZID team	19.02 - Rupture of compressor on high pressure side loss of containment of H2 at 350bar - flare / jet	19.02.02	Mechanical impact, with ignition	Hydrogen generation	2	3	1	6	2	Enclosed area for housing the hydrogen system, to protect against impacts. Speed limit on site. Control on ignition sources.	
19	19 Hydrogen Generation unit	02-Oct-19	1.0	HAZID team	19.03 - Rupture of compressor on high pressure side loss of containment of H2 at 350bar - flash fire / VCE	19.03.01	Mechanical failure of compressor resulting in loss of containment, with ignition	Hydrogen generation	2	4	1	8	2	High pressure system to be designed and installed in accordance with good practice. Preventative maintenance programme. Control on ignition sources. Area not normally manned, low exposure to personnel (maintenance checks etc once per week).	
19	19 Hydrogen Generation unit	02-Oct-19	1.0	HAZID team	19.03 - Rupture of compressor on high pressure side loss of containment of H2 at 350bar - flash fire / VCE	19.03.02	Mechanical impact, with ignition	Hydrogen generation	2	4	1	8	2	Enclosed area for housing the hydrogen system, to protect against impacts. Speed limit on site. Control on ignition sources.	
19	19 Hydrogen Generation unit	02-Oct-19	1.0	HAZID team	19.04 - Rupture of storage tank (2 tonnes) - overpressure to surrounding area	19.04.01	Catastrophic mechanical failure, with ignition	Hydrogen generation	2	5	1	10	2	High pressure system to be designed and installed in accordance with good practice. Preventative maintenance programme. Control on ignition sources. Area not normally manned, low exposure to personnel (maintenance checks etc once per week).	
19	19 Hydrogen Generation unit	02-Oct-19	1.0	HAZID team	19.04 - Rupture of storage tank (2 tonnes) - overpressure to surrounding area	19.04.02	Mechanical impact, with ignition	Hydrogen generation	2	5	1	10	2	Enclosed area for housing the hydrogen system, to protect against impacts. Speed limit on site. Control on ignition sources.	
19	19 Hydrogen Generation unit	02-Oct-19	1.0	HAZID team	19.05 - Loss of containment from road tanker - jet fire	19.05.01	Failure of transfer hose, with ignition	Hydrogen generation	3	3	1	9	3	Trained operators. Manned activity. Hose inspection prior to use. Control on ignition sources.	

Risk Assessment Register (RAR)

ID	Area	Date	Rev	Completed By	End Event	Initiating Event (Scenario) Ref.	Description	Activity	Frequency	Severity / Harm: Human Health	Severity / Harm: Environ-ment	Risk Rating: Human Health	Risk Rating: Environ-ment	Measures: Existing	Measures: Additional
	19 Hydrogen Generation unit	02-Oct-19	1.0	HAZID team	19.05 - Loss of containment from road tanker - jet fire	19.05.02	Road tanker driveaway, with ignition of release	Hydrogen generation	3	3	1	9	3	Trained operators. Manned activity with supervision from Indaver operator. Control on ignition sources.	
19	19 Hydrogen Generation unit	02-Oct-19	1.0	HAZID team	19.05 - Loss of containment from road tanker - jet fire	19.05.03	Road tanker in poor condition - corrosion, with ignition	Hydrogen generation	2	3	1	6	2	Visual inspection of tankers prior to acceptance on site. Control on ignition sources.	
19	19 Hydrogen Generation unit	02-Oct-19	1.0	HAZID team	19.06 - Loss of containment from road tanker - flash fire or VCE	19.06.01	Failure of transfer hose, with ignition	Hydrogen generation	2	4	1	8	2	Trained operators. Manned activity. Hose inspection prior to use. Control on ignition sources.	
	19 Hydrogen Generation unit	02-Oct-19	1.0	HAZID team	19.06 - Loss of containment from road tanker - flash fire or VCE	19.06.02	Road tanker driveaway, with ignition of release	Hydrogen generation	2	4	1	8	2	Trained operators. Manned activity with supervision from Indaver operator. Control on ignition sources.	
19	19 Hydrogen Generation unit	02-Oct-19	1.0	HAZID team	19.06 - Loss of containment from road tanker - flash fire or VCE	19.06.03	Road tanker in poor condition - corrosion, with ignition	Hydrogen generation	2	4	1	8	2	Visual inspection of tankers prior to acceptance on site. Control on ignition sources.	
19	19 Hydrogen Generation unit	02-Oct-19	1.0	HAZID team	19.07 - Rupture of road tanker (200kg) - overpressure to surrounding area	19.07.01	Catastrophic failure of tanker	Hydrogen generation	2	4	1	8	2	Visual inspection of tankers prior to acceptance on site. Control on ignition sources.	
20	20 Turbine	02-Oct-19	1.0	HAZID team	20.01 - Failure of turbine, resulting in vessel rupture and overpressure to surroundings	20.01.01	Failure of control system, resulting in excess temperature and pressure	Power generation	2	4	1	8	2	Control system on turbine, with monitoring of pressure, temperature and flow. Alarms on system. Interlocks to initiate safe shut down in the event of significant deviation from normal operating parameters. Pressure relief.	

Appendix 4: Recommendations Arising from HAZID&RA Exercise

The HAZID Team made the following recommendations for the Indaver facility at Duleek:

1. Indaver to conduct periodic testing of the atmospheric conditions in the bunker in Meath to see if there is any methane formation – in particular when process is stopped. Concentrations to be assessed for potential flammable hazards.

2. Fire water retention study to confirm that the bunker has the capacity to retain the fire-fighting water that would be applied in this scenario. Periodic surveys of bunker to ensure that it retains its impermeability.

3. Design of the new aqueous liquid storage tanks to incorporate measure to protect against siphoning of the tank contents (e.g. a hole in pipeline at top point on tank outlet or a check valve) in the event of line failure.

4. Review the arrangements for the provision of personal protective equipment (PPE) to drivers bringing shipments of dangerous substances to the site, to ensure that they are in accordance with good practice requirements. For ammonia deliveries, suitable respiratory protection should be provided (by reference to the Safety Data Sheet) to ensure that the personnel are protected from inhalation of toxic gas in the event of a major release.

5. Indaver to review the supplier recommendations and controls for the high pressure H2 system prior to installations and ensure that the specification meets the suppliers requirements and is compatible with the existing control systems at the site.

6. Indaver to review the customer approval procedure for screening of incoming waste streams to ensure that there are appropriate checks for unsuitable waste being fed to the hopper (for example, an LPG cylinder in the waste stream).

A full list of the measures that will be put in place at the Indaver facility (aside from these specific measures identified in the course of the HAZID&RA meeting) is contained within the HAZID&RA Worksheets in Appendix 3.

Seveso III Inventory Assessment at Duleek

Prepared for:

Indaver Ireland Limited

Ref: 462-20X0073

23rd April 2020

Byrne Ó Cléirigh, 30a Westland Square, Pearse Street, Dublin 2, D02 PN76, Ireland.
Telephone: + 353 – 1 – **6770733**. Facsimile: + 353 – 1 – **6770729**. Email: **Admin@boc.ie**. Web: **www.boc.ie**

DISCLAIMER

This report has been prepared by Byrne Ó Cléirigh Limited with all reasonable skill, care and diligence within the terms of the Contract with the Client, incorporating our Terms and Conditions and taking account of the resources devoted to it by agreement with the Client.

We disclaim any responsibility to the Client and others in respect of any matters outside the scope of the above.

This report is confidential to the Client and we accept no responsibility of whatsoever nature to third parties to whom this report, or any part thereof, is made known. Any such party relies upon the report at their own risk.

Contents

1 INTRODUCTION

At the request of Indaver Ireland Limited, Byrne Ó Cléirigh (BÓC) has conducted an assessment of the inventory of dangerous substances at the Duleek site. This assessment takes account of the list of materials currently stored and handled at the site and also the plan to introduce more materials to the site by constructing a tank farm for the storage of aqueous wastes containing a small percentage of solvent contamination as well as the storage and handling of hydrogen at a new hydrogen generation unit.

We have examined this inventory of materials to determine whether the site would qualify under the Seveso III Regulations as a result of the proposed changes[1].

2 SEVESO REGULATIONS

The Seveso III Regulations apply to operators of establishments engaged in the storage and handling of dangerous substances under the following headings.

- H - health hazards (materials that are acutely toxic to human health)
- P - physical hazards (materials presenting a fire / explosion hazard)
- E - environmental hazards (materials that are toxic to the aquatic environment)
- O - other hazards (water-reactive materials)

Schedule 1 of the regulations applies qualification thresholds to materials that fall under these headings. If the quantities of dangerous substances (q) stored by an operator exceeds these thresholds (Q), then the site qualifies as an establishment under the regulations.

The determination of whether a material falls into any of these categories is made by reference to the hazard statements that apply to it. The hazard statements are taken from the EU CLP Regulation[2].

There are two qualification thresholds in each case, one of which is used to determine if the site qualifies as a **lower tier** establishment and one which is used to determine if the site qualifies as an **upper tier** establishment.

If no single material exceeds its threshold, there is an aggregation rule in which the individual ratios (i.e. the calculated value of q/Q) for all materials within the same hazard category are added together. This aggregation is carried out for materials within each of the first three categories shown above (health, physical and environmental hazards). The aggregation rule is not applied to materials within the 'other hazards' category.

There are three possible outcomes from this aggregation process:

1. The sum of the individual ratios against the lower tier thresholds for all three hazard types is less than one (1), in which case the regulations do not apply.

[1] Chemicals act (Control of major accident hazards involving dangerous substances) regulations 2015 (SI 209 of 2015)

[2] Regulation (EC) No 1272/2008 of the European Parliament and of the Council on classification, labelling and packaging of substances and mixtures

2. The sum of the individual ratios against the lower combined inventory is greater than the lower tier threshold but less than the upper tier threshold, in which case the site qualifies as a lower tier establishment.

3. The combined inventory is greater than the upper tier threshold, in which case the site qualifies as an upper tier establishment.

3 INVENTORY OF DANGEROUS SUBSTANCES

3.1 Current operations

Indaver has provided details of the various materials that are currently stored and handled at the Duleek site. In each case we assess the materials to determine the appropriate hazard classifications to determine if they qualify under the Seveso Regulations. For those materials that do qualify, we have applied the qualifying quantities from Schedule 1 of the Regulations to determine their contribution to the overall calculation.

These are assessed in the following sub-sections.

3.1.1 Ash residues

Indaver has provided details of the composition of the boiler ash residue and flue gas residue arising from the process at Duleek. Summary details are provided in Table 1.

To determine the appropriate hazard classification of the ash residue stream, we have referred to the Classification Labelling and Packaging (CLP) Regulation[3], which is the basis for determining whether a material qualifies under Seveso III and which also describes the approach to determine if a mixture or preparation containing multiple hazardous constituents should be classed as hazardous to the environment.

Referring to the CLP Regulation, many of the heavy metals identified in flue gas and boiler ash residues are capable of forming compounds that are classed as hazardous to the aquatic environment. The rule for determining the appropriate classification for a mixture containing constituents that present this hazard is set out in Table 4.1.2 of the CLP Regulation, which we reproduce here as Table 2.

[3] Regulation (EC) No 1272/2008 of the European Parliament and of the Council on classification labelling and packaging of substances and mixtures

Table 1: Composition of ash residues at Duleek

Parameter	Units	Boiler Ash		Flue Gas Residue	
		Average	Max	Average	Max
Al	mg/kg	97,818	620,000	7,800	9,500
As	mg/kg	36	74	28	42
Ba	mg/kg	508	920	237	300
Br	mg/kg	290	440	1,630	2,200
Ca	mg/kg	177,000	230,000	280,571	410,000
Cd	mg/kg	34	42	119	160
Co	mg/kg	41	57	8	11
Cu	mg/kg	437	660	361	680
Cr	mg/kg	157	190	34	47
Fe	mg/kg	26,455	35,000	4,643	6,100
K	mg/kg	21,364	40,000	34,857	65,000
Mn	mg/kg	1,254	1,600	223	330
Mo	mg/kg	27	45	9	18
Ni	mg/kg	158	280	27	40
Pb	mg/kg	758	1,400	1,827	3,600
Sb	mg/kg	435	790	340	460
Se	mg/kg	7	10	8	10
Sn	mg/kg	319	630	386	620
Tl	mg/kg	6	6	6	6
V	mg/kg	179	350	32	71
Zn	mg/kg	7,100	11,000	7,143	12,000
Hg	mg/kg	0.1	0.3	9.1	20.0
Fluoride	mg/kg	37	71	31	50
Chloride	mg/kg	24,769	46,000	150,571	260,000
Sulphate	mg/kg	29,846	54,000	11,829	17,000
Sulphur	mg/kg	16,000	16,000	13,000	13,000
TOC %	%	0.7	1.3	1.6	2.8

Table 2: Classification of a mixture for chronic (long term) hazards, based on a summation of classified components

Sum of Components Classified as	Mixture is Classified as
Chronic Category 1 × M* ≥ 25%	Chronic Category 1
(M × 10 × Chronic Category 1) + Chronic Category 2 ≥ 25%	Chronic Category 2
(M × 100 × Chronic Category 1) + (10 × Chronic Category 2) + Chronic Category 3 ≥ 25%	Chronic Category 3
Chronic Category 1 + Chronic Category 2 + Chronic Category 3 + Chronic Category 4 ≥ 25%	Chronic Category 4

* The M-factor is a multiplying factor which may be applied where there are mixtures containing highly toxic components. This is discussed in more detail below

If the entire mixture is classed as Chronic Category 1 or 2, then it qualifies under the Seveso III Regulations. The determination of the status of the ash residue will depend on the quantities and on the relative toxicities of the various components present.

We have conducted a screening assessment of the entries of various heavy metal compounds under the CLP Regulation in order to determine the degree of toxicity to the aquatic environment that these components, or compounds containing these components, present. This is shown in Table 3.

Table 3: Toxicity data for compounds containing metals

Component	Classification of Compounds of this Material	M-Factor	Other Comments
Aluminium (Al)	n.a.	n.a.	
Arsenic (As)	Cat 1	M-1	H400 and H410 hazard statements apply, both to pure arsenic and to many common compounds of arsenic.
Barium (Ba)	Cat 3	n.a.	Barium is not classed as environmentally hazardous. However the H412 classification applies to barium oxide and so we have applied it also for this assessment.
Calcium (Ca)	n.a.	n.a.	The Calcium content in the ash comprises lime (Calcium carbonates, oxides and hydrides). These compounds are not classed as environmentally hazardous under CLP.
Cadmium (Cd)	Cat 1	M-1	H400 and H410 hazard statements apply, both to pure cadmium and to many common compounds of cadmium.
Cobalt (Co)	Cat 1	M-10	Referring to the range of Cobalt compounds identified in the CLP Regulation, a Multiplication factor of 10 applies more often than not and so we have applied it here.
Copper (Cu)	Cat 1	M-10	See note below.
Chromium (Cr)	Cat 1	M-1	H400 and/or H410 hazard statements apply, either to pure chromium or to many common compounds of chromium.
Iron (Fe)	n.a.	n.a.	
Potassium (K)	n.a.	n.a.	

Component	Classification of Compounds of this Material	M-Factor	Other Comments
Manganese (Mn)	Cat 2	n.a.	H411 hazard statement applies.
Molybdenum (Mo)	Cat 4	n.a.	H413 hazard statement applies.
Nickel (Ni)	Cat 1	M-1	Conservatively applied; the H400 classification applies to some nickel compound; many others present a lower environmental hazard.
Lead (Pb)	Cat 1	M-1	H400 and H410 hazard statements apply, both to pure lead and to many common compounds of lead.
Antimony (Sb)	Cat 2	n.a.	H411 hazard statement applies.
Selenium (Se)	Cat 1	M-1	H400 and/or H410 hazard statements apply to compounds of selenium.
Tin (Sn)	Cat 1	M-1	Multiplication factors do not generally apply to compounds containing Tin. The exception to this is in the case of organotin compounds, which are assumed not to be present in the ash / residue arising on site. Many commonly-occurring tin compounds (tin oxide, tin chloride) present a lower environmental hazard than this.
Thallium (Tl)	Cat 2	n.a.	H411 hazard statement applies.
Vanadium (V)	Cat 4	n.a.	H413 hazard statement applies.
Zinc (Zn)	Cat 1	M-1	H400 and H410 hazard statements apply, both to pure zinc and to many common compounds of zinc.
Mercury (Hg)	Cat 1	M-1	H400 and H410 hazard statements apply, both to pure mercury and to many common compounds of mercury.

Based on details provided by Indaver, the breakdown of copper compounds in the ash stream comprises the following:

- $CuCO_3$: H410, M = 10 [4]
- $Cu(OH)_2$: H410, M = 10 [4]
- CuO: H410, M = 100
- Cu: H410, M = 10
- CuCl: H410, M = 1
- $Cu_3(PO_4)_2$: Not classed as environmentally hazardous

Based on the mixture of copper compounds that may be present, the H410 hazard statement has been applied to represent the total copper content and a value of 20 has been applied to the M-factor.

We have assessed the waste data provided by Indaver based on analyses of the concentrations of each of these components in the boiler ash and in the flue gas residue. Applying these figures to the

[4] This classification applies to a mixture of copper carbonate and copper hydroxide

data for the flue gas and boiler ash, we have calculated the overall classification of the mixture in the ash. These calculations are set out in Table 4.

Table 4: Assessment of Duleek ash residues

Component	Class	M-factor	Boiler ash		Flue gas residue	
			Content (%)	(M x 10 x Cat1) + Cat 2	Content (%)	(M x 10 x Cat1) + Cat 2
Aluminium (Al)	n.a.	n.a.	9.782%	0.000%	0.780%	0.000%
Arsenic (As)	Cat 1	M-1	0.004%	0.036%	0.003%	0.028%
Barium (Ba)	Cat 3	n.a.	0.051%	0.000%	0.024%	0.000%
Calcium (Ca)	n.a.	n.a.	17.700%	0.000%	28.057%	0.000%
Cadmium (Cd)	Cat 1	M-1	0.003%	0.000%	0.012%	0.000%
Cobalt (Co)	Cat 1	M-10	0.004%	0.034%	0.001%	0.119%
Copper (Cu)	Cat 1	M-20	0.044%	0.414%	0.036%	0.080%
Chromium (Cr)	Cat 1	M-1	0.016%	8.738%	0.003%	7.229%
Iron (Fe)	n.a.	n.a.	2.645%	0.157%	0.464%	0.034%
Potassium (K)	n.a.	n.a.	2.136%	0.000%	3.486%	0.000%
Manganese (Mn)	Cat 2	n.a.	0.125%	0.000%	0.022%	0.000%
Molybdenum (Mo)	Cat 4	n.a.	0.003%	0.125%	0.001%	0.022%
Nickel (Ni)	Cat 1	M-1	0.016%	0.000%	0.003%	0.000%
Lead (Pb)	Cat 1	M-1	0.076%	0.158%	0.183%	0.027%
Antimony (Sb)	Cat 2	n.a.	0.043%	0.758%	0.034%	1.827%
Selenium (Se)	Cat 1	M-1	0.001%	0.043%	0.001%	0.034%
Tin (Sn)	Cat 1	M-1	0.032%	0.007%	0.039%	0.008%
Thallium (Tl)	Cat 2	n.a.	0.001%	0.319%	0.001%	0.386%
Vanadium (V)	Cat 4	n.a.	0.018%	0.001%	0.003%	0.001%
Zinc (Zn)	Cat 1	M-1	0.710%	0.000%	0.714%	0.000%
Mercury (Hg)	Cat 1	M-1	0.000%	7.100%	0.001%	7.143%
Totals				**17.9%**		**16.9%**

This assessment is based on the concentrations of each of the metals present in the waste residues. Based on these calculations, which apply the criteria set out in Table 2 to determine if the overall mixture would qualify as category 2 under the CLP Regulation, the total value does not reach 25% for either stream, indicating that the ashes do not qualify as a category 2 environmental hazard and so do not qualify under the Seveso Regulations.

In reality these will be present in a variety of molecules, rather than as pure elements in the waste. As such the quantities of the metallic compounds present in the wastes by mass will be slightly greater than in the values calculated above, which are based on the assumption that the metals are present in elemental form. For the purposes of scaling up the concentration figures, we have assumed that these metals are each present as metallic oxides and so we have recalculated the values for each waste stream based on the assumption that 100% of each of these metals are present as metallic oxides.

The results are shown in Table 5. We have focused only on those metals that contribute to the overall classification.

Table 5: Recalculation to allow for contribution to mass by other elements in metallic compounds

Component	Class	M-factor	Boiler ash (M x 10 x Cat1) + Cat 2	Flue gas residue (M x 10 x Cat1) + Cat 2
Arsenic	Cat 1	M-1	0.048%	0.036%
Barium	Cat 2	n.a.	0.000%	0.000%
Cadmium	Cat 1	M-1	0.038%	0.136%
Cobalt	Cat 1	M-10	0.583%	0.112%
Copper	Cat 1	M-20	9.846%	8.145%
Chromium	Cat 1	M-1	0.229%	0.050%
Manganese	Cat 1	M-1	0.198%	0.035%
Molybdenum	Cat 1	M-1	0.000%	0.000%
Nickel	Cat 1	M-1	0.201%	0.035%
Lead	Cat 1	M-1	0.836%	2.015%
Antimony	Cat 2	n.a.	0.052%	0.041%
Selenium	Cat 1	M-1	0.009%	0.011%
Tin	Cat 1	M-1	0.405%	0.491%
Thallium	Cat 2	n.a.	0.001%	0.001%
Vanadium	Cat 2	n.a.	0.000%	0.000%
Zinc	Cat 1	M-1	8.837%	8.890%
Mercury	Cat 1	M-1	0.000%	0.010%
Totals			**21.3%**	**20.0%**

The results show that the total values remain below 25% in each case, indicating that neither waste stream meets the criteria to qualify as a category 2 environmental hazard. As such the streams do not qualify under the Seveso Regulations.

3.1.2 Packaged waste

Indaver also handles shipments of packaged hazardous waste at the Duleek site. We reviewed the hazardous properties of the shipments at the site, to identify any that could qualify under the Seveso Regulations. The breakdown of these shipments by hazard category is shown in Table 6.

Table 6: Breakdown of hazardous waste packages

Hazardous waste classification	Potentially relevant under Seveso?	No. shipments	% of total
H3-A - Highly Flammable	Yes	39	33.1%
H4 - Irritant	No	19	16.1%
H5 - Harmful	No	9	7.6%
H6 - Toxic	Yes	1	0.8%
H7 - Carcinogenic	Yes	3	2.5%
H8 - Corrosive	No	23	19.5%
H10 - Teratogenic	No	29	24.6%
H11 - Mutagenic	No	1	0.8%
H13 – substances capable, after disposal, of yielding another substance with any of the above properties (e.g. as leachate).	No*	2	1.7%
H14 - Ecotoxic	Yes	17	14.4%

* There were two shipments with this classification – one of which qualified as relevant under Seveso as it was also classed as H14.

The determination of whether a waste stream could be relevant under the Seveso Regulations was based on a comparison of the hazardous properties shown here with the information in Schedule 1 of the regulations.

- H3-A highly flammable: these shipments are equivalent to P5c materials (flammable liquids) under Schedule 1.
- H6 toxic: these shipments may be equivalent to H1 or H2 materials (acute toxicity). We have checked the contents of the shipments identified as H6 to check for the constituents that give rise to this classification.
- H13 leachate:
- H14 ecotoxic: these shipments may be equivalent to E1 or E2 materials (environmental hazards). We have checked the contents of the shipments identified as H14 to check for the constituents that give rise to this classification.
- H7 carcinogen: Schedule 1 part 2 of the Seveso Regulations includes a list of named carcinogens. None of these named substances were present in the data for the waste packages identified as H7 and so they do not qualify under this category of the regulations.

Analysing the shipment sizes, the total quantity of material brought on site in drums in one year was 501 tonnes over the 118 shipments.

The breakdown of these movements was as follows:

- 189 tonnes (38%) of the total deliveries were highly flammable (P5c)
- 6.4 tonnes (0.1%) of the total deliveries were toxic. This comprised a single shipment of wood contaminated with creosote. Referring to the ECHA website, this material is a category 1B carcinogen (H350). This material is therefore not acutely toxic. Furthermore it is not included in the list of named carcinogens in Schedule 1 of the Seveso Regulations. As such this material does not qualify under the Seveso Regulations.
- 71 tonnes (14%) of the total deliveries were environmentally hazardous (E1 or E2; conservatively assumed to be E1)

Referring to the data, the largest quantity of materials delivered on site in a single day was 40.72 tonnes, comprising three shipments of waste drums. We have therefore taken this to be an upper figure for total drum storage on site.

On this basis, the total quantity of Seveso materials in the drum deliveries is taken to be as follows:

- Highly flammable (P5c): 15.34 tonnes (38% of max daily inventory)
- Environmentally hazardous (E1): 5.76 tonnes (14% of max daily inventory)

3.1.3 Other materials

Table 7 sets out a list of the other Seveso substances currently at the Duleek facility.

Table 7: List of other Seveso substances on site

Material	Quantity	Hazard Statements	Hazard Categories (Schedule 1 of Regulations)
Ammonium hydroxide (25% solution)	54 tonnes	H314, H400	E1
Diesel	45 tonnes	H226, H304, H315, H332, H351, H373, H411	Named substance
Propane	0.416 tonnes	H220, H280	Named substance
Hydrogen	0.15 tonnes	H220, H280	Named substance

3.2 Proposed new installations

The proposed development at the site will introduce two new hazardous installations, with dangerous substances present. These are as follows:

- Aqueous waste solvent tank farm
- Hydrogen generation unit

3.2.1 Aqueous waste solvent tank farm

The upgrade works for the site will include the installation of a new bulk storage tank farm, which will comprise aqueous wastes. Based on the monitoring data for the types of waste streams that will be handled at this new tank farm, the average water content of these streams is 94%. These streams will comprise a variety of flammable solvents and trace quantities of APIs.

Health Hazards

Reviewing the data on the 14 toxic shipments in more detail, we noted that in each case the toxic classification was due to the presence of methanol in the tanker. The breakdown of these waste streams is as follows: 80-100% Water, 0-6% Methanol, 0-5% Ethanol, 0-2% Isopropanol, 0-2% Acetone, <1% Dichloromethane, 0-10% Ethyl Acetate, 1-3% Tetrahydrofuran, 0-2% Acetonitrile.

Several of the materials identified in the waste data are classed as dangerous to human health, but only one of these meets the criteria to be considered H (Health Hazard), based on the criteria in Schedule 1 of the Seveso Regulations, namely Methanol This is classed as acutely toxic to human health, Category 3, by all exposure routes (H301, H311, H331). The maximum concentration of methanol in one of these tankers is therefore 6%, based on the data. The hazardous properties of methanol are H225, H331, H311, H301 and H370. It is classed as acutely toxic (category 3) by inhalation, ingestion and by skin contact. It is also classed as STOT SE1 (specific target organ toxicity – single exposure category 1).

Referring to Table 3.1 of the CLP Regulation, methanol retains its STOT SE1 classification at concentrations greater than or equal to 10%. At this level of dilution, a 10% solution of methanol would be classed as a category 4 acutely toxic material, based on the criteria in Table 3.1.2 of the CLP Regulation. As such, although the mixture would not qualify under Seveso on the basis of its acute toxicity, it would still qualify on the basis of its STOT classification. In other words, the mixture in a bulk tank will qualify as a hazard to human health under the Seveso Regulations, if the concentration of methanol ≥ 10%. On this basis, none of the waste tanker shipments qualify under the Seveso Regulations on the basis of acute toxicity.

Physical hazards

The flammable solvents qualify as P5c materials from Schedule 1 of the Seveso Regulations. As noted, the average water content in the waste streams is approximate 94%, leaving approximately 6% as flammable solvents (with trace amounts of other materials also). The determination of the whether this mixture is flammable is not based on the concentration of the solvent streams in the mixture but rather on the flash point of the mixture. If the flash point of the mixture is less than 60°C, then the mixture is classed as highly flammable – P5c. Many of the solvents in the waste data have flash points which are much lower than this and so it is conservatively assumed that the waste mixtures in the bulk tanks could be sufficiently low that the mixture would be highly flammable.

Reviewing the data on the 14 flammable waste shipments, these each comprise an aqueous mixture of water (80-100%) and flammable solvents (0-20%). Unlike materials classed as acutely toxic to human health or materials classed as environmentally hazardous, the EU CLP Regulation does not provide aggregation rules for determining the flammability of a mixture of materials. The determination is made on the basis of the flash point and boiling point of the mixture. Given the mixture of materials in these waste streams and the variation in concentration, we cannot rule out the possibility that some of these shipments would satisfy the criteria set out in Table 2.6.1 of the CLP Regulation.

- Category 1: flash point < 23°C and initial boiling point ≤ 35°C
- Category 2: flash point < 23°C and initial boiling point > 35°C

- Category 3: flash point ≥ 23°C and initial boiling point ≤ 60°C

Based on the mix of solvents present in the aqueous streams, none of the bulk tanker deliveries will qualify as category 1 flammable liquids. For the purposes of this assessment, it is assumed that these shipments will fall into the category 2 or 3 classification. In either case, this corresponds to the P5c hazard category in Schedule 1 of the Seveso Regulations.

The aqueous waste tanks therefore contribute to the Σq/Q calculation for Physical Hazards at the site. Referring to Schedule 1, the Lower Tier threshold for P5c materials is 5,000 tonnes. The two new solvent tanks will comprise 300 m^3 capacity each, giving 600 m^3 in total. The q/Q value for these materials is therefore equal to 600/5,000 = 0.12.

In addition to the inventory in the tanks, there will be additional material on site in road tankers. These tankers will be used for interim storage but we have conservatively assumed there could be up to 14 tankers present on site at one time, all of which could be in flammable service.

Environmental Hazards

Very few of the materials in the waste data are classed as environmentally hazardous and only one meets the criteria to be classed as E (Environmental Hazard) under Schedule 1, namely API. Based on data provided by Indaver, the API materials qualify as H410. A shipment of API would therefore be classed as E1 Hazardous to the aquatic environment in category Chronic 1. However, when diluted in a mixture, the classification is reduced.

Referring to the CLP Regulation, the calculation of the chronic hazards presented by a mixture is determined using the following (this is a copy of Table 4.1.2 from the CLP Regulation).

Classification of a mixture for long-term (chronic) hazards, based on summation of the concentration of classified components

Sum of components classified as:	Mixture is classified as:
Chronic 1 × M (a) ≥ 25 %	Chronic 1
(M × 10 × Chronic 1) + Chronic 2 ≥ 25 %	Chronic 2
(M × 100 × Chronic 1) + (10 × Chronic 2) + Chronic 3 ≥ 25 %	Chronic 3
Chronic 1 + Chronic 2 + Chronic 3 + Chronic 4 ≥ 25 %	Chronic 4

This means that if the concentration of a Chronic 1 material is greater than or equal to 25%, the mixture is also Chronic 1. If it is greater than or equal to 2.5%, the mixture is Chronic 2. At lower concentrations, the mixture could also be Chronic 3 or Chronic 4, but these do not meet the criteria for inclusion in the Seveso inventory.

Referring to the data from Indaver, in most cases where shipments contain API, these are in trace concentrations. They comprise wastes from aqueous washes carried out at a customer's site, where very small quantities of API materials would be included in the wash. However, one of these waste streams is identified as containing 96% water, while the remainder comprises API and excipients. At a maximum concentration of 4%, the classification for a mixture with a Chronic 1 material included would be Chronic 2. As such, there is the potential that a single tanker on site would qualify as E – Environmental Hazard in accordance with the Seveso Regulations.

When diluted further in a 300 m^3 storage tank, the concentration of API in the tank would be reduced to c.0.4%. As such, the mixture in the tank would be Chronic 3 once this mixture had been added to it. The tanks would therefore not qualify as environmentally hazardous under the Seveso Regulations.

The q/Q value for a single tanker with a mixture that is classed as E2 Hazardous to the aquatic environment in Category Chronic 2, is therefore equal to 27/200 = 0.135. Based on the data provided, there will be the occasional tanker on site to which this classification applies. To ensure that a conservative approach is adopted for the assessment, we have assumed that there could be two such tankers present at once.

3.2.2 Hydrogen Generation Unit

Indaver will also construct a hydrogen generation unit at the Duleek site. This will use water as a raw material to generate hydrogen by electrolysis. The plant will be capable of generating gas for injection into the natural gas network and for refuelling vehicles. The inventory of hydrogen will be up to 2 tonnes, based on a 100m^3 tank operating at 350 bar.

Hydrogen is classed as H220 (extremely flammable gas) under the CLP Regulation. This means that it qualifies as P2 Flammable Gas under Schedule 1 of the Seveso Regulations. Hydrogen is also included in the list of Named Substances in Schedule 1 of these Regulations, with a lower tier threshold of 5 tonnes.

This means that the presence of the hydrogen generation unit on site will have a q/Q value of 2/5 = 0.4. This will contribute to the Physical Hazards at the site.

3.3 Seveso Status of Site

Based on the findings of this assessment, we calculated the overall inventory at the Duleek site, to determine if the site would qualify as an establishment under the Seveso Regulations. The breakdown of the maximum inventory of materials at the site at one time is as shown in Table 11.

Table 11: Inventory details

Materials	Quantity (tonnes)	Hazard Statements	Other comments
14 no. road tankers with flammable solvents	378	H225	
2 no. road tankers with environmentally hazardous materials	54	H411	
Drum staging prior to furnace – drums with environmentally hazardous materials	5.76	H400, H410	
Drum staging prior to furnace – drums with flammable solvents	15.3	H225	
Ammonium hydroxide storage tank	54	H314, H400	
Diesel tank	45	H226, H304, H315, H332, H351, H373, H411	Named substance
Propane	0.416	H280,H220	Named substance
Hydrogen bulk storage	2	H220	Named substance
Hydrogen	0.15	H220	Named substance
Bulk aqueous waste solvent in tanks	600	H225	

The results of the q/Q calculation for the site are shown in Table 12.

Table 12: Inventory calculation (Σq/Q)

Category	$\Sigma q/Q_{lower\ tier}$	$\Sigma q/Q_{upper\ tier}$
Health	-	-
Physical	0.655	0.067
Environmental	0.886	0.409

Based on these results, the site will not qualify as a Seveso establishment under any of the hazard categories set out in the Seveso Regulations, even after the planned new tank farm was put in place.

4 CONCLUSIONS

Based on our assessment, the Duleek site would not qualify as a Seveso establishment with the new tank farm and with the hydrogen generation facility in place.

We note that the lower tier Σq/Q value for environmental hazards is relatively high, at 0.886, but there are several conservative assumptions built into the storage scenario, in effect assuming that all vessels were filled to capacity and that there were two road tankers present on site at the same time, where both tankers contained heptane at a concentration of 2.5% or greater. In practice, the site inventory will be lower than this.

The assessment of the ash residues has found that they do not meet the criteria to qualify as Seveso substances. The results of the calculations in this report show that the concentrations of metals in the ash / residue is too low for them to be classed as category 2 environmental hazards, which means that the ash residues do not meet the criteria in Schedule 1 of the Seveso Regulations and so the ash / residue streams do not qualify as Seveso substances.

Appendix 6: Consequence Modelling for Fires in Bunker Area

1 Introduction

The purpose of this Appendix is to determine the impacts associated with an accidental fire in the solid waste bunker area of the Indaver facility at Duleek and examine the potential impacts to the surrounding area.

The Hazard Identification and Risk Assessment (HAZID&RA) Team identified a fire in this location as a credible accident scenario. The primary hazards for a fire in this location are the potential impacts associated with products of combustion (CO, HCl, SO_2 and Dioxins).

The waste bunker has dimensions of 35 m × 18 m and will typically store c.4,000 tonnes of waste, with a capacity to store up to 6,000 tonnes.

2 Overview of Fire Scenarios

Indaver's operational experience is that smouldering of the incoming wastes can be occasionally caused e.g. by hot ashes in dustbins. The normal response in such cases is that the crane operator would remove any smouldering material using the grab crane and load it into the hopper feeding the furnace, where it would be burned under controlled conditions. The grab crane has the capacity to lift approximately 3 cubic metres of waste, equivalent to 1.2 tonnes at one time. This response would help to protect against escalation of the fire event. Nonetheless, the HAZID&RA team considered the possibility that a fire could escalate to larger sizes. The fire scenarios that have been examined for the bunker area are therefore as follows:

- Fire of 1 tonne of waste. This involves smouldering of the waste rather than a major fire event and it is conservatively assumed that up to 1 tonnes could be consumed in this scenario.
- Fire in bunker, extinguished by the fixed fire protection systems. This is a more remote event, which would involve failure of the initial response using the grab crane but the fire is extinguished by the fire protection systems at the bunker area. Based on the properties of the waste and the anticipated spread of fire in this instance, it is estimated that the fire could continue for a maximum of 2 hours, with up to 26.7 tonnes of waste being burned in this scenario.
- Full bunker fire. This is the most unlikely fire scenario at the bunker, requiring failure of both the initial response and of the fire protection systems. It is assumed for the purposes of this assessment that if the fire escalates to this extent that it would no longer be practicable to extinguish it and instead the response would be to allow it to burn down while focus of the fire fighting efforts would be to protect nearby plant and equipment.

3 Emissions from a Bunker Fire

In mass emission terms, the primary emissions in the smoke plume in the event of a fire in the bunker would be by-products of combustion as a result of the Carbon, Chlorine and Sulphur content of the waste. There could also be the potential for emissions of Dioxins from a fire in this area of the plant.

The waste in the bunker will comprise 30-35% water and 65-70% solids. Of this solids content, it will comprise c.80% Carbon, 0.4% Chlorine and 0.1% Sulphur.

3.1 Rate of Burning

As mentioned above, the waste in the bunker will comprise 30-35% water and 65-70% solids. Based on Indaver's operational experience at other facilities involved in the storage and handling of similar waste streams, the average calorific value of this waste is expected to be 9.6 MJ/kg.

In the initial stages of a fire in the bunker, this would involve a slow smouldering burn within the waste stream. A representative burning rate of 1 tonne of waste being consumed within 30 minutes was used. This slow burn would result in a correspondingly low emission rate to atmosphere. However, it is also expected that the resulting smoke plume would have lower buoyancy and there would be less plume rise than for a fully developed fire.

In the event that the scenario escalates into a fully developed fire, the rate of burning will be determined by the properties of the waste and (in the worst case scenario) by the dimensions of the bunker.

The Yellow Book[1] provides data on typical burning rates for a variety of materials. We have extracted the data for a selection of these materials in Table 1. We have also included details of the energy content of these materials, for reference.

[1] "Methods for the calculation of physical effects due to releases of hazardous materials (liquids and gases)"

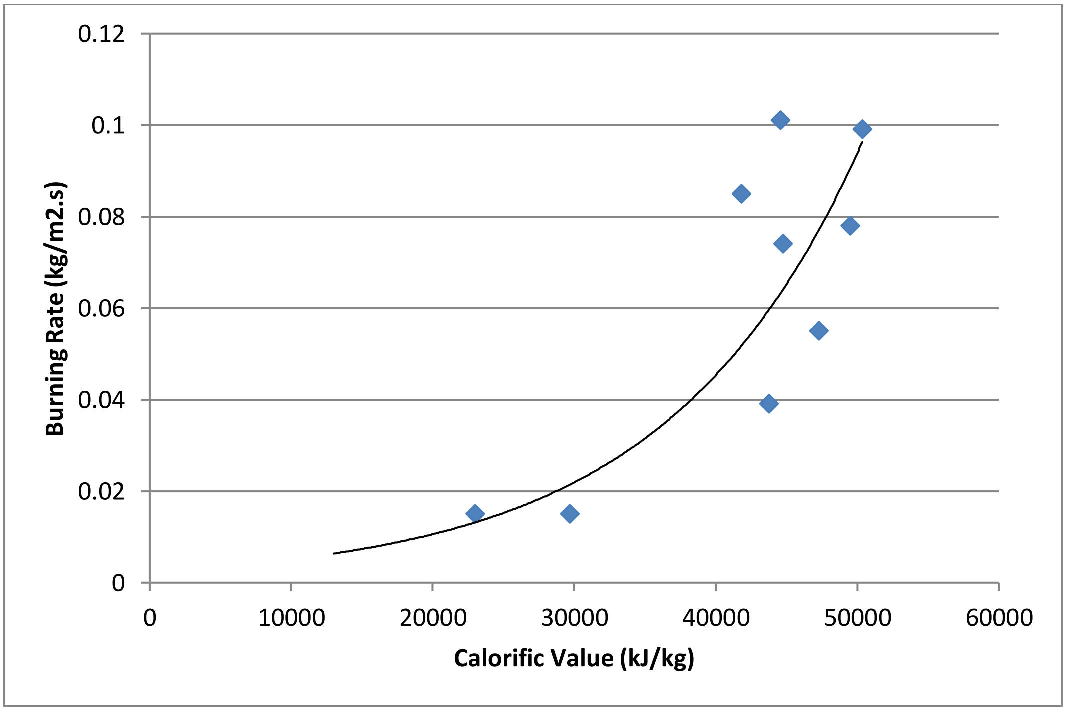
Table 1: Data on Burning Rates and Energy Content of Fuels

Fuel	Calorific Value (kJ/kg)	Rate of Burning (kg/m^2.s))
Propane	50,350	0.099
Butane	49,510	0.078
Hexane	44,752	0.074
Heptane	44,566	0.101
Benzene	41,800	0.085
Gasoline	47,300	0.055
Kerosene	43,750	0.039
Methanol	23,000	0.015
Ethanol	29,700	0.015

Figure 1 shows a plot of Burning Rate vs. Calorific values for these materials. This indicates that there is a relationship between the two parameters and we have added a best-fit line to this data.

Applying this assessment to the bunker waste, which has a calorific value of 9,600 kJ/kg, this would give a rate of burning of 0.005 kg/m^2.s. However we are conscious that this assessment involves extrapolation outside of the data range and so in order to ensure a conservative approach, we have doubled this figure in order to determine a maximum burning rate of 0.01 kg/m^2.s. This works out as a slightly lower burning rate for an equivalently sized pool of methanol or ethanol.

Figure 1: Plot of Burning Rate vs. Energy Content



The surface area of the bunker is 35 m × 18 m = 630 m^2. Based on the calculations shown above, this means that the maximum burning rate in the bunker would be of the order of 0.385 tonnes per minute, or 23.1 tonnes per hour. This rate of burning would only arise where the fire is fully developed and covers the full areas of the bunker. For a typical inventory of 4,000 tonnes these results indicate that a fully developed bunker fire could continue for approximately one week.

For the intermediate fire scenario, i.e. where the fire escalates beyond the initial smouldering phase but has not spread to the full extent of the bunker area, we have applied a burning rate of 50% of the calculated maximum value.

The details of the three fire scenarios are summarised in Table 2.

Table 2: Burning Rates for different Fire Scenarios at the Bunker

Parameter	Minor Fire, Smouldering Waste in Bunker	Intermediate Fire, extinguished by Emergency Response	Fully Developed Bunker Fire
Total quantity of waste burned (tonnes)	1	23.1	4,000
Rate of burning (t/hr)	2	11.55	23.1

Based on data provided by Indaver, the rate of evolution of flue gas to atmosphere arising from a fire in the bunker area would be c.6000 Nm^3 per tonne of waste consumed.

For the purposes of this assessment we have also made the following assumptions about the smoke plume. For a scenario involving a smouldering 1 tonne fire, the resulting smoke plume would exhibit low thermal buoyancy as the fire would be in the early stages of development. A temperature of 50°C was used for modelling the impacts of this scenario. For the more developed bunker fire scenarios, the temperature of the gases would be much higher. A figure of 300°C has been used for the smoke plume from the intermediate fire and 500°C for the fully developed fire.

3.2 By Products of Combustion of Carbon, Chlorine and Sulphur

Based on data provided by Indaver, the bunker waste will comprise up to 65% solid matter. This solid fraction will typically comprise c.80% Carbon, 0.4% Chlorine and 0.1% Sulphur, by weight. In other words, for every tonne of waste burned, there would be 0.52 tonne Carbon, 0.0026 tonne Chlorine and 0.0007 tonne Sulphur consumed.

Referring to the HSA's guidance document for Land Use Planning (LUP) provides conversion factors for the purposes of calculating combustion products from a fire. The relevant details are summarised below:

- Carbon Monoxide (CO): 9.7% C to CO
- Hydrogen Chloride (HCl): 100% Cl to HCl
- Sulphur Dioxide (SO_2): 100% S to SO_2

There would also be Carbon Dioxide formed in the fire, but the toxic impacts of this component of the smoke plume would be negligible when compared with the Carbon Monoxide emission.

On this basis, we have calculated the emission rates to atmosphere for these products of combustion for the three fire scenarios identified for the bunker. These are set out in Table 3.

Table 3: Emission Rates of Products of Combustion for Bunker Fire Scenarios

Parameter	Minor Fire, Smouldering Waste in Bunker	Intermediate Fire, extinguished by Emergency Response	Fully Developed Bunker Fire
Rate of burning (t/hr)	2	13.4	26.7
Emission rates			
Carbon Monoxide	0.103 kg/s	0.594 kg/s	1.187 kg/s
Hydrogen Chloride	0.0015 kg/s	0.0086 kg/s	0.0172 kg/s
Sulphur Dioxide	0.0007 kg/s	0.0042 kg/s	0.0083 kg/s

To assess the impacts of these emissions on the surrounding area, we have used the Probit function which is used to determine the relationship between dose exposure and potential lethal effects (see main report for more details on this function). The scenarios have been modelled to determine the maximum hazard distances to the AEGL-2 endpoint[2] and to a 1% lethality dosage level.

These model runs were conducted using AERSCREEN, a software package developed by the USEPA. This software is used to model the impacts of the release in order to calculate the worst case impacts at distance, based on worst case weather conditions.

It should be noted that it is possible that there would be no emissions to atmosphere for the smaller fire scenarios as the Reception Hall is kept under negative pressure. Combustion air for the incinerators is drawn into the process via the reception hall in order to suppress odours. As such it is possible that the smoke plume arising from the fire would be drawn into the incinerator and treated in the abatement system, which includes filters. As such this assessment has been conducted on a conservative basis.

3.2.1 Carbon Monoxide

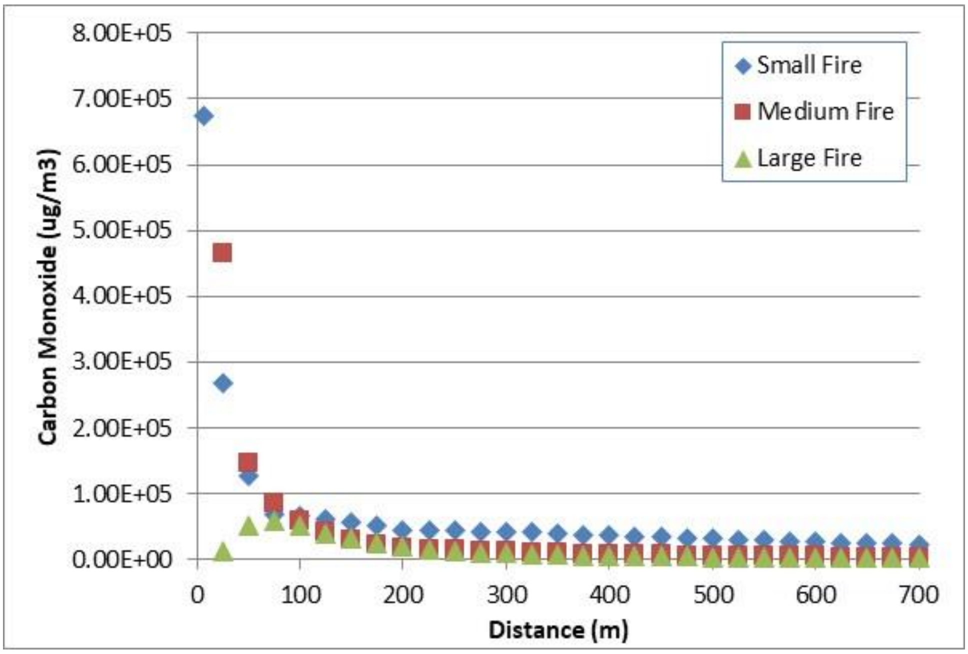
The model results for the Carbon Monoxide emissions are shown in Figure 2. This plot shows how the concentration profile varies with distance for each of the fire scenarios. Comparing the results, the impacts to the surrounding area are broadly comparable in the case of the minor fire and the intermediate fire. The impacts are less significant in the case of the fully developed fire due to the high plume buoyancy that arises in this scenario.

The maximum concentrations in the immediate vicinity of the fire tend to arise in conditions of high wind speed, as this can give rise to grounding of potentially buoyant plumes. However at longer

[2] Acute Exposure Guideline Level 2 – this is defined by the US EPA as the airborne concentration (expressed as ppm or mg/m3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

distances, the worst case impacts arise in calm conditions. As mentioned above, the model determines the worst case impacts at each distance, based on worst case weather conditions.

Figure 2: Consequence Modelling Results – Atmospheric Dispersion of CO following Bunker Fire



The AEGL-2 concentration for CO is 83 ppm or 96.6 mg/m^3. Referring to the model results for these fires, the maximum distances to this endpoint are as follows:

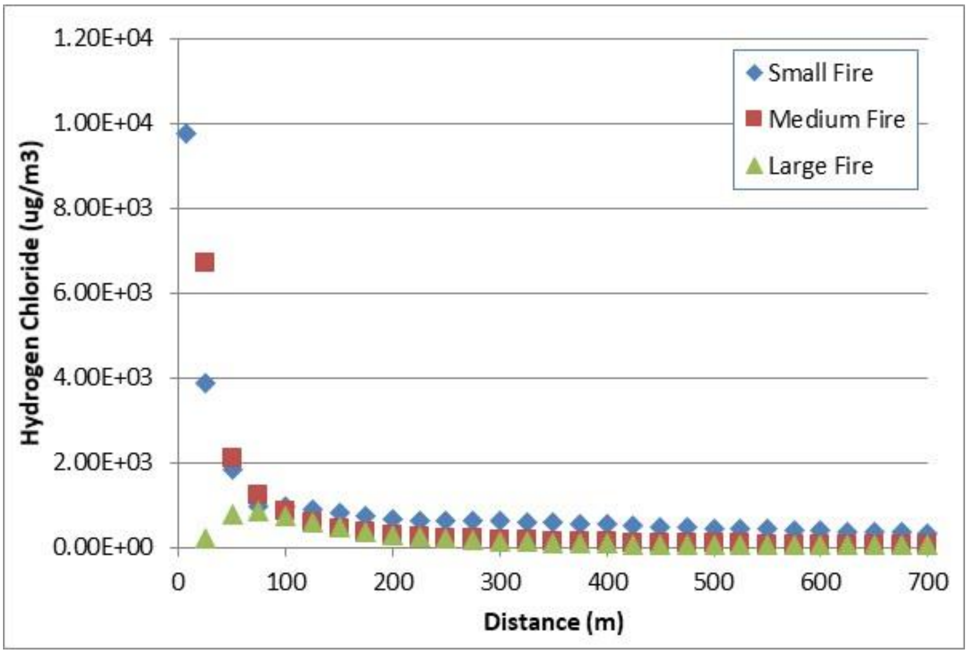
- Small Fire: 70 m
- Intermediate Fire: 75 m
- Major Fire: n.a. this concentration is not reached at any downwind receptor

Assessing the results using the Probit function in order to determine the potential for lethal effects from CO exposure, the results show that the 1% Dangerous Dose could be experienced in the immediate vicinity of the fire only and would not extend to any other buildings on site or to any off-site locations.

3.2.2 Hydrogen Chloride

The consequence modelling results for Hydrogen Chloride emissions from the bunker fire are shown in Figure 3.

Figure 3: Consequence Modelling Results – Atmospheric Dispersion of HCl following Bunker Fire

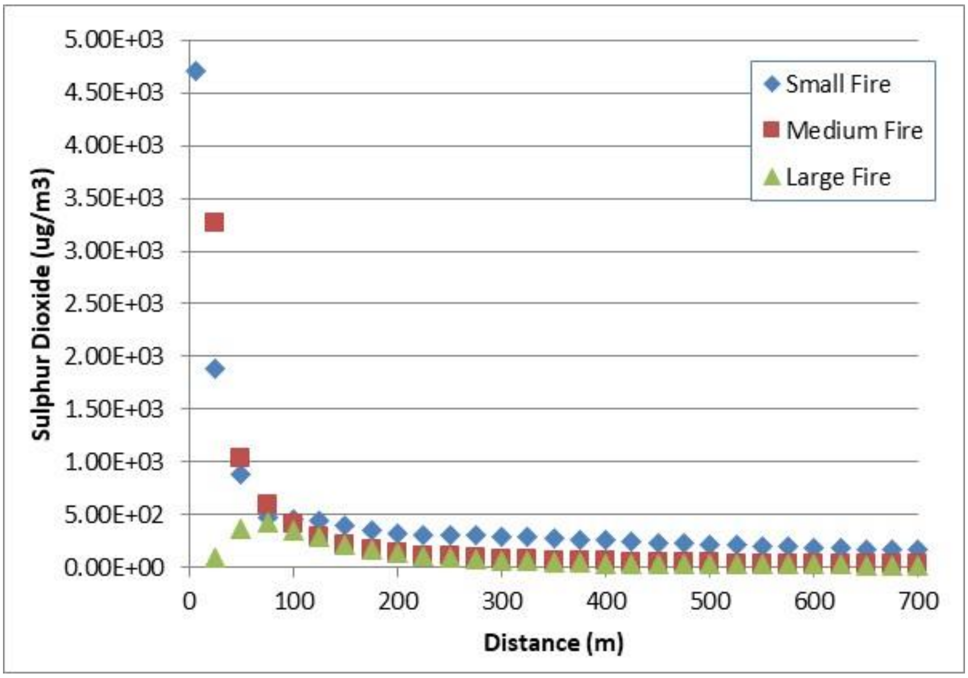


The AEGL-2 concentration for HCl is 22 ppm or 33 mg/m^3. This concentration is not reached at any location downwind of the fire. Similarly the results show that there is no risk of exposure to a dangerous dose of HCl from this scenario.

3.2.3 Sulphur Dioxide

The consequence modelling results for Sulphur Dioxide emissions from the bunker fire are shown in Figure 4.

Figure 4: Consequence Modelling Results – Atmospheric Dispersion of SO_2 following Bunker Fire



The AEGL-2 concentration for SO_2 is 0.75 ppm or 2 mg/m^3. Referring to the model results for these fires, the maximum distances to this endpoint are as follows:

- Small Fire: 24 m
- Intermediate Fire: 35 m
- Major Fire: n.a. this concentration is not reached at any downwind receptor

Using the probit function, the results show that there is no risk of exposure to a dangerous dose of HCl from this scenario at any buildings in the surrounding area, either on site or off site.

3.3 Dioxins

There are a number of reports in the literature, which quote the quantity of dioxins that could be emitted from various types of accidental fires. These included reports on emissions from house fires, building fires, chimney fires, forest fires, and vehicle fires. A figure of 72.8 ng of dioxins I-TEQ per kg of material combusted has been selected as representative of the dioxin emissions from an MSW fire.

This figure was selected as the most suitable analogue for a bunker fire because it is the reported average result from 7 trial burns involving open burning of municipal wastes in the USA. The trials were conducted by the US EPA as a means of estimating the portion of the US national dioxin burden caused by back yard burning of domestic refuse (trash) in barrels. This method of disposing of domestic waste is reported to be very common outside urbanised areas in the US. The measurements conducted showed dioxin emissions which ranged from 10 to 6000 ng I-TEQ dioxins per kg of waste burned. However it should be noted that the highest figures recorded were from fires involving wastes which had been deliberately “spiked” with high chlorine contents e.g. a prepared waste containing 7.5% by weight of PVC. This figure of 72.8 ng of dioxins I-TEQ per kg of material combusted is considered to still be valid for a fire scenario at the bunker.

The emission rates to atmosphere for the three fire scenarios at the bunker are shown in Table 4.

Table 4: Emission Rates of Dioxins for Bunker Fire Scenarios

Parameter	Minor Fire, Smouldering Waste in Bunker	Intermediate Fire, extinguished by Emergency Response	Fully Developed Bunker Fire
Rate of burning (t/hr)	2	11.6	23.1
Duration of fire (hr)	0.5	2	168
Dioxin Emission factor (ng I-TEQ per kg)	72.8	72.8	72.8
Dioxin emission rates	4.04×10^{-8} g/s	2.34×10^{-7} g/s	4.67×10^{-7} g/s

The potential impacts of these emissions on the surrounding area were assessed by dispersion modelling. In this case we have focused the assessment on the closest potentially vulnerable off-site receptors.

- Closest residence, c.300 m from bunker (max. conc: 1.68×10^{-5} µg/m^3)
- Duleek village: c.3 km from bunker: (max. conc: 2.1×10^{-6} µg/m^3)

The impacts are summarised in Table 5.

In order to determine the impacts of these emissions in the short-term, the US EPA had established a maximum 8-hr average exposure to workers on remediation sites of 0.2 ng/m^3 I-TEQ. The results in Table 5 show that this concentration level would not be reached at either location, even in the worst case conditions. However, the concentrations in the immediate vicinity of the fire would be elevated and it would be necessary for emergency responders to wear appropriate respiratory protection to protect from the smoke fumes.

In addition to assessing the concentrations in the surrounding area, and assessment was also made on the potential dioxin intake to people in the vicinity based on these potential accident scenarios.

Table 5: Impacts of Dioxin Emissions (Dioxin intake)

Impacts at Downwind Receptors	Minor Fire		Intermediate Fire		Fully Developed Fire	
	Residence	Duleek	Residence	Duleek	Residence	Duleek
Distance (m)	300	3,000	300	3,000	300	3,000
Max conc (ug/m^3)	1.68×10^{-5}	2.1×10^{-6}	4.89×10^{-6}	6.39×10^{-7}	3.98×10^{-6}	6.03×10^{-7}
Exposure time (hr)	0.5	0.5	2	2	4	4
Daily inhalation (m^3/day)	20	20	20	20	20	20
Inhalation per event (m^3)	0.42	0.42	1.67	1.67	3.33	3.33
Representative intake (ug)	7.0×10^{-6}	8.7×10^{-7}	8.2×10^{-6}	1.1×10^{-6}	1.3×10^{-5}	2.0×10^{-6}
Cumulative intake (ug)	7.0×10^{-6}	8.7×10^{-7}	1.3×10^{-5}	1.7×10^{-6}	2.0×10^{-5}	2.7×10^{-6}
Frequency (years)	1	1	20	20	100	100
Average intake (per annum)	7.0×10^{-6}	8.7×10^{-7}	6.6×10^{-7}	8.4×10^{-8}	2.0×10^{-7}	2.7×10^{-8}
Average intake (per day)	1.92×10^{-8}	2.4×10^{-9}	1.8×10^{-9}	2.3×10^{-10}	5.4×10^{-10}	7.3×10^{-11}

The following assumptions were made in this calculation:

- In the event of a fully developed fire, it is assumed that the emergency response approach would be to evacuate the area in the vicinity. An upper figure of 4 hours has been selected as the maximum exposure time.
- Based on typical respiration rates, a person at either receptor would inhale 20 m^3 of air over a 24-hour period.
- As the fire event escalates, the calculated overall dioxin exposure is cumulative (e.g. for the fully developed fire, persons in the vicinity would be exposed to concentrations typical of minor fires for the first ½ hour, of concentrations typical to an intermediate fire for the following 1.5 hours and of a fully developed fire for the remaining 2 hours.
- The following conservative assumptions were made to the analysis of the frequency of these scenarios, for the purposes of the dioxin intake calculation:
  - Instances involving smouldering waste could arise every few years. For the purposes of this assessment it has been assumed that such a fire could arise on an annual basis.
  - The intermediate fire is assumed to occur once in 20 years.
  - The fully developed fire is assumed to occur once in 100 years.

Combining the overall, the expected annual intake of Dioxins at the two locations is calculated by summing the figures for all three fires:

- Dioxin intake at nearest residence: 2.15×10^{-8} per day
- Dioxin intake at closest point at Duleek village: 2.7×10^{-9} per day

The impacts of this intake are assessed further in Table 6.

Table 6: Impacts of Potential Dioxin Intake

	Nearest Residence	Duleek Village
Average intake (ug/day)	2.15×10^{-8}	2.7×10^{-9}
Body weight (kg)	70	70
Average Intake (ug/day per kg)	3.07×10^{-10}	3.85×10^{-11}
Average Intake (pg/day per kg)	3.07×10^{-4}	3.85×10^{-5}
Safety Margin compared with WHO ceiling	3,253	25,960

It has been assumed that the same people are present each year, for the purposes of calculating their potential cumulative exposure.

The combined intake is compared with a figure of 1.0 pg I-TEQ per day per kg body weight, which is a ceiling value established by the WHO. The results show that the expected dioxin intake to people in the vicinity of the site would be several orders of magnitude less than this figure.

Sensitivity Analysis

As a final sensitivity analysis on the results, we have also calculated the effects if the dioxin emission rate was higher than had been assumed here. The figure of 72.8 ng/kg for the dioxin emission was a mean value taken from a US EPA study. However, due to the variety of sources examined by the US EPA there was a large degree of scatter in the emissions data. The highest emission rate cited in the US EPA study was an emission rate of 2,769 ng/kg of waste. This was exhibited by a stream involving household wastes with a high recycling effort, resulting in a high PVC content (4.5%). If this figure was applied to the emissions from a bunker fire, the overall dioxin intake to people in the vicinity would increase proportionately. Even in this case, the total intake would still be significantly lower than the WHO ceiling; the factors of safety would be reduced to:

- Nearest residence: Factor of Safety = 86
- Closest point at Duleek village: Factor of Safety = 683

Even based on this conservative emission rate, there would still be a significant factor of safety for any people located at either potentially sensitive location.