Appendix 8

Air Quality

Appendices 8.1- 8.9

8

APPENDIX 8.1 - AIR QUALITY STUDY

Executive Summary

The Ringaskiddy Resource Recovery Centre facility will consist of a grate incinerator for the treatment of residual municipal waste and other suitable wastes.

Air dispersion modelling was carried out using the United States Environmental Protection Agency's (USEPA) regulatory model AERMOD (version 18081). The aim of the study was to assess the effect in the ambient environment of emissions from the facility at the emission limits outlined in Council Directive 2010/75/EU. Modelling was also conducted under abnormal operating conditions to assess any short-term effect due to these infrequent events. The study demonstrates that all substances which will be emitted from the proposed facility will be at levels that are well below even the most stringent ambient air quality standards and guidelines. The dispersion model study consisted of the following components:

- Review of design emission levels and other relevant information needed for the modelling study;
- Identification of the significant substances which will be released from the facility;
- Review of background ambient air quality in the vicinity of the proposed facility;
- Air dispersion modelling of significant substances released from the facility;
- Particulate deposition modelling of Dioxins & Furans, Polycyclic Aromatic Hydrocarbons (PAHs) and heavy metals released from the facility;
- Identification of predicted ground level concentrations of released substances beyond the facility boundary and at sensitive receptors in the immediate environment;
- Evaluation of the significance of these predicted concentrations, including consideration of whether these ground level concentrations are likely to exceed the most stringent ambient air quality standards and guidelines which have been set for the protection of human health;
- Effect on public health and the environment in the unlikely event of "abnormal" operating conditions;
- The cumulative effect from the facility and surrounding industrial sources has also been undertaken.

Modelling and a subsequent impact assessment were undertaken for the following substances released from the facility:

- Nitrogen dioxide (NO_2) and Nitrogen Oxides (NO_X);
- Sulphur Dioxide (SO_2);
- Total Dust (as PM_{10} (particulate matter less than 10 microns) and $PM_{2.5}$ (particulate matter less than 2.5 microns));
- Gaseous and vaporous organic substances expressed as total organic carbon (TOC);
- Hydrogen Chloride (HCl);
- Hydrogen Fluoride (HF);
- Polycyclic Aromatic Hydrocarbons (PAHs);
- PCDD/PCDFs (Dioxins/Furans);
- Mercury (Hg);
- Cadmium (Cd) and Thallium (Tl);
- And Other Heavy Metals (as the sum of Antimony (Sb), Arsenic (As), Lead (Pb), Chromium (Cr), Cobalt (Co), Copper (Cu), Manganese (Mn), Nickel (Ni) and Vanadium (V)).

Assessment Approach

Emissions from the facility have been assessed firstly under maximum operating conditions and secondly under abnormal operating conditions. Maximum operations are based on a moving grate incinerator operating at the emission limits defined in EU Directive 2010/75/EU. Abnormal operating conditions refer to short-term periods in which the limits detailed in EU Directive 2010/75/EU are exceeded.

This is a conservative approach as the proposed facility will typically operate at levels well within emission limits defined in the EU Directive.

Modelling Under Maximum & Abnormal Operating Conditions

In order to assess the potential effect from the proposed facility under maximum and abnormal operations, a conservative approach was adopted that is designed to over-predict ground level concentrations. This cautious approach will ensure that an over-estimation of effects will occur and that the resultant emission standards adopted are protective of ambient air quality. The approach incorporated several conservative assumptions regarding operating conditions at the proposed facility. This approach incorporated the following features:

- For the maximum operating scenario, it has been assumed that the emission points are continuously operating at their maximum operating volume flow. This will over-estimate the actual mass emissions from the facility.

- For the maximum operating scenario, it has been assumed that the emission points are operating for 24-hrs/day over the course of the full year.

- Abnormal operating emissions were pessimistically assumed to occur as outlined below:

    - NO_X - 400 mg/m^3 for 3% of the year (11 days per annum);
    - SO_2 - 200 mg/m^3 for 3% of the year (11 days per annum);
    - Total Dust - 30 mg/m^3 for 3% of the year (11 days per annum);
    - TOC - 30 mg/m^3 for 3% of the year (11 days per annum);
    - HCl - 60 mg/m^3 for 3% of the year (11 days per annum);
    - HF - 4 mg/m^3 for 3% of the year (11 days per annum);
    - CO - 200 mg/m^3 for 5% of the year (18 days per annum);
    - Dioxins & Furans - 0.5 ng/m^3 for 3% of the year (11 days per annum);
    - Heavy Metals (other than Hg, Cd & Tl) - 30 mg/m^3 for 3% of the year (11 days per annum);
    - Cd & Tl - 0.2 mg/m^3 for 3% of the year (11 days per annum);
    - Hg - 1 mg/m^3 for 3% of the year (11 days per annum).

- Worst-case meteorological conditions over the period 2014 - 2018 from Cork Airport and the on-site meteorological data from 2007 have been used in all assessments. For all averaging periods the worst-case year from 2007, 2014 - 2018 was used for comparison with the ambient air quality standards.

As a result of these conservative assumptions, there will be an over-estimation of the emissions from the facility and the effect of the proposed facility on human health and the surrounding environment.

Modelled Locations

In relation to the spatial assessment of emissions from the facility, modelling has been carried out to cover locations at the boundary and within a radius of 10 km of the facility, regardless of whether any sensitive receptors are located in the area. Ambient air quality legislation designed to protect human health (i.e. by setting ambient limit values for a range of pollutants) is generally based on assessing ambient air quality at locations where the exposure of the population is significant relevant to the averaging time of the pollutant. However, in the current assessment, ambient air quality legislation has been applied to all locations regardless of whether any sensitive receptors (such as residential locations) are present for significant periods of time. This represents a worst-case approach and an examination of the corresponding concentrations at the nearest sensitive receptors relative to the actual quoted maximum concentration indicates that these receptors generally experience ambient concentrations significantly lower than that reported for the maximum value.

Ambient air concentrations have also been predicted at the most sensitive residential receptors in Cobh, Monkstown and Ringaskiddy and the surrounding geographical area as far away as Passage West, Carrigaline and Crosshaven.

Cumulative Assessment

The region around the Ringaskiddy Resource Recovery Centre is partly industrialised and thus has several other potential sources of pollutants. As a result, an investigation of facilities with IED Licences has been undertaken in the region as outlined in **Appendix 8.4**.

The effect of additional traffic associated with the facility has also been incorporated into the existing baseline concentrations thus ensuring all sources of air emissions in the region have been taken into account. This is detailed in **Appendix 8.3**.

Interaction of the wind turbine and potential effects of the plume were also assessed as outlined in **Appendix 8.8**. The assessment found that the difference in the maximum concentrations at the worst-case receptor at ground level for the years modelled are not significantly impacted by the wind turbine. The maximum difference in the "With" and "Without" scenarios for the 1-hour results (measured as a 99.8th%ile) was a difference of 4.3% of the 1-hour limit value whilst annual mean results agreed within 1.1% of the limit value. All other turbines in the region are at a significantly greater distance from the facility and will have an insignificant interaction with the plume.

Baseline Air Quality Assessment

An extensive baseline survey was carried out in the region of the proposed facility over the period from October 2018 to January 2019. The survey focused on the significant pollutants likely to be emitted from the facility and which have been regulated under Council Directive 2010/75/EU. The survey updates previous surveys which were undertaken in 2001, between 2006 – 2008 and from August 2014 to July 2015.

Nitrogen dioxide (NO_2) concentrations measured over the 2018-19 monitoring period were below both the 1-hour and annual EU limit values which is in line with the previous surveys in the region. During the monitoring period no exceedence of the 1-hour limit value of 200 $\mu g/m^3$ was observed whilst the mean over this period was 10.1 $\mu g/m^3$ which is 25% of the annual NO_2 limit value. The 2018 NO_2 diffusion tube concentrations measured over the three-month survey period are below the annual EU limit value of 40 $\mu g/m^3$ for the protection of human health. The average NO_2 concentration measured over the three-month period at each location ranged from 6 - 16 $\mu g/m^3$ which is between 16 - 42% of the EU annual limit

value of 40 μg/m^3. The results indicate a weak NO_2 spatial concentration gradient in the region.

The PM_{10} concentrations measured over the three-month period are below the 24-hour EU limit value of 50 μg/m^3 and there were no exceedances of the 24-hour limit value recorded over the three months of this monitoring campaign. The 90.4th%ile, which means the 36th highest value measured over a full year is compared to the limit value. Since there were no exceedances recorded over the three months of monitoring, it is extremely unlikely that 35 exceedances would occur over 365 days at the current location. The average PM_{10} concentration measured over the three-month period is 16.4 μg/m^3 which is only 40% of the EU annual limit value of 40 μg/m^3.

The average $PM_{2.5}$ concentration measured over the three-month period is 14.9 μg/m^3 which is below the annual average EU limit value of 25 μg/m^3. A $PM_{2.5}/PM_{10}$ ratio for the monitoring period of 0.88 has been calculated.

SO_2 diffusion tube concentrations measured over the three-month survey period are below the annual EU limit value of 20 μg/m^3 for the protection of vegetation. The average SO_2 concentration measured over the three-month period at each location ranged from 2.1 – 13.6 μg/m^3 which is between 11% – 68% of the EU annual limit value of 20 μg/m^3.

Benzene diffusion tube concentrations measured over the three-month survey period are below the annual EU limit value of 5 μg/m^3 for the protection of human health. The average benzene concentration measured over the three-month period at each location ranged from 0.8 – 3.4 μg/m^3 which is between 16% - 69% of the EU annual limit value of 5 μg/m^3.

The HF and HCl diffusion tube concentrations measured over the three-month survey period are well below the UK EALs. The average HF concentration measured over the three-month period is 0.32 μg/m^3, which is only 2% of the annual limit value of 16 μg/m^3. The average HCl concentration measured over the three-month monitoring period is 2.21 μg/m^3 which is 11% of the annual limit value of 20 μg/m^3.

The average concentrations of antimony (Sb), arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb), thallium (Tl) and vanadium (V) were significantly below their respective annual limit values, with average levels reaching only 0.04% - 47% of these limits.

Background levels of PCDD / PCDFs cannot be compared to ambient air quality concentration or deposition standards. However, levels of PCDDs and PCDFs can be compared to existing levels measured sporadically in Ireland and continuously in the UK as part of the TOMPS network. The mean PCDD/PCDF concentration measured over the period October 2018 – January 2019 indicates that results are in line with measurements conducted elsewhere in Ireland, with an upper limit of 21.5 fg/m^3 compared to previous measurements ranging from 2.8 – 46 fg/m^3.

Study Conclusions

The main study conclusions are presented below for each substance in turn:

NO_2 & NO_X

NO_2 modelling results indicate that the ambient ground level concentrations will be below the relevant air quality standards for the protection of human health for nitrogen dioxide under maximum and abnormal operation of the facility. Thus, no adverse effect on public health or

the environment is envisaged to occur under these conditions at or beyond the facility boundary. Emissions at maximum operations lead to ambient NO_2 concentrations (including background concentrations) which are 69% of the maximum ambient 1-hour limit value (measured as a 99.8th%ile) and 33% of the annual average limit value at the respective worst-case receptors.

The annual average NO_X concentration (including background concentration) will also be below the limit value for the protection of vegetation accounting for 60% of the annual limit value at the worst-case receptor in the region of the Lough Beg Proposed NHA and the Cork Harbour SPA.

SO_2, CO, PM_{10} & $PM_{2.5}$

Modelling results indicate that ambient ground level concentrations will be below the relevant air quality standards for the protection of human health for sulphur dioxide, carbon monoxide and PM_{10} under maximum and abnormal operation of the facility. Results will also be below the air quality standard for $PM_{2.5}$ under maximum and abnormal operation of the facility. Thus, no adverse effect on public health or the environment is envisaged to occur under these conditions at or beyond the facility boundary. Emissions at maximum operations equate to ambient concentrations (including background concentrations) ranging from 10% - 56% of the respective limit values at the worst-case receptors.

TOC, HCl & HF

Modelling results indicate that the ambient ground level concentrations will be below the relevant air quality guidelines for the protection of human health for TOC (assumed pessimistically to consist solely of benzene), HCl and HF under maximum and abnormal operation of the facility. Thus, no adverse effect on public health or the environment is envisaged to occur under these conditions at or beyond the facility boundary. Emissions at maximum operations equate to ambient concentrations (including background concentrations) for HCl and TOC of only 6% and 21% respectively of the ambient limit values.

HF modelling results indicate that emissions at maximum operations equate to ambient HF concentrations (including background concentrations) which will be 0.9% of the maximum ambient 1-hour limit value and 0.4% of the annual limit value.

PCDD / PCDFs (Dioxins/Furans)

Currently, no internationally recognised ambient air quality concentration or deposition standards exist for PCDD/PCDFs (Dioxins/Furans). The EU, USEPA and WHO recommended approach to assessing the risk to human health from Dioxins/Furans entails a detailed risk assessment analysis involving the determination of the effect of Dioxins/Furans in terms of the TDI (Tolerable Daily Intake) or TWI (Tolerable Weekly Intake) approach. The EU currently proposes a maximum TWI of between 14 pg WHO-TEQ/kg of body weight per day.

Background levels of Dioxins/Furans occur everywhere and existing levels in the surrounding area have been extensively monitored as part of this study. Monitoring results indicate that the existing levels are similar to rural areas in the UK and Ireland. The contribution from the facility in this context is minor, with levels at the worst-case receptor to the south of the facility, under maximum and abnormal operation, accounting for only a small fraction of existing levels. Levels at the nearest residential receptor will be minor, with the annual contribution from the proposed facility accounting for less than 1% of the existing background concentration under maximum operating conditions.

PAHs

PAHs modelling results indicate that the ambient ground level concentrations will be below the relevant air quality target value for the protection of human health under maximum and abnormal operation of the facility. Thus, no adverse effect on public health or the environment is envisaged to occur under these conditions at or beyond the facility boundary. Emissions at maximum operations equate to ambient benzo[*a*]pyrene concentrations (excluding background concentrations) which are 1.2% of the EU annual average target value at the worst-case receptor.

Hg

Hg modelling results indicate that the ambient ground level concentrations will be below the relevant air quality standards for the protection of human health under maximum and abnormal operation of the facility. Thus, no adverse effect on public health or the environment is envisaged to occur under these conditions at or beyond the facility boundary. Emissions at maximum operations equate to ambient mercury concentrations (including background concentrations) which are only 0.2% of the annual average limit value at the worst-case receptor.

Cd and Tl

Modelling results indicate that the ambient ground level concentrations will be below the relevant air quality standard for the protection of human health for cadmium under maximum and abnormal operation from the facility. Emissions at maximum levels equate to ambient Cd and Tl concentrations (including background concentrations) which are 28% of the EU annual target value for Cd close to the facility boundary (the comparison is made with the Cd limit value as this is more stringent than that for Tl).

Sum of As, Sb, Pb, Cr, Co, Cu, Ni, Mn and V

Modelling results indicate that the ambient ground level concentrations will be below the relevant air quality standards for the protection of human health for arsenic (As), nickel (Ni) and vanadium (V) (the metals with the most stringent limit values) under maximum and abnormal operation emissions from the facility (based on the ratio of metals measured at a Waste to Energy facility in Carranstown, County Meath). Thus, no adverse effect on public health or the environment is envisaged to occur under these conditions at or beyond the facility boundary. Ambient concentrations have been compared to the annual target value for As and Ni and the maximum 1-hour limit value for V as these represent the most stringent limit values for the suite of metals. Emissions at maximum operations equate to ambient As and Ni concentrations (including background concentrations) which are 17% and 48% of the EU annual target value respectively at the worst-case receptor whilst emissions at maximum operations equate to ambient V concentrations (including background concentrations) which are only 0.3% of the maximum 1-hour limit value at the worst-case receptor. Emissions under abnormal operations equate to ambient As and Ni concentrations (including background concentrations) which are 18% and 56% of the annual limit value respectively at the worst-case receptor whilst emissions at maximum operations equate to ambient V concentrations (including background concentrations) which are 0.4% of the maximum 1-hour limit value at the worst-case receptor.

National Emissions Ceiling

A comparison of the proposed Facility's operations with the obligations under the National Emissions Ceiling Directive indicates the effect of the development is to increase SO_2 levels

by 0.41% of the ceiling levels to be complied with in 2020, NO_X levels by 0.64% of the ceiling levels, VOC levels will be increased by 0.05% of the ceiling limits whilst $PM_{2.5}$ levels will be increased by 0.21% of the ceiling limits.

Summary

Modelling results indicate that the ambient ground level concentrations will be below the relevant air quality standards or guidelines for the protection of human health for all parameters under maximum and abnormal operation of the facility. The modelling results indicate that the long-term maximum concentrations occur near the southern and south-eastern boundaries of the facility. Maximum operations are based on the emission concentrations outlined in EU Directive 2010/75/EU.

An appropriate stack height has been selected to ensure that ambient air quality standards for the protection of human health will not be approached even under abnormal operating scenarios. The stack height determined by air dispersion modelling which will lead to adequate dispersion was 70 metres.

The spatial effect of the facility is limited with concentrations falling off rapidly away from the maximum peak. For example, the short-term concentrations due to process emissions at the nearest residential receptor will be less than 19% of the short-term ambient air quality limit values. The annual average concentration has an even more dramatic decrease in maximum concentration away from the facility with concentrations from emissions at the proposed facility accounting for less than 2% of the limit value (not including background concentrations) at worst case sensitive receptors near the facility.

8.1 Introduction

The Ringaskiddy Resource Recovery Centre will have one furnace and flue gas cleaning line. The line will have an 80MW moving grate furnace with a state-of-the-art flue gas cleaning system.

The combustion of waste produces a number of emissions, the discharges of which are regulated by the EU Directive on Industrial Emissions (IED) (2010/75/EU). The emissions to atmosphere which have been regulated are:

- Nitrogen Dioxide (NO_2)
- Sulphur Dioxide (SO_2)
- Total Dust (as PM_{10} and $PM_{2.5}$)
- Carbon Monoxide (CO)
- Total Organic Carbon (TOC)
- Hydrogen Fluoride (HF) and Hydrogen Chloride (HCl)
- Dioxins/Furans (PCDD/PCDFs)
- Cadmium (Cd) & Thallium (Tl)
- Mercury (Hg)
- and the sum of Antimony (Sb), Arsenic (As), Lead (Pb), Chromium (Cr), Cobalt (Co), Copper (Cu), Manganese (Mn), Nickel (Ni) and Vanadium (V).

In addition, Polycyclic Aromatic Hydrocarbons (PAHs) have been assessed as incineration is a potential emission source for this group of compounds.

The scope of the study consists of the following components:

- Review of maximum emission levels and other relevant information needed for the modelling study;
- Identification of the significant substances which are released from the facility;
- Review of background ambient air quality in the vicinity of the facility;
- Air dispersion modelling of significant substances released from the facility;
- Particulate deposition modelling of Dioxins & Furans, Polycyclic Aromatic Hydrocarbons (PAHs) and heavy metals released from the facility;
- Identification of predicted ground level concentrations of released substances at the facility boundary and at sensitive receptors in the immediate environment;
- Evaluation of the significance of these predicted concentrations, including consideration of whether these ground level concentrations are likely to exceed the most stringent ambient air quality standards and guidelines.

8.1.1 Modelling Under Maximum & Abnormal Operating Conditions

In order to assess the potential effect from the proposed facility under maximum and abnormal operations, a conservative approach was adopted that is designed to over-predict ground level concentrations. This cautious approach will ensure that an over-estimation of effects will occur and that the resultant emission standards adopted are protective of ambient air quality. The approach incorporated several conservative assumptions regarding operating conditions at the proposed facility. This approach incorporated the following features:

- For the maximum operating scenario, it has been assumed that the emission point is continuously operating at its maximum operating volume flow. This will over-estimate the actual mass emissions from the facility.

- For the maximum operating scenario, it has been assumed that the emission point is operating at maximum capacity for 24-hrs/day over the course of the full year.

- Abnormal operating emissions were obtained from the process engineer and are pessimistically assumed to occur as outlined below:

    - NO_X - 400 mg/m^3 for 3% of the year (11 days per annum)
    - SO_2 - 200 mg/m^3 for 3% of the year (11 days per annum)
    - Total Dust - 30 mg/m^3 for 3% of the year (11 days per annum)
    - TOC - 30 mg/m^3 for 3% of the year (11 days per annum)
    - HCl - 60 mg/m^3 for 3% of the year (11 days per annum)
    - HF - 4 mg/m^3 for 3% of the year (11 days per annum)
    - CO - 200 mg/m^3 for 5% of the year (18 days per annum)
    - Dioxins & Furans - 0.5 ng/m^3 for 3% of the year (11 days per annum)
    - Heavy Metals (other than Hg, Cd & Tl) - 30 mg/m^3 for 3% of the year (11 days per annum)
    - Cd & Tl - 0.2 mg/m^3 for 3% of the year (11 days per annum)
    - Hg - 1 mg/m^3 for 3% of the year (11 days per annum).

As a result of these conservative assumptions, there will be an over-estimation of the emissions from the facility and the effect of the proposed facility on human health and the surrounding environment.

8.2 Study Methodology

8.2.1 Introduction

The air dispersion modelling input data consists of detailed information on the physical environment (including building dimensions and terrain features), design details from all emission points on-site and a full year of worst-case meteorological data. Using this input data, the model predicts ambient ground level concentrations beyond the facility boundary for each hour of the modelled meteorological year. The model post-processes the data to identify the location and maximum value of the worst-case ground level concentration in the applicable format for comparison with the relevant limit values. This worst-case concentration is then added to the existing background concentration to give the worst-case predicted ambient concentration. The worst-case ambient concentration is then compared with the relevant ambient air quality standard for the protection of human health to assess the significance of the emissions from the facility.

Throughout this study a worst-case approach was taken. This will most likely lead to an over-estimation of the levels that will arise in practice. The worst-case assumptions are outlined below:

- Emissions from all emission points in the assessment were assumed to be operating at their maximum emission level, 24 hours/day over the course of a full year. This represents a very conservative approach as typical emissions from the proposed facility will be well within the emission limit values set out in the Industrial Emissions Directive.

- Maximum predicted ambient concentrations for all pollutants within a 10 km radius of the facility were reported in this study even though, in many cases, no residential receptors were near the location of this maximum ambient concentration. Concentrations at the nearest residential receptors are generally significantly lower than the maximum ambient concentrations reported.

- Worst-case background concentrations were used to assess the baseline levels of substances released from the facility.

- Worst-case meteorological conditions over the period 2014 - 2018 from Cork Airport and the on-site meteorological data from 2007 have been used in all assessments. For all averaging periods the worst-case year from 2007, 2014 - 2018 was used for comparison with the ambient air quality standards.

8.2.2 Meteorological Considerations

Meteorological data is an important input into the air dispersion model. The local airflow pattern will be influenced by the geographical location. Important features will be the location of hills and valleys or land-water-air interfaces and whether the facility is located in simple or complex terrain.

The selection of the appropriate meteorological data has followed the guidance issued by the USEPA[(1)]. A primary requirement is that the data used should have a data capture of greater than 90% for all parameters, including cloud cover, based on an analysis of the data on a quarterly basis. One synoptic meteorological station operated by Met Eireann was identified near the Facility – Cork Airport. Data collection of greater than 90% for all parameters in each quarter is required for air dispersion modelling. Cork Airport fulfils this requirement.

The additional requirements of the selection process depend on the degree to which the data is considered to be representative of the modelled domain. This criterion can be defined as "the extent to which a set of measurements taken in a space-time domain reflects the actual conditions in the same or different space-time domain taken on a scale appropriate for a specific application"[(2)]. The meteorological data should be representative of conditions affecting the transport and dispersion of pollutants in the area of interest as determined by the location of the sources and receptors being modelled.

The representativeness of the data is dependent on[(1)]:

1) the proximity of the meteorological monitoring site to the area under consideration,

2) the complexity of the terrain,

3) the exposure of the meteorological monitoring site (surface characteristics around the meteorological site should be similar to the surface characteristics within the modelling domain),

4) the period of time during which data is collected.

In the region of the facility, Cork Airport meteorological station is in a region of gentle rolling terrain and is 12km of the site. The meteorological data used in the assessment (2014 - 2018) is a recent dataset. The final issue relates to the exposure of the meteorological monitoring site and specifically relating to the surface characteristics of the station compared to the site of the proposed facility. Cork Airport is 12km from the coast and in a region of mainly agricultural land with urban characteristics to the north of the airport. In contrast, Ringaskiddy is in a coastal setting with a range of surface characteristics including water, agricultural and urban within a few kilometres of the site. Thus, some differences in surface characteristics are apparent between the meteorological station and the site. In order to ascertain the likely significance of the difference in surface characteristics, a sensitivity study was conducted as shown in **Appendix 8.5** including comparing with Roches Point meteorological station which is located within the modelling domain. Roches Point is an

automatic station which collects all relevant meteorological data with the exception of cloud cover. Roches Point was used in the model with the missing cloud cover data substituted with Cork Airport data for the same time period. Additionally, a weather station was installed on-site which measured wind speed, wind direction, temperature and relative humidity starting in October 2006 and finished at the end of December 2007. The on-site meteorological data for 2007 was used in AERMOD modelling study and in the CALPUFF modelling study as detailed in Section 8.12.

The windrose from Cork Airport for the years 2014 - 2018 is shown in Figure 8.3 with detailed data outlined in **Appendix 8.2**. The windrose indicates the prevailing wind speed and direction over the five-year period. The prevailing wind direction is generally from the south to north-westerly in direction over the period 2014 - 2018. The mean wind speed is approximately 5.4 m/s over the period 1981-2010. Calm conditions account for only a small fraction of the time in any one-year peaking at 44 hours in 2014 (0.5% of the time). The number of missing hours is also very low with no missing hours / year over the period 2014 – 2018.

8.2.3 Modelling Methodology

Emissions from the proposed facility have been modelled using the AERMOD dispersion model (Version 18081) which has been developed by the U.S. Environmental Protection Agency (USEPA)[3]. The model is a steady-state Gaussian plume model used to assess pollutant concentrations associated with industrial sources. The model has been designated the regulatory model by the USEPA for modelling emissions from industrial sources in both flat and complex terrain[1]. An overview of the model is outlined in **Appendix 8.2**.

The AERMOD model is capable of modelling most meteorological conditions likely to be encountered in the region. However, unusual meteorological conditions may occur infrequently, which may not be modelled adequately using AERMOD. One such condition is fumigation which occurs when a plume is emitted into a stable layer of air which subsequently mixes to ground level through either convective transfer of heat from the surface or because of advection to less stable surroundings[1]. A recommended air dispersion model is CALPUFF[1] (full details are outlined in Section 8.12).

8.2.4 Sensitive Receptors

In relation to the spatial assessment of emissions from the facility, modelling has been carried out to cover locations at the boundary and within a radius of 10 km of the facility, regardless of whether any sensitive receptors are located in the area. Ambient air quality legislation designed to protect human health (i.e. by setting ambient limit values for a range of pollutants) is generally based on assessing ambient air quality at locations where the exposure of the population is significant relevant to the averaging time of the pollutant. However, in the current assessment, ambient air quality legislation has been applied to all locations regardless of whether any sensitive receptors (such as residential locations) are present for significant periods of time. This represents a worst-case approach and an examination of the corresponding concentrations at the nearest sensitive receptors relative to the actual quoted maximum concentration indicates that these receptors generally experience ambient concentrations significantly lower than that reported for the maximum value.

The closest sensitive receptors to the facility are the residential properties at the eastern edge of Ringaskiddy village which are located 200 m west of the facility boundary. The Lough Beg proposed NHA is approximately 500 m south of the facility boundary.

8.2.5 Terrain

The AERMOD air dispersion model has a terrain pre-processor AERMAP[4] which was used to map the physical environment in detail over the receptor grid. The digital terrain input data used in the AERMAP pre-processor was obtained from the US Jet Propulsion Laboratory Shuttle RADAR Topography Mission (SRTM) at 1 arc-second (30m) resolution. This data was run to obtain for each receptor point the terrain height and the terrain height scale. The terrain height scale is used in AERMOD to calculate the critical dividing streamline height, H_{crit}, for each receptor. The terrain height scale is derived from the Digitial Elevation Model (DEM) files in AERMAP by computing the relief height of the DEM point relative to the height of the receptor and determining the slope. If the slope is less than 10%, the program goes to the next DEM point. If the slope is 10% or greater, the controlling hill height is updated if it is higher than the stored hill height.

In areas of complex terrain, AERMOD models the impact of terrain using the concept of the dividing streamline (H_c). As outlined in the AERMOD model formulation[1] a plume embedded in the flow below H_c tends to remain horizontal; it might go around the hill or impact on it. A plume above H_c will ride over the hill. Associated with this is a tendency for the plume to be depressed toward the terrain surface, for the flow to speed up, and for vertical turbulent intensities to increase.

AERMOD model formulation captures the effect of flow above and below the dividing streamline by weighting the plume concentration associated with two possible extreme states of the boundary layer (horizontal plume and terrain-following). The relative weighting of the two states depends on: 1) the degree of atmospheric stability; 2) the wind speed; and 3) the plume height relative to terrain. In stable conditions, the horizontal plume "dominates" and is given greater weight while in neutral and unstable conditions, the plume traveling over the terrain is more heavily weighted[2].

The terrain in the region of the facility is complex in the sense that the maximum terrain in the modelling domain peaks at 162m which is above the stack top of all emission points onsite. However, in general, as shown in Figure 8.2, the region of the site has gentle or moderately sloping terrain.

8.2.6 Geophysical Considerations

AERMOD simulates the dispersion process using planetary boundary layer (PBL) scaling theory[3]. PBL depth and the dispersion of pollutants within this layer are influenced by specific surface characteristics such as surface roughness, albedo and the availability of surface moisture. Surface roughness is a measure of the aerodynamic roughness of the surface and is related to the height of the roughness element. Albedo is a measure of the reflectivity of the surface whilst the Bowen ratio is a measure of the availability of surface moisture.

AERMOD incorporates a meteorological pre-processor AERMET[35] to enable the calculation of the appropriate parameters. The AERMET meteorological preprocessor requires the input of surface characteristics, including surface roughness (z_0), Bowen Ratio and albedo by sector and season, as well as hourly observations of wind speed, wind direction, cloud cover, and temperature. The values of albedo, Bowen Ratio and surface roughness depend on land-use type (e.g., urban, cultivated land etc) and vary with seasons and wind direction. The assessment of appropriate land-use type was carried out to a distance of 10km from the meteorological station for Bowen Ratio and albedo and to a distance of 1km for surface roughness in line with USEPA recommendations[4,5] as outlined in **Appendix 8.2**.

In relation to AERMOD, detailed guidance for calculating the relevant surface parameters has been published[6]. The most pertinent features are:

- The surface characteristics should be those of the meteorological site (Cork Airport) rather than the installation;
- Surface roughness should use a default 1km radius upwind of the meteorological tower and should be based on an inverse-distance weighted geometric mean. If land use varies around the site, the land use should be sub-divided by sectors with a minimum sector size of 30º;
- Bowen ratio and albedo should be based on a 10km grid. The Bowen ratio should be based on an un-weighted geometric mean. The albedo should be based on a simple un-weighted arithmetic mean.

AERMOD has an associated pre-processor, AERSURFACE[5], which has representative values for these parameters depending on land use type. The AERSURFACE pre-processor currently only accepts NLCD92 land use data which covers the USA. Thus, manual input of surface parameters is necessary when modelling in Ireland. Ordnance survey discovery maps (1:50,000) and digital maps such as those provided by the EPA, National Parks and Wildlife Service (NPWS) and Google Earth® are useful in determining the relevant land use in the region of the meteorological station. The Alaska Department of Environmental Conservation has issued a guidance note for the manual calculation of geometric mean for surface roughness and Bowen ratio for use in AERMET[6]. This approach has been applied to the current site with full details provided in **Appendix 8.2**.

8.2.7 Building Downwash

When modelling emissions from an industrial installation, stacks which are relatively short can be subjected to additional turbulence due to the presence of nearby buildings. Buildings are considered nearby if they are within five times the lesser of the building height or maximum projected building width (but not greater than 800m).

The USEPA has defined the “Good Engineering Practice” (GEP) stack height as the building height plus 1.5 times the lesser of the building height or maximum projected building width. It is generally considered unlikely that building downwash will occur when stacks are at or greater than GEP[1].

When stacks are less than this height, building downwash will tend to occur. As the wind approaches a building it is forced upwards and around the building leading to the formation of turbulent eddies. In the lee of the building these eddies will lead to downward mixing (reduced plume centreline and reduced plume rise) and the creation of a cavity zone (near wake) where re-circulation of the air can occur. Plumes released from short stacks may be entrained in this airflow leading to higher ground level concentrations than in the absence of the building.

The Plume Rise Model Enhancements (PRIME)[7,8] plume rise and building downwash algorithms, which calculates the impact of buildings on plume rise and dispersion, have been incorporated into AERMOD. The building input processor BPIP-PRIME produces the parameters which are required in order to run PRIME. The model takes into account the position of each stack relative to each relevant building and the projected shape of each building for 36 wind directions (at 10º intervals). The model determines the change in plume centreline location with downwind distance based on the slope of the mean streamlines and coupled to a numerical plume rise model[8].

Given that the main stack onsite is less than 2.5 times the lesser of the building height or maximum projected building width, building downwash will need to be taken into account and the PRIME algorithm run prior to modelling with AERMOD. Shown in Figure 8.8 is an example of the dominant building (in blue) which is influencing the building downwash for the main stack (A1-1). The dominant building may change as the wind direction changes for

each of the 36 wind directions. The dominant building will vary as a function of wind direction and relative building heights.

8.2.8 Assessment Methodology

Council Directive 2010/75/EU

Council Directive 2010/75/EU on Industrial Emissions (IED) has outlined air emission limit values as set out in Table A8.1. The Directive has also outlined stringent operating conditions in order to ensure sufficient combustion of waste thus ensuring that dioxin formation is minimised. Specifically, the combustion gases must be maintained at a temperature of 850°C for at least two seconds under normal operating conditions for non-hazardous waste whilst for hazardous waste containing more than 1% halogenated organic substances, the temperature should be raised to 1,100°C for at least two seconds. These measures will ensure that dioxins/furans, polychlorinated biphenyls (PCBs) and PAHs are minimised through complete combustion of waste.

Specific emission measurement requirements have been outlined in the directive for each pollutant:

1) continuous measurements of the following substances; NO_x, CO, total dust, TOC, HCl, and SO_2;
2) bi-annual measurements of heavy metals, dioxins and furans.

Indaver is committed, as a minimum, to meeting all the requirements of Council Directive 2010/75/EU. Indeed, due to the advanced post-combustion flue gas cleaning technology employed, expected average emission values will be lower than the maximum values used in this study. The maximum and average emission concentrations and mass emission rates have been detailed in Table A8.2.

The advanced post-combustion flue gas cleaning technology which will be employed to control emissions of pollutants is detailed in Chapter 4.

Guidelines On Air Quality Models

The selection of appropriate modelling methodology has followed the guidance from the EPA[9] and the USEPA[1,10,11] which have issued detailed and comprehensive guidance on the selection and use of air quality models.

Based on guidance from the USEPA, the most appropriate regulatory model for the current application is the AERMOD model (Version 18081). The model is applicable in both simple and complex terrain, urban or rural locations and for all averaging periods[1,3]. The selection of the urban/rural classification is based on the land use procedure of Auer[12] as recommended by the USEPA[1]. If 50% of the land use within a 3km circumference of the source is classified as high density residential, medium to heavy industry or commercial, the urban boundary layer option should be used; otherwise the rural boundary layer should be used. An examination of the land-use type around the facility indicated that the rural boundary layer was appropriate.

Table A8.1 Council Directive 2010/75/EU, Annex V Air Emission Limit Values

Daily Average Values	**Concentration**	
Total Dust	10 mg/m^3	
Gaseous & vaporous organic substances expressed as total organic carbon (TOC)	10 mg/m^3	
Hydrogen Chloride (HCl)	10 mg/m^3	
Hydrogen Fluoride (HF)	1 mg/m^3	
Sulphur Dioxide (SO_2)	50 mg/m^3	
Nitrogen Oxides (as NO_2)	200 mg/m^3	
Half-hourly Average Values	**Concentration**	
	(100%)	**(97%)**
Total Dust(1)	30 mg/m^3	10 mg/m^3
Gaseous & vaporous organic substances expressed as total organic carbon (TOC)	20 mg/m^3	10 mg/m^3
Hydrogen Chloride (HCl)	60 mg/m^3	10 mg/m^3
Hydrogen Fluoride (HF)	4 mg/m^3	2 mg/m^3
Sulphur Dioxide (SO_2)	200 mg/m^3	50 mg/m^3
Nitrogen Oxides (as NO_2)	400 mg/m^3	200 mg/m^3
Average Value Over 30 mins to 8 Hours	**Concentration**(2)	
Cadmium and its compounds, expressed as Cd	Total 0.05 mg/m^3	
Thallium and its compounds, expressed as Tl		
Mercury and its compounds, expressed as Hg	0.05 mg/m^3	
Antimony and its compounds, expressed as Sb	Total 0.5 mg/m^3	
Arsenic and its compounds, expressed as As		
Lead and its compounds, expressed as Pb		
Chromium and its compounds, expressed as Cr		
Cobalt and its compounds, expressed as Co		
Copper and its compounds, expressed as Cu		
Manganese and its compounds, expressed as Mn		
Nickel and its compounds, expressed as Ni		
Vanadium and its compounds, expressed as V		
Average Values Over 6 – 8 Hours	**Concentration**	
Dioxins and furans	0.1 ng/m^3	
Average Value	**Concentration**(3)	
	Daily Average Value	**30 Min Average Value**
Carbon Monoxide	50 mg/m^3	100 mg/m^3

(1) Total dust emission may not exceed 150 mg/m^3 as a half-hourly average under any circumstances
(2) These values cover also the gaseous and vapour forms of the relevant heavy metals as well as their compounds
(3) Exemptions may be authorised for incineration plants using fluidised bed technology, provided that emission limit values do not exceed 100 mg/m^3 as an hourly average value.

Table A8.2 Air Emission Values From The Proposed Ringaskiddy Resource Recovery Centre, County Cork.

Maximum 30-Minute Values	**EU Maximum Emission Concentration**	**Annual Average Daily Emission Concentration**	**Maximum Operating Values(1)**	**Average Operating Values(2)**
			Emission Rate (g/s)	**Emission Rate (g/s)**
Total Dust	30 mg/m^3	10 mg/m^3	1.76	0.45
Gaseous & vaporous organic substances expressed as total organic carbon (TOC)	20 mg/m^3	10 mg/m^3	1.17	0.45
Hydrogen Chloride (HCl)	60 mg/m^3	10 mg/m^3	3.52	0.45
Hydrogen Fluoride (HF)	4 mg/m^3	1.0 mg/m^3	0.23	0.045
Sulphur Dioxide (SO_2)	200 mg/m^3	50 mg/m^3	11.7	2.25
Nitrogen Oxides (as NO_2)	400 mg/m^3	200 mg/m^3	23.4	9.0
Daily Average Value	**Emission Concentration**	**Emission Concentration**	**Emission Rate (g/s)**	**Emission Rate (g/s)**
Cadmium and its compounds, expressed as Cd	Total 0.05 mg/m^3	Total 0.05 mg/m^3	0.0029	0.0023
Thallium and its compounds, expressed as Tl				
Mercury and its compounds, expressed as Hg	0.05 mg/m^3	0.05 mg/m^3	0.0029	0.0023
Antimony and its compounds, expressed as Sb	Total 0.5 mg/m^3	Total 0.50 mg/m^3	0.029	0.023
Arsenic and its compounds, expressed as As				
Lead and its compounds, expressed as Pb				
Chromium and its compounds, expressed as Cr				
Cobalt and its compounds, expressed as Co				
Copper and its compounds, expressed as Cu				
Manganese and its compounds, expressed as Mn				
Nickel and its compounds, expressed as Ni				
Vanadium and its compounds, expressed as V				
Average Values Over 6 – 8 Hours	**Emission Concentration**	**Emission Concentration**	**Emission Rate (µg/s)**	**Emission Rate (µg/s)**
Dioxins and furans	0.1 ng/m^3	0.1 ng/m^3	0.0059	0.0045
Average Value	**Emission Concentration**	**Emission Concentration**	**Emission Rate (g/s)**	**Emission Rate (g/s)**
Carbon Monoxide	100 mg/m^3	50 mg/m^3	5.86	2.25

(1) Maximum operating value based on maximum emission concentration in Council Directive 2010/75/EC and maximum volume flow.
(2) Average operating value based on maximum emission concentration in Council Directive 2010/75/EC and average volume flow.

8.3 ASSESSMENT OF BASELINE AIR QUALITY

8.3.1 Introduction

An extensive baseline survey was carried out in the region of the proposed Ringaskiddy Resource Recovery Centre facility over the period October 2018 to January 2019. This supplements the extensive baseline surveys undertaken in November 2006 to February 2007, from April 2008 to July 2008 and August 2014 to July 2015. These surveys focused on the significant pollutants likely to be emitted from the facility and which have been regulated in Council Directive 2010/75/EU. The substances monitored over these survey periods were NO_2, NO_X, PM_{10}, $PM_{2.5}$, benzene, SO_2, heavy metals, HCl, HF and PCDDs/PCDFs. The air monitoring program was used to determine long-term average concentrations for these pollutants in order to help quantify the existing ambient air quality in the region. NO_2, benzene and SO_2 were also monitored at a number of additional locations to give some spatial representation of the levels of these species.

The updated extensive baseline survey which was carried out in the region of the proposed Ringaskiddy Resource Recovery Centre facility over the period October 2018 to January 2019 focused on NO_2, PM_{10}, $PM_{2.5}$, benzene, SO_2, HCl, HF, PCDDs/PCDFs (dioxins/furans) and heavy metals over a 3-month long period. The air monitoring program was used to determine long-term average concentrations for these pollutants in order to help quantify the existing ambient air quality in the region. NO_2, benzene and SO_2 were also monitored at a number of additional locations to give greater spatial representation of the levels of these species.

8.3.2 Methodology

NO_2

Monitoring of nitrogen dioxide in the vicinity of Ringaskiddy was carried out using two sampling methods: chemiluminescent analysis and passive diffusion. Continuous monitoring of NO_2 was performed using a chemiluminescent analyser (Thermo Environmental Instruments, Model 42C) over a three-month period (03rd October 2018 – 03rd January 2019) at one static monitoring station (Hammond Lane Metals Recycling, see Figure 8.1) which is adjacent to the proposed waste to energy site. In this method, the NO_x ($NO + NO_2$) concentration is determined based on its direct relationship with the level of energy emitted by chemiluminescent NO_2, which is formed when nitric oxide (NO) is reacted with ozone (O_3) in an evacuated chamber within the analyser. One of the major advantages of this monitoring method is that it provides high resolution continuous measurement of NO_2, and hence the results can be used to compare with the hourly limit value. In addition, the average NO_2 level measured over the three-month monitoring period allows an approximate comparison with the annual limit value.

The spatial variation in NO_2 levels away from sources is particularly important, as a complex relationship exists between NO, NO_2 and O_3 leading to a non-linear variation of NO_2 concentrations with distance from sources. In order to assess the spatial variation in NO_2 levels in the region around Ringaskiddy, NO_2 was monitored using passive diffusion tubes over three one-month periods at 16 locations in the Ringaskiddy, Monkstown and Cobh areas (see Locations N1 – N16 in Figures 8.1 and 8.2). Passive sampling of NO_2 involves the molecular diffusion of NO_2 molecules through a polycarbonate tube and their subsequent adsorption onto a stainless steel disc coated with triethanolamine. Following sampling, the tubes were analysed using UV spectrophotometry, at a UKAS accredited laboratory (SOCOTEC laboratories, Burton-on-Trent). The diffusion tube locations were strategically positioned to allow an

assessment of both background levels and typical exposure of the residential population. The passive diffusion tube results allow an indicative comparison with the annual average limit value.

Studies in the UK have shown that diffusion tube monitoring results generally have a positive or negative bias when compared to continuous analysers. This bias is laboratory specific and is dependent on the specific analysis procedures at each laboratory. A diffusion tube bias of 0.77 was obtained for the SOCOTEC laboratory (which analysed the diffusion tubes) from the UK DEFRA website (UK DEFRA, 2018). In addition, two diffusion tubes (N16 and N17) were co-located with the continuous NO_2 monitor in order to develop a site-specific local bias adjustment factor. A site-specific bias factor of 0.73 was applied to the diffusion tube monitoring results.

SO_2

In order to assess the spatial variation in sulphur dioxide levels in the area, SO_2 was monitored using passive diffusion tubes over three one-month periods at seven locations over the period October 2018 to January 2019 (see Figure 8.1). Passive sampling of SO_2 involves the molecular diffusion of SO_2 molecules through a tube fabricated of PTFE and their subsequent adsorption onto a stainless steel gauze coated with sodium carbonate. Following sampling, the adsorbed sulphate is removed from the tubes with deionised water and analysed using ion chromatography. Analysis was carried out by SOCOTEC laboratories, Burton-on-Trent.

Benzene

In order to assess the spatial variation in benzene levels in the area, benzene was monitored using automated thermal desorption (ATD) tubes over three one-month periods at seven locations (see Location B1 – B7 in Figures 8.1). Passive sampling of benzene involves the molecular diffusion of benzene molecules through a stainless steel tube and their subsequent adsorption onto a stainless steel gauze coated with Tenax. Following sampling, the tubes were analysed using Gas Chromatography – Mass Spectrometry (GC-MS), by SOCOTEC laboratories, Burton-on-Trent.

PCDD/PCDFs

Sampling for dioxins/furans was conducted using R&P Partisol®-Plus Sequential Air Sampler (Model 2025) fitted with a PU inlet. The PU inlet housed a filter and PUF (polyurethane foam) combination. Air was drawn through the fine porosity quartz filter and PUF to trap the particulate and volatile fractions respectively. Monitoring took place at one static location (see Figure 8.1) over 3 one-month periods, with three samples collected in total. Each sample was analysed for dioxins and furans based on USEPA Method 23 using Gas Chromatography – Mass Spectrometry (GC-MS), by Concept Life Sciences laboratory, Manchester.

HCl & HF

Monitoring for HF and HCl was carried out at one static location (Hammond Lane Metals Recycling, see Figure 8.1) over 3 one-month periods. Duplicate samples for HF and HCl were taken each month. Monitoring was conducted using passive diffusion tubes and the samples were analysed for HF and HCl using ion chromatography at Gradko Environmental laboratory, Hampshire (a UKAS accredited laboratory).

PM_{10}

The PM_{10} monitoring program focused on assessing 24-hour average concentrations over a 90-day period at one static location (Hammond Lane Metals Recycling, see Figure 8.1) which is adjacent to the proposed waste to energy site.

PM_{10} sampling was carried out by means of a PM_{10} continuous monitor, R&P Partisol®-Plus Sequential Air Sampler (Model 2025). The sampler is a manual air sampling platform which has been designed to meet US EPA Reference Designation (RFPS-1298-127). Approximately 24 m^3 of air was sampled daily through a size selective inlet, which removed particles with a diameter >10 μg. The remaining particles (<10 μg) were collected on pre-weighed 47mm diameter filters. The Partisol® sampler was programmed to automatically replace each sampled filter by a new pre-weighed filter at midnight. This ensured that each filter represented a sampling period of exactly 24 hours. Gravimetric determination was carried out pre- and post-sampling at a UKAS accredited laboratory (SOCOTEC Laboratories, Burton-on-Trent). The gravimetric results allowed a calculation of the average PM_{10} concentration over each 24-hour period.

$PM_{2.5}$

In order to determine the average $PM_{2.5}/PM_{10}$ ratio at the static monitoring location (Hammond Lane Metals Recycling, see Figure 8.1), a Turnkey Instruments Osiris Environmental Dust Monitor was used to monitor both $PM_{2.5}$ and PM_{10} over an approximate 90-day period. The Osiris instrument is a light scattering device capable of continuous measurement of PM_{10} and $PM_{2.5}$. The air sample was continuously drawn into the instrument by a pump through a heated inlet at a flow rate of 600 ml/min. The incoming air passed through a laser beam in a photometer. The light scattered by the individual particles of dust was measured by the photometer and this information used to measure the size and concentration of the dust particles.

Heavy Metals

Sampling for heavy metals was conducted using the same methodology as for PM_{10}. Quartz filters were utilised as they have low background heavy metal concentrations. Following sampling and re-weighing, the quartz filters were acid digested in batches of 5 - 7 samples and the metals suite determined by inductively coupled plasma – mass spectrometry (ICP-MS) by SOCOTEC Laboratories, Burton-on-Trent.

8.3.3 Results And Discussion

NO_2

Nitrogen dioxide (NO_2) results are presented in Table A8.3 and Table A8.4. The NO_2 chemiluminescent results, undertaken in 2018-19, indicated compliance with NO_2 limit values over the three-month monitoring period. During the monitoring period no exceedence of the 1-hour limit value of 200 $\mu g/m^3$ was observed whilst the mean over this period was 10.1 $\mu g/m^3$ which is 25% of the annual NO_2 limit value (see Figure 8.9). The 2018 NO_2 diffusion tube concentrations measured over the three-month survey period are below the annual EU limit value of 40 $\mu g/m^3$ for the protection of human health. The average NO_2 concentration measured over the three month period at each location ranged from 6 - 16 $\mu g/m^3$ which is between 16 - 42% of the EU annual limit value of 40 $\mu g/m^3$. The results indicate a weak NO_2 spatial concentration gradient in the region.

Previous results at 15 locations also indicated compliance with the NO_2 annual limit value over the same geographical area. NO_2 diffusion monitoring results, amounting to six months of data over the period August 2014 to May 2015, indicated an average concentration of between 6 – 19 $\mu g/m^3$ which is between 15 – 48% of the EU annual limit value as shown in Table A8.5.

SO_2

Sulphur dioxide (SO_2) results are presented in Table A8.6. The SO_2 diffusion tube concentrations measured over the three-month survey period are below the annual EU limit value of 20 $\mu g/m^3$ for the protection of vegetation. The average SO_2 concentration measured over the three-month period at each location ranged from 2.1 – 13.6 $\mu g/m^3$ which is between 11% – 68% of the EU annual limit value of 20 $\mu g/m^3$.

Previous SO_2 diffusion monitoring results amounting to six months of data over the period August 2014 to May 2015, at six locations in Ringaskiddy, Cobh and Monkstown, indicated an average concentration of between 5 – 13 $\mu g/m^3$ which is between 25 – 65% of the EU annual limit value for the protection of vegetation as shown in Table A8.7.

Benzene

Benzene results are presented in Table A8.8. The benzene diffusion tube concentrations measured over the three-month survey period are below the annual EU limit value of 5 $\mu g/m^3$ for the protection of human health. The average benzene concentration measured over the three-month period at each location ranged from 0.8 – 3.4 $\mu g/m^3$ which is between 16% - 69% of the EU annual limit value of 5 $\mu g/m^3$.

Previous benzene diffusion monitoring results amounting to six months of data over the period August 2014 to May 2015, at six locations in Ringaskiddy, Cobh and Monkstown, indicated an average concentration of between 1.2 – 1.3 $\mu g/m^3$ which is between 24 – 26% of the EU annual limit value as shown in Table A8.9.

PCDDs & PCDFs

Background levels of PCDD/PCDFs occur everywhere and existing levels in the Ringaskiddy area have been monitored over a continuous three-month period. The results are detailed in Table A8.10. No ambient air quality concentration or deposition standards currently exist for PCDD/PCDFs.

Non-detects (i.e. levels below the limit of detection) may be assigned a value of either zero, half the limit of detection or the limit of detection. Depending on the number of congeners below the limit of detection and the approach to non-detects, significant variations may be perceived in inter-comparison exercises of samples. For the purposes of this monitoring study, non-detects have been assigned a value of zero for the lower limit TEQ calculation and assigned a value equal to the limit of detection for the upper limit TEQ calculation.

Historically, a number of systems for assessing the toxicity of PCDD/F have been developed, all using the concept of Toxic Equivalence Factors (TEQ). This concept assess the toxicity of other PCDD/F congeners and assigns a weighting compared to the known toxicity of 2,3,7,8 TCDD. The US EPA, NATO/CCMS system and the EC systems now use the same TEF Factors and the World Health Organisation has also adopted a similar system, allowing direct comparability of TEQ values. The NATO/CCMS TEFs (giving a result which is defined as I-TEQ), which correspond exactly with the EC and US EPA TEFs, have been used to calculate TEQs for the PCDD/Fs measured during this study.

The lower limit TEQ for the first monitoring period (October/November 2018) was 1.3 fg/m^3 and 24.7 fg/m^3 for the upper limit. For the second monitoring period (November/December 2018) results for all congeners were below the limit of detection. As a result, the lower limit TEQ is 0 fg/m^3 and the upper limit TEQ is 17.3 fg/m^3 by assuming results are equal to zero and the limit of detection in turn as referenced above. Results for the third and final monitoring period (December 2018/January 2019) were 41.5 fg/m^3 for the lower limit TEQ and 47.3 fg/m^3 for the upper limit TEQ. This results in an average lower limit TEQ for the three-month monitoring period of 14.3 fg/m^3 and an upper limit TEQ of 29.8 fg/m^3.

Previous monitoring was carried out over four 4-5 (approx.) day periods. A summary of the results for the one-month period is detailed in Table A8.11. The mean PCDD/PCDF concentration measured over the four one-week periods during April - May 2008 indicates that results are in line with measurements conducted elsewhere in Ireland, with an upper limit of 13.5 fg/m^3 compared to previous measurements ranging from 2.8 – 46 fg/m^3.

HCl & HF

Results of the HF and HCl monitoring at the static monitoring point (Hammond Lane Metals Recycling) are presented in Table A8.12 for HF and Table A8.13 for HCl. The HF and HCl diffusion tube concentrations measured over the three-month survey period are well below the UK EALs. The average HF concentration measured over the three-month period is 0.32 µg/m^3, which is only 2% of the annual limit value of 16 µg/m^3. The average HCl concentration measured over the three-month monitoring period is 2.21 µg/m^3 which is 11% of the annual limit value of 20 µg/m^3.

PM_{10}

Daily concentrations of PM_{10} measured using the sequential PM_{10} sample are shown in Table A8.14 and Figure 8.10. The results can be directly compared with the 24-hour

limit value (which is set as a 90.4th%ile), and the three-month average can be indicatively compared with the annual limit value.

The 24-hour PM_{10} concentrations measured over the three-month period are below the 24-hour EU limit value of 50 $\mu g/m^3$ and there were no exceedances of the 24-hour limit value recorded over the three months of this monitoring campaign. The 90.4th%ile, which means the 36th highest value measured over a full year is compared to the limit value. Since there were no exceedances recorded over the three months of monitoring, it is extremely unlikely that 35 exceedances would occur over 365 days at the current location.

The average PM_{10} concentration measured over the three-month period is 16.4 $\mu g/m^3$ which is only 40% of the EU annual limit value of 40 $\mu g/m^3$.

Previous monitoring results, amounting to six months of data over the period August 2014 to July 2015, indicated average PM_{10} concentrations measured during the monitoring campaigns of 20 $\mu g/m^3$, which is below the annual limit value of 40 $\mu g/m^3$ as shown in Table A8.15. Five exceedances of the 24-hour limit value were recorded over the six-month monitoring campaign. Since only 5 exceedances were recorded over the monitoring survey, it is extremely unlikely that 35 exceedances would occur over 365 days at the current location. Furthermore, monitoring was ongoing during a period of construction near the monitoring station which is likely to have contributed to the period of elevated values in September 2014.

$PM_{2.5}$

Daily concentrations of $PM_{2.5}$ measured using the Osiris continuous $PM_{2.5}$ monitor are shown in Table A8.14. The average $PM_{2.5}$ concentration measured over the three-month period is 14.9 $\mu g/m^3$ which is below the annual average EU limit value of 25 $\mu g/m^3$. A $PM_{2.5}/PM_{10}$ ratio for the monitoring period of 0.88 has been calculated.

Metals

Ambient concentrations of the suite of metals were measured over 13 sets of 5 - 7 day periods spread over three months at the static monitoring point during the period October 2018 – January 2019. The results for each sample are detailed in Tables A8.16 and A8.17 and Figure 8.11. The average concentrations of antimony (Sb), arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb), thallium (Tl) and vanadium (V) were significantly below their respective annual limit values, with average levels reaching only 0.04% - 47% of these limits (see Tables A8.17 and A8.18).

Previous heavy metal monitoring results amounting to six months of data over the period August 2014 to July 2015 indicated an average concentration for each of the heavy metals which was between 0.004 – 37% of the EU annual limit value (see Tables A8.18 - A8.20).

Table A8.3 Summary of Continuous NO_2 Monitoring Results at On-Site Monitoring Station (Year 2018-19)

Monitoring Period	**Details**	
October 2018	Total No. Days Sampling	29
	No. Hourly Averages >200 µg/m^3	0
	Monthly Average	12.6 µg/m^3
November 2018	Total No. Days Sampling	30
	No. Hourly Averages >200 µg/m^3	0
	Monthly Average	8.3 µg/m^3
December 2018	Total No. Days Sampling	31
	No. Hourly Averages >200 µg/m^3	0
	Monthly Average	9.3 µg/m^3
January 2019	Total No. Days Sampling	3
	No. Hourly Averages >200 µg/m^3	0
	Monthly Average	9.3 µg/m^3
March - May 2008 Monitoring Period	*Total No. Days Sampling*	*93*
	No. Hourly Averages >200 µg/m^3	*0*
	99.8th%ile of 1-hour Averages	*49.5 µg/m^3*
	Monitoring Period Average	*10.1 µg/m^3*
	Limit Values	**200 µg/m^3 Note 1, 40 µg/m^3 Note 2**

Note 1 EU Council Directive 2008/50/EC - 1-hour limit of 200 µg/m^3 as a 99.8th%ile (i.e. 18 hours >200 µg/m^3 permitted per year).

Note 2 EU Council Directive 2008/50/EC - Annual average limit value.

Table A8.4 Average NO_2 Concentrations Measured in Ringaskiddy, Cobh & Monkstown Using Passive Diffusion Tubes (October 2018 – January 2019).

Location	**NO_2 (µg/m^3) 03/10/18 – 01/11/18**	**NO_2 (µg/m^3) 01/11/18 – 28/11/18**	**NO_2 (µg/m^3) 12/12/18 – 17/011/19**	**NO_2 Average (µg/m^3)**	***Adjusted NO_2 Average (µg/m^3)***
N1 – Before Bridge to Haulbowline Island	17.5	16	10.4	14.6	10.7
N2 – Car Park East of Hammond Lane	12.4	13.1	9	11.5	8.4
N3 – Opposite Bus Stop on L2545	16.4	15.7	12	14.7	10.7
N4 – L2545 (Martello Park)	13.2	11	9.5	11.2	8.2
N5 – Entrance to NVD	15.3	12.9	12.7	13.6	10.0
N6 – Ringaskiddy Terminal Car Park	16.3	15.8	14.4	15.5	11.3
N7 – Ringaskiddy Village	16.3	17.1	12.1	15.2	11.1
N8 – Ringport Business Park	13.7	11.8	8.6	11.4	8.3
N9 – Loughbeg 1	14.2	14.3	10.6	13.0	9.5
N10 – Before Entrance to Johnson & Johnson	13.8	11.5	8.7	11.3	8.3
N11 – Loughbeg 2 (Near National School)	11.1	8.7	6.1	8.6	6.3
N12 – Monkstown Car Park	20.3	19.7	15.6	18.5	13.5
N13 – Scotsman's Road	7.8	11.4	8.1	9.1	6.6
N14 – Cobh Promenade	19.6	21.5	missing	20.6	15.0
N15 – Cobh Cathedral	25	19.7	23.6	22.8	16.6
N16 – Onsite Hammod Lane	13.6	14.8	9.8	12.7	9.3
N17 – Onsite Hammod Lane	15.3	13.6	9.8	12.9	9.4
Limit Value					*40 µg/m^3 Note 1*

Note 1 EU Council Directive 2008/50/EC (as an annual average).

Note 2 Diffusion tube monitoring bias adjustment carried out based on UK DEFRA methodology. The diffusion tube bias is 0.73.

Table A8.5 Average NO_2 Concentrations Measured in Ringaskiddy, Cobh & Monkstown Using Passive Diffusion Tubes (August 2014 – May 2015).

Location	**NO_2 ($\mu g/m^3$) 14/08/14 – 15/09/14**	**NO_2 ($\mu g/m^3$) 15/09/14 - 20/10/14**	**NO_2 ($\mu g/m^3$) 20/10/14 – 21/11/14**	**NO_2 ($\mu g/m^3$) 14/01/15 – 13/02/15**	**NO_2 ($\mu g/m^3$) 13/02/15 – 16/03/15**	**NO_2 ($\mu g/m^3$) 31/03/15 – 01/05/15**	**NO_2 Average ($\mu g/m^3$)**	***Adjusted NO_2 Average ($\mu g/m^3$)***
N1 – Before Bridge to Haulbowline Island	10.2	13.4	15.8	20.3	18.7	12.6	15	12
N2 – Car Park East of Hammond Lane	7.6	Missing	16.9	14.8	12.6	8	12	10
N3 – Opposite Bus Stop on L2545	4.8	11.4	Missing	12.2	9.9	9.1	9	8
N4 – L2545 (Martello Park)	9.9	13	17.2	16.9	13.7	11.9	14	11
N5 – Entrance to NVD	8.3	9.5	14	14.1	10.3	9.5	11	9
N6 – Ringaskiddy Terminal Car Park	5.9	10.1	16.1	14	10.9	8.9	11	9
N7 – Ringaskiddy Village	8.3	9.6	13.3	15.2	8.4	8.4	11	9
N8 – Ringport Business Park	10.2	11.5	12.1	14.4	9.9	10.5	11	9
N9 – Loughbeg 1	9	11.3	9.7	14.6	7.5	11.1	11	9
N10 – Before Entrance to Johnson & Johnson	8.5	11	11.8	14.3	9.9	10.1	11	9
N11 – Loughbeg 2 (Near National School)	6.3	8.8	9	9.9	7	7	8	6
N12 – Monkstown Car Park	9.3	14.4	17.1	21.5	12.3	14.4	15	12
N13 – Scotsman's Road	9.2	10.6	11.3	10.5	8	9	10	8
N14 – Cobh Promenade	21.4	12.8	13.6	17.6	12.5	10.8	15	12
N15 – Cobh Cathedral	Missing	Missing	23.1	28.6	24.6	19.9	23	19
Limit Value								*40 $\mu g/m^3$ Note 1*

Note 1 EU Council Directive 2008/50/EC (as an annual average).

Note 2 Diffusion tube monitoring bias adjustment carried out based on UK DEFRA methodology. The diffusion tube bias is 0.81.

Table A8.6 Average SO_2 Concentrations Measured in Ringaskiddy Using Passive Diffusion Tubes (October 2018 – January 2019).

Location	**SO_2 (µg/m^3) 03/10/18 – 01/11/18**	**SO_2 (µg/m^3) 01/11/18 – 28/11/18**	**SO_2 (µg/m^3) 12/12/18 – 17/01/19**	**SO_2 Average (µg/m^3)**
S1 - Car Park East of Hammond Lane	2.6	13.6	2.5	6.2
S2 - Outside Marine Institute on L2545	2.6	2.8	7.6	4.3
S3 - L2545 (Martello Park)	2.6	3.4	3.4	3.1
S4 - Ringaskiddy Village	2.6	5.7	4.2	4.2
S5 - Monkstown Car Park	2.6	2.8	2.5	2.6
S6 - Cobh Promenade	2.6	5.7	3.4	3.9
S7 - Hammond Lane Metals Recycling	2.6	2.8	2.1	2.5
			Limit Value	*20 µg/m^3 Note 1*

Note 1 EU Council Directive 2000/69/EC (annual average limit for the protection of ecosystems).

Table A8.7 Average SO_2 Concentrations Measured in Ringaskiddy, Cobh and Monkstown Using Passive Diffusion Tubes (August 2014 – May 2015).

Location	**SO_2 (µg/m^3) 14/08/14 - 15/09/14**	**SO_2 (µg/m^3) 15/09/14 - 20/10/14**	**SO_2 (µg/m^3) 20/10/14 - 21/11/14**	**SO_2 (µg/m^3) 14/01/15 - 13/02/15**	**SO_2 (µg/m^3) 13/02/15 - 16/03/15**	**SO_2 (µg/m^3) 31/03/15 - 01/05/15**	**SO_2 Average (µg/m^3)**
S1- Car Park East of Hammond Lane	9.1	7.7	3.6	4.3	20.3	3.7	8
S2 - Opposite Bus Stop on L2545	7.9	5	3.4	4.1	7.8	3.8	5
S3 - L2545 (Martello Park)	9.5	4.8	4.9	5.4	14.7	3.1	7
S4 - Ringaskiddy Village	10.9	8.6	32.9	10.9	9.3	4.7	13
S5 - Monkstown Car Park	9.7	7.1	10.4	5	7.6	7.9	8
S6 - Cobh Promenade	12	18.5	13.9	7.5	7.5	5	11
Limit Value							*20 µg/m^3 Note 1*

Note 1 EU Council Directive 2008/50/EC (annual average limit for the protection of ecosystems).

Table A8.8 Average Benzene Concentrations Measured in Ringaskiddy Using Passive Diffusion Tubes (October 2018 – January 2019).

Location	**Benzene (µg/m^3) 03/10/18 – 01/11/18**	**Benzene (µg/m^3) 01/11/18 – 28/11/18**	**Benzene (µg/m^3) 12/12/18 – 17/01/19**	**Benzene Average (µg/m^3)**
B1 - Car Park East of Hammond Lane	0.9	0.9	0.9	0.9
B2 - Outside Marine Institute on L2545	0.9	0.8	0.7	0.8
B3 - L2545 (Martello Park	0.8	3	0.8	1.5
B4 - Ringaskiddy Village	1	8.4	0.9	3.4
B5 - Monkstown Car Park	3	0.9	1	1.6
B6 - Cobh Promenade	1	0.6	0.8	0.8
B7 - Hammond Lane Metals Recycling	0.9	0.7	0.8	0.8
			Limit Value	*5 µg/m^3 Note 1*

Note 1 EU Council Directive 2000/69/EC (as an annual average).

Table A8.9 Average Benzene Concentrations Measured in Ringaskiddy Using Passive Diffusion Tubes (August 2014 – May 2015).

Location	**Benzene (µg/m^3) 14/08/14 - 15/09/14**	**Benzene (µg/m^3) 15/09/14 - 20/10/14**	**Benzene (µg/m^3) 20/10/14 - 21/11/14**	**Benzene (µg/m^3) 21/11/14 - 22/12/14**	**Benzene (µg/m^3) 14/01/15 - 13/02/15**	**Benzene (µg/m^3) 13/02/15 - 16/03/15**	**Benzene (µg/m^3) 31/03/15 - 01/05/15**	**Benzene Average (µg/m^3)**
S1- Car Park East of Hammond Lane	1	Note 1	Note 1	1	1	1	3	1.3
S2 - Opposite Bus Stop on L2545	Note 1	Note 1	Note 1	1	2	1	1	1.2
S3 - L2545 (Martello Park)	1	Note 1	Note 1	2	2	1	1	1.3
S4 - Ringaskiddy Village	1	Note 1	Note 1	2	2	1	1	1.3
S5 - Monkstown Car Park	1	1	Note 1	2	2	1	1	1.2
S6 - Cobh Promenade	1	2	Note 1	2	2	1	1	1.3
Limit Value								*5 µg/m^3 Note2*

Note 1 Sample tube damaged due to heavy rainfall

Note 2 EU Council Directive 2008/50/EC (as an annual average).

Table A8.10 Average PCDD/PCDF Concentrations Measured at the On-Site Monitoring Station (Sampling Periods 1, 2 & 3) (October 2018 – January 2019).

PCDD Congeners	I-TEF Note 1	Sampling Period 1: Oct / Nov 18			Sampling Period 2: Nov / Dec 18			Sampling Period 3: Dec 18 / Jan 19		
		Concentration Note 2 (fg/m³)	Lower Limit TEQ Note 3 (fg/m³)	Upper Limit TEQ Note 4 (fg/m³)	Concentration Note 2 (fg/m³)	Lower Limit TEQ Note 3 (fg/m³)	Upper Limit TEQ Note 4 (fg/m³)	Concentration Note 2 (fg/m³)	Lower Limit TEQ Note 3 (fg/m³)	Upper Limit TEQ Note 4 (fg/m³)
2,3,7,8-TCDD	1	*<7.5*		7.5	*<5.4*		5.4	*<3.7*		3.7
1,2,3,7,8-PeCDD	0.5	*<4.3*		2.1	*<5.4*		2.7	28.1	14.0	14.0
1,2,3,4,7,8-HxCDD	0.1	*<4.3*		0.4	*<5.4*		0.5	*<5.6*		0.6
1,2,3,6,7,8-HxCDD	0.1	*<6.4*		0.6	*<5.4*		0.5	9.7	1.0	1.0
1,2,3,7,8,9-HxCDD	0.1	*<4.3*		0.4	*<6.5*		0.7	8.2	0.8	0.8
1,2,3,4,6,7,8-HpCDD	0.01	*<427.7*		4.3	*<43.5*		0.4	76.7	0.8	0.8
OCDD	0.001	151.8	0.2	0.2	*<149.7*		0.1	170.3	0.2	0.2
PCDF Congeners	**I-TEF Note 1**									
2,3,7,8-TCDF	0.1	*<10.7*		1.1	*<8.2*		0.8	17.4	1.7	1.7
1,2,3,7,8-PCDF	0.05	*<4.3*		0.2	*<6*		0.3	13.3	0.7	0.7
2,3,4,7,8-PCDF	0.5	*<8.6*		4.3	*<5.4*		2.7	26.2	13.1	13.1
1,2,3,4,7,8-HxCDF	0.1	*<6.4*		0.6	*<7.1*		0.7	22.5	2.2	2.2
1,2,3,6,7,8-HxCDF	0.1	*<7.1*		0.7	*<6.5*		0.7	24.3	2.4	2.4
1,2,3,7,8,9-HxCDF	0.1	*<11.1*		0.4	*<5.4*		0.6	*<28.1*		1.5
2,3,4,6,7,8-HxCDF	0.1	4.3	1.1	1.1	*<6*		0.5	15	2.8	2.8
1,2,3,4,6,7,8-HpCDF	0.01	*<47*		0.5	*<38.1*		0.4	117.9	1.2	1.2
1,2,3,4,7,8,9-HpCDF	0.01	*<10.7*		0.1	*<6.8*		0.1	22.5	0.2	0.2
OCDF	0.001	*<85.5*		0.1	*<40.8*		0.04	355.5	0.4	0.4
		Total TEQ	**1.3**	**24.7**	**Total TEQ**	**0.0**	**17.3**	**Total TEQ**	**41.5**	**47.3**

Note 1 Annex 1, Council Directive 2000/76/EC.

Note 2 Ambient concentration of congener (values in italics indicate levels below the limit of detection).

Note 3 Lower Limit TEQ calculated assuming non-detects are equal to zero (i.e. congeners with ambient levels below the limit of detection not included in Total TEQ)

Note 4 Upper Limit TEQ calculated assuming non-detects are equal to the limit of detection (i.e. congeners with ambient levels below the limit of detection included in Total TEQ).

Table A8.11 Summary of PCDD / PCDF Concentrations Measured at On-Site Monitoring Station (April - May 2008)

Pollutant	Averaging Period	Minimum PCDDs/PCDFs (I-TEQ) (fg/m^3)	Maximum PCDDs/PCDFs (I-TEQ) (fg/m^3)
April / May 2008 Monitoring			
PCCD/PCDFs	21/04/08 - 25/04/08	18.6	18.6
PCCD/PCDFs	02/05/08 - 06/05/08	9.5	11.8
PCCD/PCDFs	08/05/08 - 13/05/08	13.9	14.2
PCCD/PCDFs	19/05/08 - 23/05/08	7.4	9.3
PCCD/PCDFs	**4-Week Average**	**12.4**	**13.5**

Table A8.12 Average HF Concentrations Measured at On-Site Monitoring Station (October 2018 – January 2019).

Location	HF ($\mu g/m^3$) 03/10/18 - 01/11/18	HF ($\mu g/m^3$) 01/11/18 - 28/11/18	HF ($\mu g/m^3$) 28/11/18 - 03/01/19	Average HF ($\mu g/m^3$)
Hammond Lane Metals Recycling	0.32	0.33	0.32	0.32
Hammond Lane Metals Recycling	0.32	0.33	0.32	0.32
			Limit value	*16 $\mu g/m^3$ Note 1*

Note 1 UK Environment Assessment Level (EAL) as an annual average

Table A8.13 Average HCl Concentrations Measured at On-Site Monitoring Station (October 2018 – January 2019).

Location	HCl ($\mu g/m^3$) 03/10/18 - 01/11/18	HCl ($\mu g/m^3$) 01/11/18 - 28/11/18	HCl ($\mu g/m^3$) 28/11/18 - 03/01/19	Average HCl ($\mu g/m^3$)
Hammond Lane Metals Recycling	2.23	2.45	1.94	2.21
Hammond Lane Metals Recycling	2.23	2.45	1.94	2.21
			Limit value	*20 $\mu g/m^3$ Note 1*

Note 1 UK Environment Assessment Level (EAL) as an annual average

Table A8.14 Results of PM_{10} / $PM_{2.5}$ monitoring carried out at an on-site location in Ringaskiddy, Co. Cork (October 2018 – January 2019).

Date	Partisol PM_{10}	Date	Osiris $PM_{2.5}$
04-Oct-18	12.85	13-Nov-18	18.20
05-Oct-18	12.18	14-Nov-18	22.64
06-Oct-18	11.68	15-Nov-18	14.93
07-Oct-18	14.18	16-Nov-18	13.89
08-Oct-18	23.33	17-Nov-18	15.35
09-Oct-18	27.90	18-Nov-18	16.13
10-Oct-18	34.51	19-Nov-18	8.48
11-Oct-18	21.21	20-Nov-18	3.83
12-Oct-18	23.41	21-Nov-18	3.15
13-Oct-18	11.35	22-Nov-18	10.24
14-Oct-18	9.90	23-Nov-18	11.45
15-Oct-18	12.93	24-Nov-18	7.31
16-Oct-18	14.68	25-Nov-18	6.15
17-Oct-18	25.53	26-Nov-18	4.80
18-Oct-18	5.20	27-Nov-18	17.83
19-Oct-18	24.83	28-Nov-18	34.84
20-Oct-18	36.14	12-Dec-18	16.63
21-Oct-18	13.97	13-Dec-18	21.41
22-Oct-18	13.51	14-Dec-18	16.18
23-Oct-18	25.99	15-Dec-18	15.25
24-Oct-18	25.82	16-Dec-18	4.78
25-Oct-18	24.83	17-Dec-18	31.21
26-Oct-18	22.00	18-Dec-18	24.88
27-Oct-18	15.64	19-Dec-18	10.85
28-Oct-18	11.89	20-Dec-18	8.91
29-Oct-18	16.72	21-Dec-18	12.07
30-Oct-18	15.64	22-Dec-18	15.28
31-Oct-18	14.80	23-Dec-18	2.38
01-Nov-18	8.32	24-Dec-18	4.15
02-Nov-18	3.04	25-Dec-18	8.35
03-Nov-18	32.85	26-Dec-18	8.48
04-Nov-18	7.36	27-Dec-18	3.88
05-Nov-18	5.86	28-Dec-18	11.98
14-Nov-18	18.67	29-Dec-18	1.10
15-Nov-18	19.54	30-Dec-18	3.58
16-Nov-18	24.20	31-Dec-18	10.12
17-Nov-18	27.03	01-Jan-19	6.53
18-Nov-18	31.89	02-Jan-19	7.68
19-Nov-18	16.88	03-Jan-19	9.79
20-Nov-18	10.48	08-Jan-19	15.07
21-Nov-18	14.06	09-Jan-19	3.44
22-Nov-18	24.08	10-Jan-19	3.38
23-Nov-18	18.30	11-Jan-19	2.59
24-Nov-18	19.38	12-Jan-19	2.13
25-Nov-18	20.29	13-Jan-19	5.64
26-Nov-18	12.64	14-Jan-19	13.64
27-Nov-18	20.54	15-Jan-19	3.81
28-Nov-18	23.83	16-Jan-19	4.85
29-Nov-18	11.27	17-Jan-19	5.08
30-Nov-18	2.08	29-Jan-19	23.18
01-Dec-18	12.43	30-Jan-19	4.90
02-Dec-18	7.24	31-Jan-19	10.28
03-Dec-18	15.64	01-Feb-19	4.75
04-Dec-18	18.71	02-Feb-19	4.47
05-Dec-18	12.10	03-Feb-19	9.59
06-Dec-18	7.73	04-Feb-19	7.99
07-Dec-18	8.57	05-Feb-19	13.96
08-Dec-18	13.18	06-Feb-19	18.61

Date	Partisol PM_{10}	Date	Osiris $PM_{2.5}$
09-Dec-18	16.05	07-Feb-19	8.74
10-Dec-18	8.48	08-Feb-19	33.11
11-Dec-18	19.09	09-Feb-19	14.59
12-Dec-18	16.59	10-Feb-19	6.07
13-Dec-18	9.11	11-Feb-19	14.82
14-Dec-18	16.67	12-Feb-19	23.26
15-Dec-18	12.85	13-Feb-19	31.20
16-Dec-18	9.90	14-Feb-19	19.55
17-Dec-18	10.94	15-Feb-19	28.79
18-Dec-18	24.66	16-Feb-19	25.97
19-Dec-18	19.29	17-Feb-19	21.60
20-Dec-18	11.02	18-Feb-19	12.11
21-Dec-18	14.72	19-Feb-19	19.40
22-Dec-18	14.10	20-Feb-19	23.35
23-Dec-18	7.65	21-Feb-19	39.24
24-Dec-18	8.23	22-Feb-19	42.84
25-Dec-18	16.43	23-Feb-19	40.11
26-Dec-18	12.02	24-Feb-19	22.25
27-Dec-18	9.52	25-Feb-19	33.21
28-Dec-18	17.09	26-Feb-19	17.03
29-Dec-18	5.90	27-Feb-19	14.49
30-Dec-18	7.94	28-Feb-19	21.17
31-Dec-18	16.97	-	-
01-Jan-19	19.13	-	-
02-Jan-19	13.18	-	-
03-Jan-19	12.60	-	-
04-Jan-19	13.60	-	-
05-Jan-19	16.97	-	-
06-Jan-19	19.00	-	-
07-Jan-19	17.96	-	-
08-Jan-19	28.11	-	-
Average	**16.14**	**Average**	**14.19**
No. Days > 50	**0**	**$PM_{2.5}/PM_{10}$ ratio**	**0.88**
90.4th percentile	**25.69**		
Limit Values Note 1	*Daily 50 µg/m^3* *Annual 40 µg/m^3*	*Limit Values* Note 1	*Annual 25 µg/m^3*

Note 1 EU Council Directive 2008/50/EC - annual limit value.

Table A8.15 PM_{10} Concentrations Measured at On-Site Monitoring Station (August 2014 - July 2015)

Date	PM_{10} (µg/m^3)	Date	PM_{10} (µg/m^3)
22-Aug-14	21	30-Oct-14	8
23-Aug-14	8	31-Oct-14	18
24-Aug-14	12	01-Nov-14	11
25-Aug-14	18	02-Nov-14	8
26-Aug-14	9	03-Nov-14	12
27-Aug-14	17	04-Nov-14	8
28-Aug-14	16	05-Nov-14	10
29-Aug-14	11	06-Nov-14	6
30-Aug-14	20	07-Nov-14	10
31-Aug-14	7	08-Nov-14	14
01-Sep-14	5	09-Nov-14	13
02-Sep-14	2	10-Nov-14	16
03-Sep-14	2	11-Nov-14	10
04-Sep-14	16	12-Nov-14	8
05-Sep-14	46	13-Nov-14	12
06-Sep-14	30	14-Nov-14	14
07-Sep-14	27	15-Nov-14	16
08-Sep-14	46	16-Nov-14	14
09-Sep-14	50	17-Nov-14	11
10-Sep-14	54	18-Nov-14	15
11-Sep-14	29	19-Nov-14	16
12-Sep-14	54	20-Nov-14	21
13-Sep-14	35	21-Nov-14	3
14-Sep-14	50	22-Nov-14	3
15-Sep-14	46	23-Nov-14	25
16-Sep-14	42	24-Nov-14	30
17-Sep-14	67	25-Nov-14	24
18-Sep-14	37	26-Nov-14	25
19-Sep-14	30	27-Nov-14	19
20-Sep-14	58	28-Nov-14	28
21-Sep-14	42	29-Nov-14	32
22-Sep-14	37	30-Nov-14	32
23-Sep-14	29	01-Dec-14	24
24-Sep-14	41	02-Dec-14	19
25-Sep-14	37	03-Dec-14	29
26-Sep-14	32	29-Jan-15	4
27-Sep-14	25	30-Jan-15	18
28-Sep-14	38	31-Jan-15	13
29-Sep-14	42	01-Feb-15	25
10-Oct-14	7	02-Feb-15	37
11-Oct-14	10	03-Feb-15	22
12-Oct-14	16	04-Feb-15	19
13-Oct-14	12	05-Feb-15	16
14-Oct-14	11	06-Feb-15	24
15-Oct-14	8	07-Feb-15	26
16-Oct-14	14	08-Feb-15	25
17-Oct-14	13	09-Feb-15	17
18-Oct-14	19	10-Feb-15	32
19-Oct-14	9	11-Feb-15	26
20-Oct-14	8	12-Feb-15	23
21-Oct-14	13	14-Feb-15	16
22-Oct-14	11	15-Feb-15	16
23-Oct-14	1	16-Feb-15	11
24-Oct-14	6	17-Feb-15	14
25-Oct-14	5	18-Feb-15	20
26-Oct-14	5	19-Feb-15	14
27-Oct-14	13	20-Feb-15	12
28-Oct-14	12	21-Feb-15	15
29-Oct-14	6	22-Feb-15	10
Limit Values	*40*[Note 1]	*Limit Values*	*40*[Note 1]

Note 1 EU Council Directive 2008/50/EC - annual limit value.

Date	PM_{10} (µg/m^3)	Date	PM_{10} (µg/m^3)
23-Feb-15	10	09-Apr-15	50
24-Feb-15	6	10-Apr-15	48
25-Feb-15	6	11-Apr-15	9
26-Feb-15	15	12-Apr-15	14
27-Feb-15	11	13-Apr-15	20
28-Feb-15	19	29-Apr-15	11
01-Mar-15	13	30-Apr-15	11
02-Mar-15	4	01-May-15	23
03-Mar-15	8	02-May-15	16
04-Mar-15	13	03-May-15	5
05-Mar-15	19	08-May-15	13
06-Mar-15	31	09-May-15	12
07-Mar-15	17	10-May-15	22
08-Mar-15	17	11-May-15	28
09-Mar-15	19	14-May-15	23
10-Mar-15	38	15-May-15	14
11-Mar-15	11	16-May-15	17
12-Mar-15	14	17-May-15	15
17-Mar-15	55	18-May-15	11
18-Mar-15	49	19-May-15	10
19-Mar-15	49	20-May-15	15
20-Mar-15	20	25-Jun-15	20
21-Mar-15	17	26-Jun-15	14
22-Mar-15	16	27-Jun-15	21
23-Mar-15	12	28-Jun-15	17
24-Mar-15	15	29-Jun-15	25
25-Mar-15	11	30-Jun-15	32
26-Mar-15	19	01-Jul-15	16
27-Mar-15	0.2	02-Jul-15	15
03-Apr-15	20	03-Jul-15	21
04-Apr-15	18	04-Jul-15	19
05-Apr-15	18	05-Jul-15	15
06-Apr-15	11	06-Jul-15	15
07-Apr-15	29	07-Jul-15	17
08-Apr-15	30	08-Jul-15	14
Mean		***20***	
No. Exceedances of 24-hour Limit Value		***5***	
Limit Values		**40(1), 50(2)**	

(1) EU Council Directive 2008/50/EC - (as an annual average).
(2) EU Council Directive 2008/50/EC - (as a 90th percentile of 24 hour averages).

Table A8.16 Levels of heavy metals measured at an on-site location in Ringaskiddy during the period 04/10/18 – 27/11/18.

Species	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Limit Values (ng/m^3)(1)
	04/10/18 - 10/10/18 (ng/m^3)	11/10/18 - 17/10/18 (ng/m^3)	18/10/18 - 24/10/18 (ng/m^3)	25/10/18 - 31/10/18 (ng/m^3)	01/11/18 - 05/11/18 (ng/m^3)	14/11/18 - 20/11/18 (ng/m^3)	21/11/18 - 27/11/18 (ng/m^3)	
Antimony	0.60	<0.60	<0.60	<0.60	<3.33	<0.12	0.18	5000
Arsenic	<1.79	<1.79	<1.79	<1.79	<3.33	<0.24	0.30	6(2)
Cadmium	<0.60	<0.60	<0.60	<0.60	<4.17	<0.18	0.30	5(2)
Chromium	23.81	<17.86	<17.86	<17.86	7.50	5.95	5.95	5000
Cobalt	<1.19	<1.19	1.19	<1.19	<1.67	0.12	0.24	200
Copper	17.86	5.36	11.90	11.90	4.17	4.17	5.36	2000
Lead	5.95	4.17	4.76	4.17	4.17	2.98	3.99	500
Manganese	17.86	<4.76	11.90	5.95	8.33	4.17	5.36	150
Mercury	<17.86	<17.86	<17.86	<17.86	<4.17	<0.48	<0.48	1000
Nickel	<11.90	<11.90	<11.90	<11.90	8.33	2.38	2.38	20(2)
Thallium	<0.60	<0.60	<0.60	1.19	<5.00	<0.12	0.30	1000
Vanadium	<3.57	<3.57	<3.57	<3.57	3.33	1.85	0.60	5000

(1) Annual average limit values set by the EU, WHO, TA Luft Guidelines or a derived as an Environmental Assessment Level.

(2) EU Directive 2004/107/EC

Table A8.17 Levels of heavy metals measured at an on-site location in Ringaskiddy during the period 28/11/18 – 08/01/19.

Species	Period 8 28/11/18 - 04/12/18 (ng/m^3)	Period 9 05/12/18 - 11/12/18 (ng/m^3)	Period 10 11/12/18 - 17/12/18 (ng/m^3)	Period 11 18/12/18 - 24/12/18 (ng/m^3)	Period 12 25/12/18 - 31/12/18 (ng/m^3)	Period 13 01/01/19 - 08/01/19 (ng/m^3)	Average (ng/m^3)	Limit Values (ng/m^3)(1)
Antimony	<0.30	0.48	<0.30	<0.30	<0.30	0.36	0.6	5000
Arsenic	<0.18	<0.18	<0.18	<0.18	<0.18	<1.56	1.0	6(2)
Cadmium	<0.12	0.24	0.42	<0.12	<0.12	<1.04	0.7	5(2)
Chromium	5.95	5.95	5.36	5.95	5.95	5.21	10.1	5000
Cobalt	<0.60	<0.60	<0.60	<0.60	<0.60	<0.42	0.8	200
Copper	<3.57	<3.57	<3.57	3.57	<3.57	5.21	6.4	2000
Lead	3.57	5.95	46.43	3.57	11.90	2.60	8.0	500
Manganese	<0.24	2.68	3.33	1.79	1.19	5.21	5.6	150
Mercury	<5.95	5.95	<5.95	<5.95	<5.95	<1.04	8.3	1000
Nickel	<11.90	<11.90	<11.90	<11.90	<11.90	<2.60	9.4	20(2)
Thallium	<0.06	<0.06	<0.06	<0.06	<0.06	<1.56	0.8	1000
Vanadium	<0.36	<0.36	0.54	<0.36	2.38	<4.17	2.2	5000

(1) Annual average limit values set by the EU, WHO, TA Luft Guidelines or a derived as an Environmental Assessment Level.

(2) EU Directive 2004/107/EC

Table A8.18 Levels of heavy metals measured at an on-site location in Ringaskiddy during the period 04/09/14 – 13/11/14.

Species	**Period 1 04/09/14 - 09/09/14 (ng/m^3)**	**Period 2 10/09/14 - 14/09/14 (ng/m^3)**	**Period 3 15/09/14 - 21/09/14 (ng/m^3)**	**Period 4 22/09/14 - 28/09/14 (ng/m^3)**	**Period 5 10/10/14 - 16/10/14 (ng/m^3)**	**Period 6 17/10/14 - 23/10/14 (ng/m^3)**	**Period 7 24/10/14 – 30/10/14 (ng/m^3)**	**Period 8 31/10/14 - 06/11/14 (ng/m^3)**	**Period 9 07/11/14 - 13/11/14 (ng/m^3)**	**Limit Values (ng/m^3)[1]**
Antimony	0.63	0.50	0.95	0.65	5.60	5.60	5.48	5.42	5.30	5000
Arsenic	0.21	0.17	0.60	0.30	0.60	0.60	0.60	0.42	0.60	6[2]
Cadmium	0.35	0.33	0.46	0.18	0.18	0.18	0.12	0.12	0.24	5[2]
Chromium	13.89	15.00	14.29	11.90	36.31	34.52	36.31	33.93	39.88	5000
Cobalt	0.69	0.58	0.65	0.47	0.60	0.36	0.48	0.42	0.54	200
Copper	7.64	6.67	6.55	3.45	5.95	7.14	4.88	3.81	5.30	2000
Lead	9.72	10.00	15.48	4.82	8.33	7.14	5.54	5.77	5.89	500
Manganese	15.28	15.83	14.88	10.12	12.50	11.90	13.10	12.50	14.29	150
Mercury	0.56	0.67	0.42	0.42	0.36	0.36	0.12	0.12	0.12	1000
Nickel	9.72	10.83	11.31	7.14	8.33	7.14	5.48	5.42	8.33	20[2]
Thallium	0.07	0.08	0.02	0.01	0.04	0.03	0.02	0.05	0.03	1000
Vanadium	2.15	2.92	3.10	1.79	0.60	0.60	3.57	1.61	1.19	5000

[1] Annual average limit values set by the EU, WHO, TA Luft Guidelines or a derived as an Environmental Assessment Level.

[2] EU Directive 2004/107/EC

Table A8.19 Levels of heavy metals measured at an on-site location in Ringaskiddy during the period 14/11/14 – 12/03/15.

Species	Period 10 14/11/14 - 20/11/14 (ng/m^3)	Period 11 21/11/14 - 27/11/14 (ng/m^3)	Period 12 28/11/14 - 03/12/14 (ng/m^3)	Period 13 29/01/15 - 04/02/15 (ng/m^3)	Period 14 05/02/15 - 11/02/15 (ng/m^3)	Period 15 12/02/15 and 14/02/15 - 19/02/15 (ng/m^3)	Period 16 20/02/15 – 26/02/15 (ng/m^3)	Period 17 27/02/15 - 05/03/15 (ng/m^3)	Period 18 06/03/15 - 12/03/15 (ng/m^3)	Limit Values (ng/m^3)[1]
Antimony	7.74	5.71	6.53	4.82	2.38	1.49	1.25	1.49	1.19	5000
Arsenic	2.02	1.19	0.69	0.12	0.30	0.42	0.18	1.19	0.60	6[2]
Cadmium	0.42	0.25	0.28	0.12	0.18	0.18	0.12	0.12	0.12	5[2]
Chromium	35.12	36.90	36.11	39.88	50.60	47.02	45.83	48.21	31.55	5000
Cobalt	0.60	0.53	0.46	0.50	0.55	0.57	0.77	0.60	0.36	200
Copper	9.52	7.74	8.33	5.00	5.36	3.87	3.21	8.93	8.33	2000
Lead	101.19	14.29	9.72	6.55	7.14	7.74	3.75	4.58	8.93	500
Manganese	14.88	16.67	17.36	14.29	19.05	14.29	13.10	14.29	12.50	150
Mercury	0.12	0.06	0.06	0.04	0.04	0.12	0.06	0.12	0.12	1000
Nickel	5.71	5.60	6.32	5.65	5.95	7.14	5.65	5.95	4.17	20[2]
Thallium	0.04	0.02	0.04	0.04	0.04	0.03	0.02	0.06	0.05	1000
Vanadium	1.90	1.43	2.22	0.71	0.36	1.49	0.77	1.55	0.83	5000

[1] Annual average limit values set by the EU, WHO, TA Luft Guidelines or a derived as an Environmental Assessment Level.

[2] EU Directive 2004/107/EC

Table A8.20 Levels of heavy metals measured at an on-site location in Ringaskiddy during the period 17/03/15 – 08/07/15.

Species	Period 19 17/03/15 - 23/03/15 (ng/m^3)	Period 20 24/03/15 - 26/03/15 (ng/m^3)	Period 21 03/04/15 - 12/04/15 (ng/m^3)	Period 22 29/04/15 - 02/05/15 (ng/m^3)	Period 23 03/05/15 and 08/05/15 - 11/05/15 (ng/m^3)	Period 24 14/05/15 - 20/05/15 (ng/m^3)	Period 25 25/06/15 - 01/07/15 (ng/m^3)	Period 26 02/07/15 - 08/07/15 (ng/m^3)	Averages – Sept 14 – July 15 (ng/m^3)	Limit Values (ng/m^3)[1]
Antimony	1.96	2.08	1.92	2.19	1.67	1.85	4.76	4.76	**3.2**	**5000**
Arsenic	0.06	0.14	0.63	0.21	0.33	0.24	4.76	4.76	**0.8**	**6[2]**
Cadmium	0.30	0.14	5.42	0.31	0.17	0.18	5.95	5.95	**0.9**	**5[2]**
Chromium	51.8	50.0	62.5	54.2	52.5	50.6	45.2	44.1	**39.2**	**5000**
Cobalt	0.65	0.63	0.88	0.73	0.53	0.54	1.79	1.79	**0.7**	**200**
Copper	3.81	1.39	6.25	3.13	4.67	3.81	5.95	5.95	**5.6**	**2000**
Lead	8.33	7.50	17.92	6.04	4.83	4.70	23.81	5.95	**12.1**	**500**
Manganese	18.45	16.67	21.25	16.67	15.00	14.88	17.86	11.90	**15.0**	**150**
Mercury	0.03	0.07	0.04	0.21	0.75	0.18	5.36	5.36	**0.6**	**1000**
Nickel	7.14	6.11	8.75	6.88	14.17	10.12	5.95	5.36	**7.3**	**20[2]**
Thallium	0.02	0.04	0.03	0.02	0.08	0.06	5.95	5.95	**0.5**	**1000**
Vanadium	1.73	0.92	2.46	0.67	1.92	2.08	3.57	3.57	**1.8**	**5000**

(1) Annual average limit values set by the EU, WHO, TA Luft Guidelines or a derived as an Environmental Assessment Level.

(2) EU Directive 2004/107/EC

8.4 Modelling Methodology

8.4.1 Introduction

Emissions from the proposed facility have been modelled using the AERMOD dispersion model which is the USEPA's regulatory model used to assess pollutant concentrations associated with industrial sources(1). Emissions have been assessed, firstly under maximum emission limits of the EU Directive 2010/75/EU and secondly under abnormal operating conditions.

8.4.2 Process Emissions

The Ringaksiddy Resource Recovery Centre facility has one main process emission point (flue). The operating details of this major emission point are outlined in Table A8.21. Full details of emission concentrations and mass emissions are given in **Appendix 8.6**.

Table A8.21 Process Emission Design Details

Stack Reference	Stack Height (m)	Exit Diameter (m)	Cross-Sectional Area (m^2)	Temp (K)	Volume Flow (Nm^3/hr)(1)	Exit Velocity (m/sec actual)(2)
Grate	70	2.30	4.15	408	211,000 – Maximum 161,977 – Nominal	19.9 15.3

(1) Normalised to 11% O_2, dry, 273K.
(2) Actual, 408K, 6.9% O_2, 16.9% H_2O

The AERMOD model was run using a unitised emission rate of 1 g/s for the stack. The unitised concentration output has then been adjusted for each substance based on the specific emission rate of each.

8.4.3 Background Concentrations

The ambient concentrations detailed in the following sections include both the emissions from the facility and the ambient background concentration for that substance. Background concentrations have been derived from a conservative analysis of the existing background air quality and an analysis of cumulative sources in the region in the absence of the development. A detailed baseline air quality assessment (Section 8.3) was carried out to assess background levels of those pollutants, which are likely to be released from the site. Appropriate background values have been outlined in Table A8.22. In arriving at the combined annual background concentration, cognisance has been taken of the accuracy of the approach and the degree of double counting inherent in the assessment. In relation to NO_2, PM_{10}, $PM_{2.5}$ and benzene the baseline monitoring program will have taken into account the existing traffic levels and existing home heating and minor industrial sources. However, traffic levels associated with the development have been incorporated into the final combined background levels. The values have been rounded accordingly based on this conservative approach. A similar approach has been adopted for the other pollutants.

In order to obtain the predicted environmental concentration (PEC), background data was added to the process emissions. In relation to the annual averages, the ambient background concentration was added directly to the process concentration. However, in relation to the short-term peak concentrations, concentrations due to emissions from elevated sources cannot be combined in the same way. Guidance from the UK DEFRA(13) advises that for NO_2, SO_2 and PM_{10} an estimate of the maximum combined pollutant concentration can be obtained as shown below:

NO_2 - The 99.8th%ile of total 1-hour NO_2 is equal to the minimum of either A or B below:

a) 99.8th%ile hourly background total oxidant (O_3 & NO_2) + 0.05 x (99.8th%ile process contribution NO_x)

b) The maximum of either:

99.8th% process contribution NO_x + 2 x (annual mean background NO_2)
or
99.8th% hourly background NO_2 + 2 x (annual mean process contribution NO_x)

PM_{10} - The 90.4th%ile of total 24-hour mean PM_{10} is equal to the maximum of either A or B below:

a) 90.4th%ile of 24-hour mean background PM_{10} + annual mean process contribution PM_{10}
b) 90.4th%ile 24-hour mean process contribution PM_{10} + annual mean background PM_{10}

SO_2 - The 99.7th%ile of total 1-hour SO_2 is equal to the maximum of either A or B below:

a) 99.7th%ile hourly background SO_2 + (2 x annual mean process contribution SO_2)
b) 99.7th%ile hourly process contribution SO_2 + (2 x annual mean background contribution SO_2)

SO_2 - The 99.2th%ile of total 24-hour SO_2 is equal to the maximum of either A or B below:

a) 99.2th%ile of 24-hour mean background SO_2 + (2 x annual mean process contribution SO_2)
b) 99.2th%ile 24-hour mean process contribution SO_2 + (2 x annual mean background contribution SO_2).

Table A8.22 Estimated annual background concentrations in the region of Ringaskiddy (μg/m^3).

	NO_2	**NO_X**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**	**CO**	**TOC[(2)]**	**HCl**	**HF**	**Dioxins[(1)]**	**B(*a*)P**	**Cd**	**Hg**	**As**	**V**	**Ni**
Baseline Monitoring Program - Year 2014 – 2015 & 2018 - 2019	10	13	9	16	14	-	1	2.2	0.32	0.030 pg/m^3	-	0.001	0.008	0.001	0.002	0.009
Annual Background Concentration - Year 2023	10	13	9	16	14	450	1	2.2	0.32	0.030 pg/m^3	0.54 ng/m^3	0.001	0.008	0.001	0.002	0.009
Facility Traffic - Year 2023[(3)]	0.4	0.8	-	0.05	0.05	0.005	0.005	-	-	-	-	-	-	-	-	-
Cumulative Assessment	2	3	1	-[(4)]	-[(4)]	-[(4)]	-[(4)]	-[(4)]	-[(4)]	0.001 pg/m^3	-[(4)]	-[(4)]	-[(4)]	-[(4)]	-[(4)]	-[(4)]
Annual Background & Facility Traffic Concentration (Year 2023)	**12**	**17**	**10**	**16**	**14**	**500**	**1.0**	**2.2**	**0.32**	**0.031 pg/m^3**	**0.54 ng/m^3**	**0.001**	**0.008**	**0.001**	**0.002**	**0.009**

(1) Dioxins reported as non-detects as equal to the limit of detection.
(2) Assumed to consist solely of benzene as a worst-case.
(3) Derived using the DMRB screening model (see Appendix 8.3).
(4) No other significant source in the region.

8.5 Nitrogen Dioxide Emissions and Results

8.5.1 Source Information

Source information including emission release heights, volume flows, locations and stack diameters has been summarised in **Appendix 8.6**.

8.5.2 Modelling of Nitrogen Dioxide

Nitrogen oxides (NO_X), containing both nitrogen oxide (NO) and nitrogen dioxide (NO_2) are emitted from the combustion process on-site, although it is the latter which is considered the more harmful to human health. These combustion processes lead to emissions which are mainly in the form of nitrogen oxide (NO) (typically 95%) with small amounts of the more harmful nitrogen dioxide.

Ambient Ground Level Concentrations (GLCs) of Nitrogen Dioxide have been predicted for the following scenarios in Table A8.23.

Table A8.23 Emission Scenario for Nitrogen Dioxide

Pollutant	Scenario	Concentration	Emission Rate (g/s)
NO_2	Maximum 1-Hr Operation	400 mg/m^3	23.4
	Maximum 24-Hr Operation	200 mg/m^3	11.7
	Abnormal Operation(1)	400 mg/m^3	23.4

(1) Abnormal operation scenario based on an emission level of 400 mg/m^3 for 3% of the time (assumed to occur for one 24-hour period once per month (12 days per annum)).

8.5.3 Comparison with Standards and Guidelines

The relevant air quality standard for Nitrogen Dioxide has been detailed in Table A8.24. In this report the ambient air concentrations have been referenced to Council Directive 2008/50/EC, which has been transposed into Irish Legislation as S.I. 180 of 2011. The directive also details margins of tolerance, which are trigger levels for certain types of action in the period leading to the attainment date. The margin of tolerance reached 0% in 2010.

An annual average limit for NO_x (NO and NO_2) is generally applicable for the protection of vegetation in highly rural areas away from major sources of NO_x such as large conurbations, factories and high road vehicle activity such as a dual carriageway or motorway. Annex VI of EU Directive 2008/50/EC identifies that monitoring to demonstrate compliance with the NO_X limit for the protection of vegetation should be carried out at distances greater than:

- 5 km from the nearest motorway or dual carriageway,
- 5 km from the nearest major industrial installation,
- 20 km from a major urban conurbation.

As a guideline, a monitoring station should be indicative of approximately 1000 km^2 of surrounding area. However, representing a worst-case approach, the standard has been applied in the region of the nearby proposed Lough Beg NHA and the Cork Harbour SPA.

Table A8.24 EU Ambient Air Standards - Council Directive 2008/50/EC

Pollutant	Regulation	Limit Type	Margin of Tolerance	Value
Nitrogen Dioxide	2008/50/EC	Hourly limit for protection of human health - not to be exceeded more than 18 times/year	0% After 2010	200 $\mu g/m^3$ NO_2
		Annual limit for protection of human health	0% After 2010	40 $\mu g/m^3$ NO_2
		Critical level for protection of vegetation	None	30 $\mu g/m^3$ NO + NO_2

8.5.4 Modelling Results

Modelling was carried out for the scenarios described in Section 8.5.2. Table A8.25 details the predicted annual average and maximum one-hour NO_2 GLC for each scenario at the worst-case locations whereas Table A8.26 details the spatial variation in nitrogen dioxide concentrations at specific locations in the surrounding region. Table A8.25 also details the predicted NO_X GLC for each scenario at the worst-case locations in the region of the proposed NHA and SPA.

Table A8.25 Dispersion Model Results – Nitrogen Dioxide

Pollutant / Scenario	Averaging Period	Process Contribution (µg/m³)	Background Concentration (µg/m³)(1)	Predicted Emission Concentration (µg/Nm³)	Standard(2) (µg/Nm³)	Facility emissions as a % of ambient limit value
NO_2 / Maximum	Annual Mean(3)	1.0	12	13.0	40	2.5%
	99.8th%ile of 1-hr means(4)	90.9	N/A(4)	138.7	200	45.5%
NO_2 / Abnormal Operation	Annual Mean(3)	1.4	12	13.4	40	3.5%
	99.8th%ile of 1-hr means(4)	90.9	N/A(4)	138.7	200	45.5%
NO_X / Maximum	Annual Average (In NHA / SPA Only)	1.1	17	18.1	30	4.0%
NO_X / Abnormal Operation	Annual Average (In NHA / SPA Only)	1.12	17	18.1	30	4.0%

(1) Includes contribution from traffic and background sources (based on baseline monitoring results).
(2) Directive 2008/50/EC
(3) Conversion factor (annual average) based on the default ratio of 0.75.
(4) Derived using the UK LAQM(09) Guidance (Reference 13) as outlined in Section 8.4.3 with detailed results presented in Appendix A8.7.

Table A8.26 Dispersion Model Results – Nitrogen Dioxide Maximum Operation, Specific Receptors

Pollutant / Location	Averaging Period	Process Contribution (μg/m³)	Background Concentration (μg/m³)(1)	Predicted Emission Concentration (μg/Nm³)	Standard(2) (μg/Nm³)	Facility emissions as a % of ambient limit value
NO_2 Maximum / Worst-case Residential Receptor	Annual Mean(3)	0.36	12	12.4	40	0.9
	99.8th%ile of 1-hr means(4)	37.6	N/A(4)	105.8	200	19
NO_2 Typical / Ringaskiddy School	Annual Mean(3)	0.18	12	12.2	40	0.5
	99.8th%ile of 1-hr means(4)	15.0	N/A(4)	105.5	200	7.5
NO_2 Typical / Ringaskiddy Centre	Annual Mean(3)	0.25	12	12.3	40	0.6
	99.8th%ile of 1-hr means(4)	26.0	N/A(4)	105.6	200	13
NO_2 Typical / Cobh	Annual Mean(3)	0.29	12	12.3	40	0.7
	99.8th%ile of 1-hr means(4)	14.2	N/A(4)	105.7	200	7.1
NO_2 Typical / Carrigaline	Annual Mean(3)	0.05	12	12.05	40	0.1
	99.8th%ile of 1-hr means(4)	4.7	N/A(4)	105.2	200	2.4
NO_2 Typical / Crosshaven	Annual Mean(3)	0.19	12	12.2	40	0.5
	99.8th%ile of 1-hr means(4)	17.3	N/A(4)	105.5	200	8.7

(1) Includes contribution from traffic and background sources (based on baseline monitoring results).
(2) Directive 2008/50/EC
(3) Conversion factor following based on default ratio of 0.75.
(4) Derived using the UK LAQM(09) Guidance (Reference 13) as outlined in Section 8.4.3.

8.5.5 Concentration Contours

The geographical variation in NO_2 ground level concentrations beyond the facility boundary are illustrated as concentration contours in Figures 8.12 to 8.13. The contents of each figure are described below.

Figure 8.12 Maximum Operations: Predicted NO_2 99.8th Percentile Concentration

Figure 8.13 Maximum Operations: Predicted NO_2 Annual Average Concentration

8.5.6 Result Findings

In relation to the maximum one-hour limit value, modelling results indicate that the ambient ground level concentrations are below these ambient standards for the protection of human health under maximum and abnormal operation of the facility. Thus, no adverse effect on public health or the environment is envisaged to occur under these conditions at or beyond the facility boundary. Emissions at maximum operations equate to ambient NO_2 concentrations (including background concentrations) which are 69% of the maximum ambient 1-hour limit value (measured as a 99.8th%ile) at the worst-case receptor (to the south of the stack). The annual average NO_2 concentration (including background concentration) is also below the limit value for the protection of human health accounting for 33% of the annual limit value at the worst-case receptor which is located at the south-east boundary of the facility. The effect under abnormal operation is essentially unchanged compared to normal operation due to the infrequent nature of the occurrence (abnormal operation is assumed to occur for approximately 3% of the time in any one year).

The modelling results indicate that the maximum 1-hour and annual average NO_2 concentrations occur at or near the facility's southern and south-eastern boundaries. Concentrations fall off rapidly away from this maximum and for the maximum 1-hour concentration (as a 99.8th%ile) will be only 19% of the limit value (not including background concentrations) at the nearest sensitive receptor to the facility (see Table A8.27). The annual average NO_2 concentration decreases away from the facility with concentrations from emissions at the proposed facility accounting for only 0.9% of the limit value (not including background concentrations) at worst case sensitive receptors near the facility. Thus, the results indicate that the potential effect from the proposed facility on human health and the environment is minor and limited to the immediate environs of the facility (i.e. close to the facility boundary).

In the surrounding areas of Cobh, Carrigaline and Monkstown, NO_2 levels are significantly lower than background sources with the concentration from emissions at the proposed facility accounting for less than 0.8% of the NO_2 annual limit value for the protection of human health.

The annual average NO_X concentration due to process emissions is 4% of the limit value for the protection of vegetation and when the background concentration is included accounts for 60% of this annual limit value at the worst-case receptor in the region of the nearby ecologically sensitive areas.

8.6 Sulphur Dioxide, Carbon Monoxide and Total Dust (as PM_{10} and $PM_{2.5}$) Emissions and Results

8.6.1 Source Information

Source information including emission release heights, volume flows, locations and stack diameters has been summarised in **Appendix 8.6**.

Ambient Ground Level Concentrations (GLCs) of Sulphur Dioxide (SO_2), Carbon Monoxide (CO) and Total Dust (as PM_{10} and $PM_{2.5}$) have been predicted for the following scenarios in Table A8.27.

Table A8.27 Emission Scenario for Sulphur Dioxide, Carbon Monoxide and Total Dust (as PM_{10} and $PM_{2.5}$)

Pollutant	Scenario	Concentration	Emission Rate (g/s)
SO_2	Maximum 1-Hr Operation	200 mg/m^3	11.72
	Maximum 24-Hr Operation	50 mg/m^3	2.93
	Abnormal 24-Hr Operation(1)	200 mg/m^3	11.72
CO	Maximum 1-Hr Operation	150 mg/m^3	8.79
	Maximum 24-Hr Operation	50 mg/m^3	2.93
	Abnormal 24-Hr Operation(2)	200 mg/m^3	11.72
Total Dust	Maximum 1-Hr Operation	30 mg/m^3	1.76
	Maximum 24-Hr Operation	10 mg/m^3	0.586
	Abnormal 24-Hr Operation(3)	30 mg/m^3	1.76

(1) Abnormal operation scenario based on an emission level of 200 mg/m^3 for 3% of the time (assumed to occur for one 24-hour period once per month).
(2) Abnormal operation scenario based on an emission level of 200 mg/m^3 for 5% of the time (assumed to occur for one 36-hour period once per month).
(3) Abnormal operation scenario based on an emission level of 30 mg/m^3 for 3% of the time (assumed to occur for one 24-hour period once per month).

8.6.2 Comparison with Standards And Guidelines

The relevant air quality standards for Sulphur Dioxide, Carbon Monoxide, PM_{10} and $PM_{2.5}$ have been detailed in Table A8.28. In this report the ambient air concentrations for SO_2, CO and PM_{10} / $PM_{2.5}$ have been referenced to Council Directive 2008/50/EC, which has been transposed into Irish Law as S.I. 180 of 2011.

An annual average and winter limit value for SO_2 is applicable for the protection of ecosystems in highly rural areas away from major sources of SO_2 such as large conurbations and industrial facilities. This standard has been applied in the region of the nearby proposed Lough Beg NHA and the Cork Harbour SPA.

Table A8.28 EU Ambient Air Quality Current & Proposed Standards

Pollutant	Regulation	Limit Type	Current Margin of Tolerance	Value
Sulphur Dioxide	2008/50/EC	Hourly limit for protection of human health - not to be exceeded more than 24 times/year	None	350 μg/m^3
		Daily limit for protection of human health - not to be exceeded more than 3 times/year	None	125 μg/m^3
		Annual & Winter critical level for the protection of ecosystems	None	20 μg/m^3
Carbon Monoxide	2008/50/EC	8-hour limit (on a rolling basis) for protection of human health	None	10 mg/m^3
PM_{10}	2008/50/EC	24-hour limit for protection of human health - not to be exceeded more than 35 times/year	None	50 μg/m^3
		Annual limit for protection of human health	None	40 μg/m^3
$PM_{2.5}$	2008/50/EC	Annual target value for protection of human health	None	25 μg/m^3

8.6.3 Modelling Results

Modelling was carried out for the three scenarios described in Section 8.6.1.

Tables A8.29 – A8.32 detail the predicted SO_2, CO, PM_{10} and $PM_{2.5}$ GLC for each scenario.

Table A8.29 Dispersion Model Results – Sulphur Dioxide

Pollutant / Scenario	Averaging Period	Process Contribution (μg/m^3)	Background (μg/m^3)	Predicted Emission Concentration (μg/Nm^3)	Standard(1) (μg/Nm^3)
SO_2 / Maximum Operation	99.7th%ile of 1-hr means	42.4	N/A(3)	54.6	350
	99.2th%ile of 24-hr means	4.61	N/A(3)	20.4	125
SO_2 / Abnormal Operation(2)	99.7th%ile of 1-hr means	42.4	N/A(3)	54.6	350
	99.2th%ile of 24-hr means	4.61	N/A(3)	20.4	125
SO_2 / Maximum	Annual Average (In NHA / SPA Only)	0.27	10	10.3	20
SO_2 / Abnormal	Annual Average (In NHA / SPA Only)	0.30	10	10.3	20

(1) Directive 2008/50/EC
(2) Abnormal operation scenario based on an emission level of 200 mg/m^3 for 3% of the time (assumed to occur for one 24-hour period once per month).
(3) Derived using the UK LAQM(09) Guidance (Reference 13) as described in Section 8.4.3.

Table A8.30 Dispersion Model Results – Carbon Monoxide

Pollutant / Scenario	Averaging Period	Process Contribution (µg/m³)	Background (µg/m³)(1)	Predicted Emission Concentration (µg/Nm³)	Standard(2) (µg/Nm³)
CO / Maximum	Rolling Eight Hour	27.5	1,000	1,028	10,000
CO / Abnormal Operation(3)	Rolling Eight Hour	36.7	1,000	1,037	10,000

(1) Based on two times the annual mean.
(2) Directive 2008/50/EC
(3) Abnormal operation scenario based on an emission level of 200 mg/m^3 for 5% of the time (assumed to occur for one 36-hour period once per month).

Table A8.31 Dispersion Model Results – Total Dust (referenced to PM_{10})

Pollutant / Scenario	Averaging Period	Process Contribution (µg/m³)	Background (µg/m³)	Predicted Emission Concentration (µg/Nm³)	Standard(1) (µg/Nm³)
PM_{10} / Maximum	90th%ile of 24-hr means	0.25	N/A(3)	28.9	50
	Annual mean	0.07	16	16.1	40
PM_{10} / Abnormal Operation(2)	90th%ile of 24-hr means	0.25	N/A(3)	28.9	50
	Annual mean	0.07	16	16.1	40

(1) Directive 2008/50/EC
(2) Abnormal operation scenario based on an emission level of 30 mg/m^3 for 3% of the time (assumed to occur for one 24-hour period once per month).
(3) Derived using the UK LAQM(09) Guidance (Reference 13) as discussed in Section 8.4.3.

Table A8.32 Dispersion Model Results – Total Dust (referenced to $PM_{2.5}$)

Pollutant / Scenario	Averaging Period	Process Contribution (µg/m³)	Background (µg/m³)	Predicted Emission Concentration (µg/Nm³)	Limit Value(1) (µg/Nm³)
$PM_{2.5}$ / Maximum	Annual mean	0.07	14	14.1	25
$PM_{2.5}$ / Abnormal Operation(2)	Annual mean	0.07	14	14.1	25

(1) Council Directive 2008/50/EC
(2) Abnormal operation scenario based on an emission level of 30 mg/m^3 for 3% of the time (assumed to occur for one 24-hour period once per month).

8.6.4 Concentration Contours

The geographical variation in SO_2, PM_{10} and $PM_{2.5}$ ground level concentrations beyond the Facility boundary are illustrated as concentration contours in Figures 8.14 to 8.17. The contents of each figure are described below.

Figure 8.14 Maximum Operations: Predicted SO_2 99.7th Percentile of Hourly Concentrations

Figure 8.15 Maximum Operations: Predicted SO_2 99.2th Percentile of 24-Hourly Concentrations

Figure 8.16 Maximum Operations: Predicted PM_{10} 90th Percentile of 24-Hourly Concentrations

Figure 8.17 Maximum Operations: Predicted PM_{10} Annual Concentrations

8.6.5 Result Findings

SO_2

SO_2 modelling results indicate that the ambient ground level concentrations are below the relevant air quality standards for the protection of human health for sulphur dioxide under maximum and abnormal operation of the facility. Thus, no adverse effect on public health or the environment is envisaged to occur under these conditions at or beyond the facility boundary. Emissions at maximum operations equate to ambient SO_2 concentrations due to process emission which are 12% of the maximum ambient 1-hour limit value (measured as a 99.7th%ile) and 4% of the maximum ambient 24-hour limit value (measured as a 99.2th%ile) at the worst-case receptor. When background concentrations are included this rises to 16% of the maximum ambient 1-hour limit value (measured as a 99.7th%ile) and 16% of the maximum ambient 24-hour limit value (measured as a 99.2th%ile) at the worst-case receptor.

Emissions at maximum operations equate to ambient SO_2 concentrations due to process emissions which are 1.7% of the annual limit value at the worst-case receptor in the region of the proposed Lough Beg NHA and the Cork Harbour SPA. When background concentrations are included this rises to 50% of the annual limit value at the worst-case receptor in the region of the NHA and SPA.

CO

CO modelling results indicate that the ambient ground level concentrations are below the relevant air quality standards for the protection of human health for CO under maximum and abnormal operation of the facility. Thus, no adverse effect on public health or the environment is envisaged to occur under these conditions at or beyond the facility boundary. Emissions at maximum operations equate to ambient CO concentrations due to process emission which are less than 0.3% of the maximum rolling 8-hour limit value at the worst-case receptor. When background concentrations are included this rises to 10% of the maximum rolling 8-hour limit value at the worst-case receptor.

PM_{10}

PM_{10} modelling results indicate that the ambient ground level concentrations are below the relevant air quality standards for the protection of human health for PM_{10} under maximum and abnormal operation of the facility. Thus, no adverse effect on public health or the environment is envisaged to occur under these conditions at or beyond the facility boundary. Emissions at maximum operations equate to ambient PM_{10} concentrations

(including background concentrations) which are 58% of the maximum ambient 24-hour limit value (measured as a 90th%ile) with the contribution from the proposed facility equating to 0.5% of the limit value. Emissions at maximum operations equate to ambient PM_{10} concentrations which are 40% of the annual average limit value at the worst-case receptor with the contribution from the proposed facility equating to less than 0.2% of the limit value.

$PM_{2.5}$

$PM_{2.5}$ modelling results indicate that the ambient ground level concentrations are below the proposed air quality standard for the protection of human health for $PM_{2.5}$ under maximum and abnormal operation of the facility. Thus, no adverse effect on public health or the environment is envisaged to occur under these conditions at or beyond the facility boundary. Emissions at maximum operations equate to ambient $PM_{2.5}$ concentrations (including background concentrations) which are 56% of the proposed annual average limit value at the worst-case receptor, with the contribution from the proposed facility equating to less than 0.3% of the limit value.

8.7 Total Organic Carbon (TOC), Hydrogen Chloride and Hydrogen Fluoride Emissions and Results

8.7.1 Source Information

Source information including emission release heights, volume flows, locations and stack diameters has been summarised in **Appendix 8.6**.

Ambient Ground Level Concentrations (GLCs) of Total Organic Carbon (TOC), Hydrogen Chloride (HCl) and Hydrogen Fluoride (HF) have been predicted for the following scenarios in Table A8.33.

Table A8.33 Emission Scenario for TOC, HCl and HF

Pollutant	Scenario	Concentration	Emission Rate (g/s)
TOC	Maximum 1-Hr Operation	30 mg/m^3	1.17
	Maximum 24-Hr Operation	10 mg/m^3	0.586
	Abnormal Operation(1)	30 mg/m^3	1.17
HCl	Maximum 1-Hr Operation	60 mg/m^3	3.52
	Maximum 24-Hr Operation	10 mg/m^3	0.586
	Abnormal Operation(2)	60 mg/m^3	3.52
HF	Maximum 1-Hr Operation	4 mg/m^3	0.234
	Maximum 24-Hr Operation	1 mg/m^3	0.059
	Abnormal Operation(3)	4 mg/m^3	0.234

(1) Abnormal operation scenario based on an emission level of 30 mg/m^3 for 3% of the time (assumed to occur for one 24-hour period once per month).
(2) Abnormal operation scenario based on an emission level of 60 mg/m^3 for 3% of the time (assumed to occur for one 24-hour period once per month).
(3) Abnormal operation scenario based on an emission level of 4 mg/m^3 for 3% of the time (assumed to occur for one 24-hour period once per month).

8.7.2 Comparison With Standards And Guidelines

The organic compound emissions from the facility will consist of a range of aliphatic and aromatic compounds at low concentration. The toxicity of these compounds will vary by several orders of magnitude. Ambient benzene levels have been regulated by the EU (Council Directive 2008/50/EC) due to the higher toxicity of this compound compared to other common hydrocarbons (see Table A8.34). In this assessment, it has been assumed that all emissions from the facility are composed of benzene. This is a very pessimistic assumption and thus will significantly overestimate the effect of TOC emissions from the facility.

In the absence of specific Irish air quality guidelines, air quality guidelines for the protection of humans, which have been set by the UK DEFRA (Expert Panel on Air Quality Standards (2008)), have been used in the assessment. Ambient air quality standards for HCl and HF are based on the UK DEFRA environmental assessment levels (EALs) (see Table A8.34).

Table A8.34 Air Standards for TOC, HCl and HF

Pollutant	Regulation	Limit Type	Value
TOC (assumed to be benzene)	EU Council Directive 2008/50/EC	Annual Average	5 μg/m^3
HCl	UK DEFRA EAL	Maximum 1-Hour	800 μg/m^3
HCl	UK DEFRA EAL	Annual Average	20 μg/m^3
HF	UK DEFRA EAL	Maximum 1-Hour	160 μg/m^3
HF	UK DEFRA EAL	Annual Average	16 μg/m^3

8.7.3 Modelling Results

Modelling was carried out for the three scenarios described in Section 8.7.1 for each pollutant.

Tables A8.35 – A8.37 details the predicted TOC, HCl and HF GLC for each scenario.

Table A8.35 Dispersion Model Results – TOC (assumed to be benzene)

Pollutant / Scenario	Averaging Period	Process Contribution (μg/m^3)	Background (μg/m^3)	Predicted Emission Concentration (μg/Nm^3)	Standard(1) (μg/Nm^3)
TOC / Maximum	Annual Average	0.07	1	1.1	5
TOC / Abnormal Operation(2)	Annual Average	0.07	1	1.1	5

(1) Council Directive 2008/50/EC
(2) Abnormal operation scenario based on an emission level of 30 mg/m^3 for 3% of the time (assumed to occur for one 24-hour period once per month).

Table A8.36 Dispersion Model Results – HCl

Pollutant / Scenario	Averaging Period	Process Contribution (μg/m^3)	Background (μg/m^3)	Predicted Emission Concentration (μg/Nm^3)	Standard(1) (μg/Nm^3)
HCl / Maximum	Maximum 1-hour	18.9	4.4	23.3	800
HCl / Maximum	Annual	0.07	2.2	2.3	20
HCl / Abnormal Operation(2)	Maximum 1-hour	18.9	4.4	23.3	800
HCl / Abnormal Operation(2)	Annual	0.08	2.2	2.3	20

(1) UK DEFRA EAL
(2) Abnormal operation scenario based on an emission level of 60 mg/m^3 for 3% of the time (assumed to occur for one 24-hour period once per month).

Table A8.37 Dispersion Model Results – HF

Pollutant / Scenario	Averaging Period	Process Contribution (μg/m³)	Annual Mean Background (μg/m³)	Predicted Emission Concentration (μg/Nm³)	Standard (μg/Nm³)(1)
HF / Maximum	Maximum 1-hr	1.26	0.64	1.9	160
	Annual Average	0.007	0.32	0.33	16
HF / Abnormal Operation(2)	Maximum 1-hr	1.26	0.64	1.9	160
	Annual Average	0.0075	0.32	0.33	16

(1) UK DEFRA
(2) Abnormal operation scenario based on an emission level of 4 mg/m³ for 3% of the time (assumed to occur for one 24-hour period once per month).

8.7.4 Concentration Contours

The geographical variation in TOC (as benzene), HCl and HF ground level concentrations beyond the facility boundary is illustrated as concentration contours in Figures 8.18 – 8.20. The content of the figures is described below.

Figure 8.18 Maximum Operations: Predicted TOC (as benzene) Annual Average Concentration

Figure 8.19 Maximum Operations: Predicted HCl Maximum 1-Hour Concentration

Figure 8.20 Maximum Operations: Predicted HF Annual Average Concentration

8.7.5 Result Findings

TOC

TOC modelling results indicate that the ambient ground level concentrations are below the relevant air quality standard for the protection of human health for benzene under maximum and abnormal operation of the facility. Thus, no adverse effect on public health or the environment is predicted to occur under these conditions at or beyond the facility boundary. Emissions at maximum operations equate to a maximum ambient TOC concentration (including background concentration) which is 21% of the benzene annual limit value.

HCl

HCl modelling results indicate that the ambient ground level concentrations are below the relevant air quality guideline for the protection of human health for HCl under maximum and abnormal operation of the facility. Thus, no adverse effect on public health or the environment is envisaged to occur under these conditions at or beyond the facility boundary. Emissions at maximum operations equate to ambient HCl concentrations (including background concentrations) which are 2.9% of the maximum ambient 1-hour limit value and 12% of the annual mean limit value.

HF

HF modelling results indicate that the ambient ground level concentrations are below the relevant air quality standards and guidelines for HF for the protection of human health under maximum and abnormal operation of the facility. Thus, no adverse effect on public health or the environment is envisaged to occur under these conditions at or beyond the facility boundary. Emissions at maximum operations equate to ambient HF concentrations (including background concentrations) which are 1.2% of the maximum ambient 1-hour limit value and 2.0% of the annual limit value.

8.8 Dioxin-Like Compounds

8.8.1 Description of Dioxin-Like Compounds

The term “Dioxin-like Compounds” generally refers to three classes of compounds; polychlorinated dibenzo-p-dioxins (PCDDs or CDDs), polychlorinated dibenzofurans (PCDFs or CDFs), and polychlorinated biphenyls (PCBs). PCDDs include 75 individual compounds, or congeners, PCDFs include 135 congeners and PCBs include 209 congeners (see Table A8.38). Both PCDDs and PCDFs are usually formed as unintentional by-products through a variety of chemical reactions and combustion processes. These compounds are lipophilic that bind to sediment and organic matter in the environment and tend to be absorbed in animal and human fatty tissue. They are also generally extremely resistant towards chemical and biological degradation processes, and, consequently, persist in the environment and accumulate in the food chain[14].

The toxic effects of dioxins are initiated at the cellular level, by the binding of the dioxin to a specific protein in the cytoplasm of the body cells, the aryl hydrocarbon receptor (AhR). The binding of TCDD to the AhR constitutes a first and necessary step to initiate the toxic and biochemical effects of this compound. Dioxins effects in humans include increased prevalence of diabetes, immunotoxic effects and effects on neurodevelopment and neurobehaviour in children. Studies have shown TCDD to be carcinogenic but a lack of direct DNA-damaging effects indicates that TCDD is not an initiator but a promoter of carcinogenesis[15].

130 of the 209 PCB congeners have historically been manufactured for a variety of uses including dielectric fluids in transformers and capacitors and as lubricants and adhesives. However, the marketing, use and disposal of PCBs has been severely restricted in the EU through Directives 85/467/EC and 96/59/EC[14].

The toxicity of dioxins varies widely with 2, 3, 7, 8-TCDD being the most potent dioxin congener and with only particular configurations of these compounds thought to have dioxin-like toxicity (See Table A8.39). For PCDDs (Dioxins), only 7 of the 75 congeners have dioxin-like toxicity; these are the ones with chlorine substitutions in, at least, the 2, 3, 7 and 8 positions. For PCDFs (Furans), only 10 of the 135 congeners have dioxin-like toxicity; these are again the ones with chlorine substitutions in, at least, the 2, 3, 7 and 8 positions. In relation to PCBs, only 13 of the 209 congeners are likely to have dioxin-like toxicity; these are the PCBs with four or more chlorines with just one or no substitutions in the ortho position (coplanar)[14,15].

As dioxin-like compounds have varying degrees of toxicity, a toxicity equivalency procedure has been developed to describe the cumulative toxicity of these mixtures. The procedure involved assigning individual Toxicity Equivalency Factors (TEFs) to the 2, 3, 7, 8- substituted PCDD and PCDF congeners and to selected coplanar and mono-ortho PCBs. The TEFs are referenced to 2, 3, 7, 8-TCDD, which is assigned a TEF of 1.0. Calculation of the toxic equivalency (TEQ) of a mixture involves multiplying the concentration of individual congeners by their respective TEF. The sum of the TEQ concentrations for the individual congeners is the TEQ concentration for the mixture.

Since 1989, three different TEF schemes have been developed[16,17]:

I-TEQ$_{DF}$ – Developed by NATO/CCMS in 1988, the I-TEQ$_{DF}$ (DF = dioxin, furan, I = International) procedure assigns TEFs only for the 7 dioxins (PCDDs) and 10 furans (PCDFs). This scheme does not include dioxin-like PCBs. This scheme has been adopted in Council Directive 2010/75/EU and has been applied in the current assessment.

TEQ$_{DFP}$-WHO$_{94}$ – In 1994, the WHO added 13-dioxin-like PCBs to the TEF scheme for dioxins and furans. However, no changes were made to the TEFs for dioxins and furans I-TEQ$_{DF}$ (DFP = dioxin, furan, PCBs).

TEQ_{DFP}-WHO_{98} – In 1998, the WHO re-evaluated the TEF scheme for dioxins, furans and dioxin-like PCBs. Changes were made to the TEFs for dioxins, furans and dioxin-like PCBs. Table A8.39 outlines the TEF for the most recent scheme for comparison with the scheme recommended in Council Directive 200/76/EC (I-TEQ_{DF}).

8.8.2 Modelling Strategy

The emissions of dioxin-like compounds from the facility have been evaluated in this chapter. Firstly, the stack emissions have been characterised in terms of mass of each Dioxin/Furan congener released, and the partitioning of these releases into a vapour and particle phase. Thereafter, air dispersion modelling has been used to translate these releases to ambient air vapour and particle phase concentrations, and wet and dry particulate deposition fluxes, in the vicinity of the release.

As recommended by the USEPA, individual dioxin congeners have been modelled from source to receptor. Only at the interface to human exposure, e.g., ingestion, inhalation, dermal absorption, etc., are the individual congeners recombined and converted into the toxic equivalence of 2, 3, 7, 8-TCDD to be factored into a quantitative risk assessment.

Emission Rate

The dioxin emission factor is defined as the total mass (in vapour and particulate form) of dioxin-like compound emitted per mass of feed material combusted. For the current proposal, a test burn is not possible as the Ringaskiddy Resource Recovery Centre has not been commissioned yet. However, Indaver has several flue gas cleaning systems similar to that proposed in the current facility, in operation in Europe. An analysis of these flue gas cleaning systems has suggested that the likely emission rate will outperform the most stringent limit value set by the EU in the Council Directive on Industrial Emissions (2010/75/EU).

Congener-specific emission data are needed for the analyses of the ambient air effects and deposition flux of dioxin-like compounds using air dispersion and deposition models. As each specific congener has different physico-chemical properties, the proportion of each congener will affect the final result. Thus, the congener profile expected from the current facility must be derived. The congener profile will be dependent on various factors including the type of waste being burnt, the temperature of combustion, the type of combustion chamber being operated and the air pollution control devices (APCDs) installed. In the present case, no site-specific stack testing for specific congeners is possible as the facility is not yet built.

Shown in Table A8.40 are typical relative PCDD/PCDF congener emission factors for municipal waste incinerators (MWI) as reported by the USEPA (1998)[18] for a municipal waste incinerator similar to that proposed in the current scheme, a mass burn refractometry system with wet scrubbing (MB-REF WS) (Indaver however differs in that semi-dry scrubbing is proposed rather than wet scrubbing) taken from the Database of Sources of Environmental Releases of Dioxin-Like Compounds in the United States (USEPA, 1998 (CD-ROM))[18]. It would be expected that the relative congener profiles for this type of incinerator to be somewhat similar to the current case. Figures 8.21 – 8.22 show the ratio of congeners and the TEQ equivalent releases from this type of facility corrected to the maximum emission limit outlined in Council Directive 2010/75/EU.

Vapour / Particulate Partitioning

In order to accurately model emissions of PCDD/PCDFs (Dioxins/Furans), PAHs and mercury, the partitioning of stack emissions into the vapour and particle (V/P) state is required.

In relation to PCDD/PCDFs (Dioxins/Furans), V/P partitioning based on stack tests data is highly uncertain[10]. Research has indicated that higher temperatures favour the vaporous states for the lower chlorinated congeners and the particulate state for the higher chlorinated congeners[10]. However, measured data has indicated significant variability in the V/P partitioning. For these reasons, the USEPA has indicated that V/P distributions obtained from stack sampling should not be used.

Data can also be obtained from ambient air sampling using a glass fibre particulate filter and polyurethane foam (PUF) absorbent trap. As the sampler is not subjected to artificial heating or cooling, the method can be used to imply the vapour phase and particle bound partitioning of PCDD/Fs (Dioxins/Furans) in ambient air. However, the results will be only approximate as mass transfer between the particulate matter on the filter and the vapour trap cannot be ruled out[10].

The recommended USEPA approach to obtaining the vapour/particulate partitioning at the current time is theoretical and based on the Junge-Pankow model for estimating the particle/gas distribution of PCDD/PCDFs (Dioxins/Furans)[10]. This model is the one most commonly used for estimating the adsorption of semi-volatile compounds to aerosols:

$$\Phi = c\Theta / (\rho^o_L + c\Theta)$$

where:

Φ = fraction of compound adsorbed to aerosol particles
c = constant (assumed 17.2 Pa-cm)
Θ = particle surface area per unit volume of air, cm^2 aerosol/cm^3 air
ρ^o_L = saturation liquid phase vapour pressure, Pa

The particulate fraction can also be expressed by:

$$\Phi = C_p(TSP) / (C_g + C_p(TSP))$$

where:

Φ = fraction of compound adsorbed to aerosol particles
C_p = concentration of semi-volatile compounds associated with aerosols, ng/μg particles
C_g = gas-phase concentration, ng/m^3
TSP = total suspended particle concentration, $\mu g/m^3$

In the above calculations, it is assumed that all compounds emitted from the combustion sources are freely exchangeable between vapour and particle fractions. This may be a simplification as some of the particulate fraction may be trapped and be unavailable for exchange.

As the ρ^o_L is referenced to 25ºC and an ambient temperature of 10ºC has been assumed which is appropriate for average annual temperatures in Ireland, the ρ^o_L has been converted to the ambient temperature as indicated in Table A8.41. Other relevant data used in the calculations and the derived particle fraction at 10ºC is also shown in Table A8.41.

The advantages of the theoretical approach is that it is based on current adsorption theory, considers the molecular weight and degree of halogenation of the congeners and uses the availability of surface area for adsorption of atmospheric particles corresponding to specific airsheds (background plus local sources used in the current case).

8.8.3 Modelling of Vapours and Particles Concentrations

PCDD/PCDFs have a range of vapour pressures and thus exist in both vapour and particle-bound states to varying degrees. In order to adequately model dispersion and deposition of PCDD/PCDFs, modelling of both vapour and particle-bound states is thus necessary.

For the deposition modelling of PCDD/PCDFs, both wet and dry gaseous and particulate deposition were calculated.

Gaseous Deposition

Dry Gaseous Deposition

For the dry gaseous deposition modelling of PCDD/PCDFs, four physiochemical parameters are required for dioxins / furans. The dry gaseous deposition velocity formulation is based on three resistance terms; aerodynamic resistance, quasi-laminar resistance to bulk transfer and a bulk surface resistance term. The four physiochemical parameters required to calculate these resistance terms are D_a (diffusivity of modelled gas in air (cm/s)), D_w (diffusivity of modelled gas in water (cm/s)), Henry's Law constant for modelled gas (Pa-m^3/mol) and r_{cl} (leaf cuticular resistance (s/m). The values derived for the 2,3,7,8-TCDD is shown in Table A8.42.

Wet Gaseous Deposition

Wet gaseous deposition physically washes out the chemically contaminated vapours from the atmosphere. Wet gaseous deposition flux depends on the precipitation rate, the concentration of the pollutant in the liquid phase and the molecular weight of the pollutant. The AERMOD model formulation assumes that the wet gaseous deposition flux is the same for snow as for rain.

For the vapour phase modelling, both dry and wet gaseous deposition was considered. Using the congener profile from Table A8.38 and the vapour – particle partitioning from Table A8.39, the vapour concentrations of the respective dioxin congeners was determined as outlined in Table A8.44 for the stack and diagrammatically in Figure 8.23. Results are shown under maximum operating conditions. The results from wet and dry gaseous deposition modelling have also been reported in Table A8.44 and diagrammatically in Figure 8.24.

Particulate Deposition

Dry Particulate Deposition

When modelling particulate PCDD/PCDFs, the surface area weighting rather than mass weighting is used for deposition. The surface weighting reflects the mode of formation where volatiles condense on the surface of particulates in the flue gas cleaning system (see Column 6 of Table A8.43). This distribution is suitable as a default for some combustion facilities equipped with either electrostatic precipitators (ESPs) or fabric filters, because the distribution is relatively typical of particle size arrays that have been measured at the outlet to advanced equipment designs[10]. Thus, the apportionment of emissions by particle size becomes a function of the surface area of the particle which is available for chemical adsorption.

Dry particulate deposition is based on a resistance scheme in which the deposition velocity is based on the predominant particle size distribution via two methods. Method 1 is used when a significant fraction (> 10%) of the total particulate mass has a diameter greater than 10 microns and the particle size distribution is reasonably well known. The method is based on the gravitational settling velocity and two resistance terms; aerodynamic resistance and quasi-laminar resistance to bulk transfer. Method 2 is used when the particle size

distribution is not well known and when a small fraction (less than 10% of the mass) consists of particles with a diameter of 10 microns or larger. The deposition velocity for method 2 is given as the weighted average of the deposition velocity for the coarse mode and fine mode. In the results below method 1 has been used, based on the generalised particle-size distribution recommended by the USEPA as outlined in Table A8.43[6], as it gives similar concentrations to method 2 but significantly higher deposition results.

Wet Particulate Deposition

Wet particulate deposition physically washes out the chemically contaminated particulate from the atmosphere. Wet deposition flux depends on the fraction of the time precipitation occurs and the fraction of material removed by precipitation per unit of time by particle size. The AERMOD model formulation is based on a particle washout coefficient which is based on the collision efficiency and the mean diameter of raindrops. It is also assumed that the wet deposition flux is the same for snow as for rain.

For the particle-phase concentration, the congener profile from Table A8.38 and the vapour – particle partitioning from Table A8.39 were used to give the particulate concentrations of the respective dioxin congeners as determined in Table A8.45 and diagrammatically in Figure 8.23. Results are shown under maximum operating conditions.

For the particle-bound deposition, the congener profile from Table A8.38 and the vapour – particle partitioning from Table A8.39 were used to give the particulate emission rate of the respective dioxin congeners. The deposition flux for each congener was calculated by multiplying the emission rate of each congener by the unitised deposition flux as shown in Table A8.46 and diagrammatically in Figure 8.24. Results are shown under maximum operating conditions.

8.8.4 Comparison with Standards And Guidelines

Currently, no internationally recognised ambient air quality concentration or deposition standards exist for PCDD/PCDFs (Dioxins/Furans). Both the USEPA and WHO recommended approach to assessing the risk to human health from Dioxins/Furans entails a detailed risk assessment analysis involving the determination of the effect of Dioxins/Furans in terms of the EU TWI (Tolerable Weekly Intake) approach[17,18]. The TWI was set by the EU in order to protect human health and was based on applying a safety factor to the LOAEL (Lowest Observed Abnormal Effect Levels) for dioxin and furans. Occasional short term exceedances of the TWI would have no health consequences provided the long-term average is not exceeded. The EU currently proposes a maximum TWI of 14 pg WHO-TEQ /kg body weight. This reflects the concept that guidance values for the protection of human health should consider total exposure to the substance including air, water, soil, food and other media sources (further details in Chapter 6 (Population And Human Health)).

Table A8.38 The number of dioxin-like and total congeners within dioxin, furan, and coplanar PCB Homologue groups[1].

Homologue Group	n: Number of Dioxin-Like Congeners	N: Number of Congeners	1/N
I. Dioxins			
Tetra-CDD	1	22	0.022
Penta-CDD	1	14	0.071
Hexa-CDD	3	10	0.100
Hepta-CDD	1	2	0.500
Octa-CDD	1	1	1.000
II. Furans			
Tetra-CDF	1	38	0.026
Penta-CDF	2	28	0.036
Hexa-CDF	4	16	0.063
Hepta-CDF	2	4	0.250
Octa-CDF	1	1	1.000
III. Mono-ortho coplanar PCBs			
Tetrachloro-PCBs	1	42	0.024
Pentachloro-PCBs	5	46	0.022
Hexachloro-PCBs	4	42	0.024
Heptachloro-PCBs	3	24	0.042

(1) USEPA (2004) Estimating Exposure to Dioxin-Like Compounds Volume II, Chapter 3

Table A8.39 The TEF scheme for TEQ_{DFP}-WHO_{98} and I-TEQ_{DF} [1].

Dioxin Congeners	TEF	Furan Congeners	TEF
2,3,7,8-TCDD	1.0	2,3,7,8-TCDF	0.1
1,2,3,7,8-PeCDD	1.0 (0.5)[2]	1,2,3,7,8-PeCDF	0.05
1,2,3,4,7,8-HxCDD	0.1	2,3,4,7,8-PeCDF	0.5
1,2,3,6,7,8-HxCDD	0.1	1,2,3,4,7,8-HxCDF	0.1
1,2,3,7,8,9-HxCDD	0.1	1,2,3,6,7,8-HxCDF	0.1
1,2,3,4,6,7,8-HpCDD	0.01	1,2,3,7,8,9-HxCDF	0.1
OCDD	0.0001 (0.001)[2]	2,3,4,6,7,8-HxCDF	0.1
PCB Chemical Structure	**TEF**	1,2,3,4,6,7,8-HpCDF	0.01
3,3',4,4'-TeCB	0.0001	1,2,3,4,7,8,9-HpCDF	0.01
3,4,4',5-TCB	0.0001	OCDF	0.0001 (0.001)[2]
2,3,3',4,4'-PeCB	0.0001		
2,3,4,4',5-PeCB	0.0005		
2,3',4,4',5-PeCB	0.0001		
2',3,4,4',5-PeCB	0.0001		
3,3',4,4',5-PeCB	0.1		
2,3,3',4,4',5-HxCB	0.0005		
2,3,3',4,4',5'-HxCB	0.0005		
2,3',4,4',5,5'-HxCB	0.00001		
3,3',4,4',5,5'-HxCB	0.01		
2,3,3',4,4',5,5'-HpCB	0.0001		

(1) USEPA (2004) Estimating Exposure to Dioxin-Like Compounds Volume II, Chapter 1
(2) Values in parentheses are those given in Annex VI, Council Directive 2010/75/EU and equate to I-TEQ_{DF}.

Table A8.40 PCDD/PCDF Relative Emission Factors for Municipal Waste Incinerator (MB-Ref WS)[18]

	Emission Factor (relative to sum of toxic congeners)	**Emission Concentration (ng/m^3 from stack)**	**Grate Incinerator Emission Factor (ng/sec from stack)**
Congener Group	Nondetects set to zero	Nondetects set to zero	Nondetects set to zero
2,3,7,8-TCDD	0.0006	0.0014	0.08091
1,2,3,7,8-PeCDD	0.0070	0.0077	0.45007
1,2,3,4,7,8-HxCDD	0.0121	0.0027	0.15590
1,2,3,6,7,8-HxCDD	0.0148	0.0033	0.19054
1,2,3,7,8,9-HxCDD	0.0276	0.0061	0.35613
1,2,3,4,6,7,8-HpCDD	0.1276	0.0028	0.16454
OCDD	0.2159	0.0005	0.02782
2,3,7,8-TCDF	0.0114	0.0012	0.07321
1,2,3,7,8-PeCDF	0.0246	0.0270	1.58311
2,3,4,7,8-PeCDF	0.0870	0.0191	1.12206
1,2,3,4,7,8-HxCDF	0.0370	0.0081	0.47757
1,2,3,6,7,8-HxCDF	0.0000	0.0000	0.00000
1,2,3,7,8,9-HxCDF	0.0620	0.0136	0.79963
2,3,4,6,7,8-HxCDF	0.2130	0.0047	0.27458
1,2,3,4,6,7,8-HpCDF	0.0246	0.0005	0.03168
1,2,3,4,7,8,9-HpCDF	0.1304	0.0003	0.01680
OCDF	0.0006	0.0014	0.08091
Total PCDD/PCDF	**1.0**	**0.1 ng/m^3**	**5.86 ng/sec**

(1) Database of Sources of Environmental Releases of Dioxin-Like Compounds in the United States (1998, USEPA (CD-ROM)).

Table A8.41 PCDD/PCDF Particle Fraction, Φ, at 10ºC In Airshed (Background plus Local Sources)[10]

Congener Group	**E-Hρ^o_L (25ºC)**	**E-Hρ^o_L (10ºC)[2]**	**Particle Fraction**
2,3,7,8-TCDD	1.14×10^{-4}	1.87×10^{-5}	0.763
1,2,3,7,8-PeCDD	1.74×10^{-5}	2.47×10^{-6}	0.961
1,2,3,4,7,8-HxCDD	3.96×10^{-6}	4.98×10^{-7}	0.992
1,2,3,6,7,8-HxCDD	3.96×10^{-6}	4.98×10^{-7}	0.992
1,2,3,7,8,9-HxCDD	3.96×10^{-6}	4.98×10^{-7}	0.992
1,2,3,4,6,7,8-HpCDD	1.02×10^{-6}	1.18×10^{-7}	0.998
OCDD	2.77×10^{-7}	2.91×10^{-8}	0.9995
2,3,7,8-TCDF	1.23×10^{-4}	2.01×10^{-5}	0.75
1,2,3,7,8-PeCDF	3.64×10^{-5}	5.46×10^{-6}	0.917
2,3,4,7,8-PeCDF	2.17×10^{-5}	3.11×10^{-6}	0.951
1,2,3,4,7,8-HxCDF	10.09×10^{-6}	1.09×10^{-6}	0.982
1,2,3,6,7,8-HxCDF	10.09×10^{-6}	1.09×10^{-6}	0.982
1,2,3,7,8,9-HxCDF	4.99×10^{-6}	6.49×10^{-7}	0.989
2,3,4,6,7,8-HxCDF	4.99×10^{-6}	6.49×10^{-7}	0.989
1,2,3,4,6,7,8-HpCDF	2.24×10^{-6}	2.77×10^{-7}	0.995
1,2,3,4,7,8,9-HpCDF	1.31×10^{-6}	1.56×10^{-7}	0.9974
OCDF	2.60×10^{-7}	2.71×10^{-8}	0.9995

(1) USEPA (2004) Estimating Exposure to Dioxin-Like Compounds Volume II, Chapter 3

(2) Background plus local sources default values: $\Theta = 3.5 \times 10^{-6}$ cm^2 aerosol/cm^3 air, TSP = 60 μg/m^3.

Table A8.42 Gas Deposition Physiochemical Parameters for 2,3,7,8-TCDD

Compound	D_a (cm/s)	D_w (cm/s)	H (Pa m^3 mol^{-1})	r_{cl} (sm^{-1})
2,3,7,8-TCDD	0.052	0.00000439	3.34	7.84

Table A8.43 Generalized Particle Size Distribution & Proportion of Available Surface Area[10]

Mean Particle Diameter (μm)	Particle Radius (μm)	Surface Area/Volume (μm^{-1})	Fraction of Total Mass[2]	Proportion Available Surface Area	Fraction of Total Surface Area[3]
>15.0	7.50	0.400	0.128	0.0512	0.0149
12.5	6.25	0.480	0.105	0.0504	0.0146
8.1	4.05	0.741	0.104	0.0771	0.0224
5.5	2.75	1.091	0.073	0.0796	0.0231
3.6	1.80	1.667	0.103	0.1717	0.0499
2.0	1.00	3.000	0.105	0.3150	0.0915
1.1	0.55	5.455	0.082	0.4473	0.1290
0.7	0.40	7.500	0.076	0.5700	0.1656
>0.7	0.40	7.500	0.224	1.6800	0.4880

(1) USEPA (2004) Chapter 3: Air Dispersion and Deposition Modelling, Human Health Risk Assessment Protocol, Region 6 Centre for Combustion Science and Engineering
(2) Used in the deposition modelling of metals (except Hg)
(3) Used in the deposition modelling of PCDD/PCDFs, PAHs and Hg.

8.8.5 Modelling Results

Tables A8.44 – A8.49 detail the predicted PCCD/PCDFs (Dioxins/Furans) GLC and deposition flux for the maximum scenario based on a default municipal waste incinerator profile under maximum operating conditions.

Table A8.44 PCDD/PCDF Annual Vapour Concentrations and Deposition Under Maximum Operations

Congener Group	Vapour Fraction	Vapour Emission Rate (ng/sec)	Annual Vapour Concentration (fg/m^3)	Annual Dry Vapour Deposition (ng/m^2)	Annual Wet Vapour Deposition (ng/m^2)
2,3,7,8-TCDD	0.237	1.92E-02	2.19E-03	8.34E-04	1.17E-05
1,2,3,7,8-PeCDD	0.039	1.76E-02	2.00E-03	7.64E-04	1.07E-05
1,2,3,4,7,8-HxCDD	0.008	1.25E-03	1.42E-04	5.43E-05	7.61E-07
1,2,3,6,7,8-HxCDD	0.008	1.52E-03	1.74E-04	6.63E-05	9.30E-07
1,2,3,7,8,9-HxCDD	0.008	2.85E-03	3.25E-04	1.24E-04	1.74E-06
1,2,3,4,6,7,8-HpCDD	0.002	3.29E-04	3.75E-05	1.43E-05	2.01E-07
OCDD	0.0005	1.39E-05	1.59E-06	6.05E-07	8.49E-09
2,3,7,8-TCDF	0.25	1.41E-02	1.61E-03	6.15E-04	8.62E-06
1,2,3,7,8-PeCDF	0.083	6.08E-03	6.93E-04	2.64E-04	3.71E-06
2,3,4,7,8-PeCDF	0.049	7.76E-02	8.84E-03	3.37E-03	4.73E-05
1,2,3,4,7,8-HxCDF	0.018	2.02E-02	2.30E-03	8.79E-04	1.23E-05
1,2,3,6,7,8-HxCDF	0.018	8.60E-03	9.80E-04	3.74E-04	5.24E-06
1,2,3,7,8,9-HxCDF	0.011	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2,3,4,6,7,8-HxCDF	0.011	8.80E-03	1.00E-03	3.83E-04	5.37E-06
1,2,3,4,6,7,8-HpCDF	0.005	1.37E-03	1.57E-04	5.97E-05	8.37E-07
1,2,3,4,7,8,9-HpCDF	0.0026	8.24E-05	9.39E-06	3.58E-06	5.03E-08
OCDF	0.0005	8.40E-06	9.58E-07	3.65E-07	5.13E-09
Sum			**0.020 fg/m^3**	**0.008 ng/m^2**	**0.00011 ng/m^2**
Equivalent Daily Deposition Flux				**0.021 pg/m^2/day**	**0.00030 pg/m^2/day**

Table A8.45 PCDD/PCDF Annual Particulate Concentrations Under Maximum Operations

Congener Group	Particulate Fraction	Particulate Emission Rate (ng/sec)	Annual Particulate Concentration (fg/m^3)
2,3,7,8-TCDD	0.763	6.17E-02	7.47E-03
1,2,3,7,8-PeCDD	0.961	4.33E-01	5.23E-02
1,2,3,4,7,8-HxCDD	0.992	1.55E-01	1.87E-02
1,2,3,6,7,8-HxCDD	0.992	1.89E-01	2.29E-02
1,2,3,7,8,9-HxCDD	0.992	3.53E-01	4.27E-02
1,2,3,4,6,7,8-HpCDD	0.998	1.64E-01	1.99E-02
OCDD	0.9995	2.78E-02	3.37E-03
2,3,7,8-TCDF	0.75	4.24E-02	5.13E-03
1,2,3,7,8-PeCDF	0.917	6.71E-02	8.12E-03
2,3,4,7,8-PeCDF	0.951	1.51E+00	1.82E-01
1,2,3,4,7,8-HxCDF	0.982	1.10E+00	1.33E-01
1,2,3,6,7,8-HxCDF	0.982	4.69E-01	5.67E-02
1,2,3,7,8,9-HxCDF	0.989	0.00E+00	0.00E+00
2,3,4,6,7,8-HxCDF	0.989	7.91E-01	9.57E-02
1,2,3,4,6,7,8-HpCDF	0.995	2.73E-01	3.31E-02
1,2,3,4,7,8,9-HpCDF	0.9974	3.16E-02	3.82E-03
OCDF	0.9995	1.68E-02	2.03E-03
Sum			**0.69 fg/m^3**

Table A8.46 PCDD/PCDF Annual Particulate Deposition Fluxes Under Maximum Operations

Congener Group	Particulate Emission Rate (ng/sec)	Dry Particulate Deposition Flux (ng/m^2)	Wet Particulate Deposition Flux (ng/m^2)	Combined Particulate Deposition Flux (ng/m^2)
2,3,7,8-TCDD	6.17E-02	8.09E-04	2.69E-03	2.69E-03
1,2,3,7,8-PeCDD	4.33E-01	5.67E-03	1.89E-02	1.89E-02
1,2,3,4,7,8-HxCDD	1.55E-01	2.03E-03	6.74E-03	6.74E-03
1,2,3,6,7,8-HxCDD	1.89E-01	2.48E-03	8.24E-03	8.24E-03
1,2,3,7,8,9-HxCDD	3.53E-01	4.63E-03	1.54E-02	1.54E-02
1,2,3,4,6,7,8-HpCDD	1.64E-01	2.15E-03	7.16E-03	7.16E-03
OCDD	2.78E-02	3.64E-04	1.21E-03	1.21E-03
2,3,7,8-TCDF	4.24E-02	5.56E-04	1.85E-03	1.85E-03
1,2,3,7,8-PeCDF	6.71E-02	8.79E-04	2.93E-03	2.93E-03
2,3,4,7,8-PeCDF	1.51E+00	1.97E-02	6.56E-02	6.56E-02
1,2,3,4,7,8-HxCDF	1.10E+00	1.44E-02	4.80E-02	4.80E-02
1,2,3,6,7,8-HxCDF	4.69E-01	6.14E-03	2.04E-02	2.04E-02
1,2,3,7,8,9-HxCDF	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2,3,4,6,7,8-HxCDF	7.91E-01	1.04E-02	3.45E-02	3.45E-02
1,2,3,4,6,7,8-HpCDF	2.73E-01	3.58E-03	1.19E-02	1.19E-02
1,2,3,4,7,8,9-HpCDF	3.16E-02	4.14E-04	1.38E-03	1.38E-03
OCDF	1.68E-02	2.20E-04	7.32E-04	7.32E-04
Sum		**0.074 ng/m^2**	**0.248 ng/m^2**	**0.248 ng/m^2**
Equivalent Daily Deposition Flux		**0.204 pg/m^2/day**	**0.679 pg/m^2/day**	**0.679 pg/m^2/day**

Table A8.47 Dispersion Model Summary of Combined Vapour and Particulate Concentrations – PCCD/PCDFs

Pollutant / Scenario	Annual Mean Background(1) (fg/m^3)	Averaging Period	Process Contribution (fg/m^3)	Predicted Emission Concentration (fg/Nm^3)
PCCD/PCDFs / Maximum Operation	31	Annual Average	0.71	31.7
PCCD/PCDFs / Abnormal Operation	31	Annual Average	0.83	31.8

(1) Baseline results for dioxins given as sum of cumulative effects (in the absence of the proposed facility) and baseline monitoring data as Non-detects = limit of detection.

(2) Abnormal operation scenario based on an emission level of 0.5 ng/m^3 for 3% of the time (assumed to occur for one 24-hour period once per month).

Table A8.48 Deposition Model Summary of Combined Particulate & Gaseous Deposition Flux

Pollutant / Scenario	Averaging Period	Background Particulate Deposition Flux (pg/m^2/day)	Process Contribution (pg/m^2/day)	Predicted Total Particulate Deposition Flux (pg/m^2/day)
PCCD/PCDFs / Maximum	Annual Average	30	0.70	30.7
PCCD/PCDFs / Abnormal	Annual Average	30	0.80	30.8

Table A8.49 I-TEQ values derived from measurements of airborne dioxins in various locations

Location	Site Type	I-TEQ[(1)] (fg/m^3)
Kilcock , Co. Meath (1998)[(2)]	Rural	Range 2.8 – 7
Ireland[(2)]	Baseline	Mean – 26
	Potential Effect Areas	Mean – 49
Ringaskiddy (2001)[(3)]	Industrial	Lower Limit – 4.0[(6)] Upper Limit – 16.4[(7)]
Poolbeg (2003-2006)[(8)]	Industrial	Lower Limit – 42[(6)] Upper Limit – 44[(7)]
Germany (1992)[(4)]	Rural	< 70
	Urban	71 – 350
	Close to Major Source	351 – 1600
Manchester (2008 - 2010)[(5)]	Urban	Range – 19 - 48
London (2008 - 2010)[(5)]	Urban	Range –- 11 - 41
Auchencorth (2008 - 2010)[(5)]	Semi-rural	Range – 1 - 6
High Muffles (2008 - 2010)[(5)]	Rural	Range – 2 - 9
Haulbowline (2008)[(9)]	Industrial	19.2[(9)]

(1) I-TEQ_{DF} values based on NATO/CCMS (1988) and as used in Annex 1, Council Directive 2010/75/EU.
(2) Taken from Chapter 8 of Thermal Waste Treatment Plant, Kilcock EIS, Air Environment (1998)
(3) Taken from Chapter 9 of Waste Management Facility, Indaver Ringaskiddy EIS, Baseline Dioxin Survey (2001)
(4) Raffe, C (1996) Sources and environmental concentrations of dioxins and related compounds, *Pure & Appl. Chem* **Vol. 68**, No. 9, pp 1781-1789
(5) Taken from TOMPS Network website, http://uk-air.defra.gov.uk/data/tomps-data
(6) Lower Limit TEQ calculated assuming non-detects are equal to zero.
(7) Upper limit assuming non-detects are equal to limit of detection.
(8) Taken from Chapter 8 of Dublin Waste To Energy Facility EIS, Baseline Dioxin Survey (2006).
(9) Taken From REC Ltd Monitoring Report For WYG In 2008, Haulbowline Island.

Table A8.50 Mean I-TEQ Deposition Fluxes Of Dioxins In Various Locations

Location	Site Type	Mean I-TEQ[(1)] (pg/m^2/ day)
Germany (1992)[(2)]	Rural	5 – 22
	Urban	10 – 100
	Close to Major Source	123 – 1293
UK[(3)]	Stevenage	3.2
	London	5.3
	Cardiff	12
	Manchester	28

(1) I-TEQ_{DF} values based on NATO/CCMS (1988) and as used in Annex 1, Council Directive 2010/75/EU.
(2) Raffe, C (1996) Sources and environmental concentrations of dioxins and related compounds, *Pure & Appl. Chem* Vol. 68, No. 9, pp 1781-1789
(3) Duarte-Davidson et al (1994) Polychlorinated Dibenzo-*p*-Dioxins (PCDDs) and Furans (PCDFs) in Urban Air and Deposition, *Environ. Sci. & Pollut. Res.*, 1 (4), 262-270

8.8.6 Concentration Contours

The maximum PCCD/PCDFs (Dioxins/Furans) ground level concentrations and deposition fluxes beyond the Facility boundary are shown in Figures 8.25 - 8.26. The content of the figure is described below.

Figure 8.25 Maximum Operations: Predicted PCCD/PCDFs (Dioxins/Furans) Annual Average Particulate Concentration

Figure 8.26 Maximum Operations: Predicted PCCD/PCDFs (Dioxins/Furans) Annual Average Total Particulate Deposition

8.8.7 Result Findings

Background levels of PCDD/PCDFs (Dioxins/Furans) occur everywhere and existing levels in the surrounding area have been extensively monitored as part of this study. Monitoring results indicate that the existing levels are typical of rural areas in Ireland and the UK (as shown in Table A8.49). The contribution from the facility in this context is minor with levels under maximum and abnormal scenarios remaining significantly below levels which would be expected in urban areas even at the worst-case receptor located at the southern and south-eastern boundaries of the facility. Levels at the nearest residential receptor will be minor, with the annual contribution from the proposed facility accounting for less than 5% of the existing background concentration under maximum and abnormal operating conditions.

Shown in Table A8.48 is the maximum dioxin deposition rate. Modelled total dioxin particulate deposition flux indicate that deposition levels under maximum and abnormal operations would be expected to be significantly less than that experienced in urban background locations (see Table A8.50).

8.9 Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous chemicals found in urban airsheds throughout the world[20]. They are formed from the incomplete combustion of organic matter and are released into ambient air as constituents of highly complex mixtures of polycyclic organic matter (POM). They are also found in crude oil, coal tar, creosote and asphalt. In towns and cities, road traffic emissions are the dominant source of PAHs. In a recent study in Birmingham, 88% of the concentration of benzo[*a*]pyrene (B[*a*]P) in air was due to road traffic emissions[21].

PAHs can occur in the form of gases (e.g. 2-ringed naphthalene), solids adsorbed to surfaces of fine particles (e.g. 5-ringed benzo[*a*]pyrene) and in both gas- and particle-phases (e.g. 3-ringed phenanthrene). The air concentrations of gas-phase 2- and 3-ring PAHs are generally significantly higher than those of the 5- and 6- ring particle phase species. Moreover, the percentage found in the gas phase decreases with the size of the PAH. It has also been found that at higher masses of suspended particulate matter (TSP) in the air parcel the percentage of PAHs in the particle phase increases significantly[20].

The International Agency for Research on Cancer (IARC) has classified 48 PAHs according to their likely human carcinogenicity in 1987[20]. The three potent animal carcinogens benzo[*a*]pyrene, benz[*a*]anthracene and dibenz[*ah*]anthracene are classified as "probably carcinogenic to humans". "Possible human carcinogens" consists of four compounds – benzo[*b*]fluoranthene, benzo[*k*]fluoranthene, indeno[123-*cd*]pyrene and chrysene. The USEPA has also classified seven chemicals as probable human carcinogens (USEPA Class B2). In 1993, the USEPA formally adopted provisional guidance for estimating cancer risks associated with PAHs[22]. The procedure makes use of the relative potencies of several PAHs with respect to benzo[*a*]pyrene which is thought to be one of the most potent PAHs[20-24].

Various approaches have been adopted to quantify exposure to the complex mixtures of PAHs including Total PAH levels or the level of a marker substance such as benzo[*a*]pyrene. Recent studies have found that the relation of B[*a*]P to the levels of 18 other individual PAHs was relatively stable[25]. Together these 19 PAH compounds constitute 90-95% of the PAHs measured in the air in this study[25]. The UK DETR Expert Panel on PAHs[24] has reviewed extensively the data available in terms of animal toxicology in deriving an ambient air quality standard for PAHs. The approach used by the Panel was to compare the sum of potential carcinogenic contribution of seven individual PAHs (possible & probable carcinogens, see above) in ambient air with that of B[*a*]P. Contributions to total carcinogenicity from other PAH compounds are expected to be small relative to those considered above. Results from the comparison indicated that the estimated contribution of B[*a*]P to the total carcinogenicity of the seven chosen PAH compounds was similar in the three locations studied (ranging from 37.5% - 49.3%)[24]. The overall conclusion from this approach was that using B[*a*]P as a marker of PAH exposure in the environment was suitable so long as major changes in the ambient mixture of PAH compounds do not occur in the future and that an air quality standard for PAH mixtures could be expressed in terms of the ambient concentration of B[*a*]P.

The EU has confirmed the validity of this approach in Council Directive 2004/107/EC which designates B[*a*]P as a marker for PAHs in general. The Directive set a target value for the protection of human health for B[*a*]P of 1.0 ng/m^3 to be achieved in 2012.

Background PAHs are monitored at four sites in Ireland over the period 2013 - 2017[26]. Shown in Table A8.51 are B[*a*]P concentrations at these sites. Annual average background concentrations of B[*a*]P in this network ranged from 0.05 – 1.61 ng/m^3 over the period 2013 - 2017. Shown in Table A8.52 are B[*a*]P deposition rates at two sites in Ireland. Annual average background deposition rates of B[*a*]P ranged from 1.7 – 27.6 ng/m^2/day over the period 2013 - 2017.

Table A8.51 Annual average B[a]P concentration at selected sites in Ireland In 2013 - 2017[26]

Year	B[a]P Annual Mean Concentration (ng/m^3) in 2013 - 2017			
	Rathmines	**Heatherton Park**	**Galway**	**Kilkitt**
		Zone B	Zone C	Zone D
2013	0.17	0.46	0.19	0.07
2014	0.26	1.16	0.38	0.05
2015	0.29	0.47	0.27	0.06
2016	0.34	0.51	0.43	0.07
2017	0.14	0.12	-	0.14
Average	0.24	0.54	0.32	0.08

Table A8.52 Annual average B[a]P deposition rate at selected sites in Ireland In 2013 - 2017[26]

Year	B[a]P Annual Mean Deposition (ng/m^2/day) in 2013 - 2017	
	Rosemount, UCD	**Shannon Estuary**
	Zone A	Zone D
2013	1.7	1.9
2014	6.9	6.0
2015	6.5	14.7
2016	15.6	27.6
2017	15.2	4.4
Average	9.2	10.9

8.9.1 Modelling Strategy

For the purposes of this assessment, emissions of B[*a*]P from the facility have been assumed to be at the upper range of the levels outlined in the Waste Incineration BREF document (1.0 μg/m^3). Literature data has indicated that B[*a*]P exists almost solely in the particulate phase[20] and the EU reference method for the monitoring of B[*a*]P is based on particulate sampling only[27]. Therefore, the current analysis assumes that B[a]P exists in the particulate phase only.

The emission of B[*a*]P from the facility has thus been evaluated in terms of mass of release into the particle-bound phase. Thereafter, air dispersion and deposition modelling has been employed to translate these releases to ambient air particle phase concentration and wet and dry particulate deposition amounts, in the vicinity of the release. The maximum scenario has been modelled as outlined in Table A8.53.

When modelling PAHs the surface area weighting rather than mass weighting is used for deposition. The surface weighting reflects the mode of formation where volatiles condense on the surface of particulates in the flue gas cleaning system (see Column 6 of Table A8.43). Thus, the apportionment of emissions by particle size becomes a function of the surface area of the particles which is available for chemical adsorption. The ambient particulate concentration of B[a]P was determined as shown in Table A8.55. Results are shown under both maximum and abnormal operating conditions.

8.9.2 Deposition Modelling of Particulates

In order to model dry deposition of PAHs, using AERMOD, the generalised particle-size distribution recommended by the USEPA has again been used as outlined in Table A8.43[10,11]. For the deposition modelling of B[*a*]P both wet and dry particulate deposition were calculated. Results are shown in Table A8.56 for maximum operating conditions.

Table A8.53 Emission Scenario for B[*a*]P

Pollutant	Scenario	Emission Concentration	Emission Rate (mg/s)
B[*a*]P	Maximum Operation	1.0 μg/m^3	0.059

8.9.3 Comparison With Standards And Guidelines

Predicted GLCs have been compared with the applicable EU ambient air quality target value for B[*a*]P as set out in Table A8.54.

Table A8.54 B[a]P Ambient Air Quality Standards & Guidelines

Pollutant	Regulation	Limit Type	Target Value
B[a]P	Council Directive 2004/107/EC	Annual Average	1.0 ng/m^3

8.9.4 Modelling Results

Tables A8.55 – A8.57 details the predicted B[*a*]P GLC for the particulate concentration and deposition scenarios.

Table A8.55 B[a]P Particulate Concentrations Under Maximum Operating Conditions

Compound	Particulate Fraction	Particulate Emission Rate (μg/sec)	Annual Averaged Particulate Concentration (pg/m^3)
B[a]P	1.0	Maximum – 58.6	7.1

Table A8.56 B[*a*]P Deposition Fluxes – Maximum Operating Conditions

Compound	Fraction	Emission Rate (μg/sec)	Annual Deposition Flux (μg/m^2)
B[a]P - Maximum Operation	Dry particulate	58.6	0.77
	Wet particulate		2.56
	Total particulate		2.56
Sum of Total Particulate Deposition			**2.6 μg/m^2**
			7.0 ng/m^2/day

Table A8.57 Dispersion Model Summary Of Particulate B[a]P Concentrations Under Maximum Operating Conditions.

Pollutant / Scenario	Annual Mean Background (pg/m^3)	Averaging Period	Process Contribution (pg/m^3)	Predicted Emission Concentration (pg/Nm^3)	Standard (pg/Nm^3)
B[a]P / Maximum	540	Annual mean	7.1	547.1	1000

8.9.5 Result Findings

B[*a*]P modelling results indicate that the ambient ground level concentrations are significantly below the EU target value for the protection of human health under maximum operation of the facility. Thus, no adverse effect on public health or the environment is envisaged to occur under these conditions at or beyond the facility boundary. Emissions at maximum operations lead to ambient B[a]P particle-bound concentrations (excluding background concentrations) which are only 1.0% of the annual average limit value at the boundary of the facility.

8.10 Mercury

8.10.1 Mercury's Environmental Transport & Fate

Mercury exists in three oxidation states; metallic or elemental (Hg^0); mercurous (Hg_2^{2+}); and mercuric (Hg^{2+}). Elemental Hg is a liquid at room temperature with low volatility. Other forms of mercury are solids with low vapour pressures. It is naturally occurring and cycles between the atmosphere, land and water through a series of complex transformations. Elemental mercury is the most common form of mercury found in the atmosphere whereas in all other environmental media, mercury is found in the form of inorganic mercuric salts and organo-mercury compounds[28].

USEPA methodology assumes that stack emissions containing mercury include both vapour and particle-bound phases. Additionally, the USEPA assumes that mercury exits the stack in only the elemental and divalent species. These assumptions were also used for the current assessment. Of the total mercury in the stack, 80% is estimated to be in the vapour phase and 20% is particle-bound. In addition, the USEPA assumes that speciation of the total mercury is 80% divalent (20% in the particle-bound and 60% in the vapour phase) and 20% elemental (all 20% in the vapour phase)[28]. Although the USEPA allows a loss to the global cycle for each form of mercury (99% of the elemental vapour form, 32% of the divalent vapour form, and 64% of the particle-bound form are assumed lost to the global cycle and do not deposit within the localized study area), this has not been incorporated into the current assessment in keeping with the worst-case approach adopted throughout.

8.10.2 Comparison With Standards And Guidelines

Predicted GLCs have been compared with the applicable WHO ambient air quality guideline for mercury as set out in Table A8.58.

Table A8.58 Hg Ambient Air Quality Standards & Guidelines

Pollutant	Regulation	Limit Type	Value
Inorganic Mercury (as Hg)	WHO	Annual Average	1.0 $\mu g/m^3$

8.10.3 Deposition Modelling of Mercury Vapours

Dry Gaseous Deposition

For the dry gaseous deposition modelling of mercury, four physicochemical parameters are required for both elemental gaseous mercury and divalent gaseous mercury. The dry gaseous deposition velocity formulation is based on three resistance terms; aerodynamic resistance, quasi-laminar resistance to bulk transfer and a bulk surface resistance term. The four physiochemical parameters required to calculate these resistance terms are D_a (diffusivity of modelled gas in air (cm/s)), D_w (diffusivity of modelled gas in water (cm/s)), Henry's Law constant for modelled gas (Pa-m^3/mol) and r_{cl} (leaf cuticular resistance (s/m)). The values derived for the two relevant mercury states are shown in Table A8.59.

Table A8.59 Gas Deposition Physiochemical Parameters[3]

Mercury Phase	D_a (cm/s)	D_w (cm/s)	H (Pa m^3 mol^{-1})	r_{cl} (sm^{-1})
Elemental Gas	0.07	0.0000063	150	1E+7
Divalent Gas	0.06	0.00032	6E-6	1E+7

Wet Gaseous Deposition

Wet gaseous deposition physically washes out the chemically contaminated vapours from the atmosphere. Wet gaseous deposition flux depends on the precipitation rate, the concentration of the pollutant in the liquid phase and the molecular weight of the pollutant. The AERMOD model formulation assumes that the wet gaseous deposition flux is the same for snow as for rain.

8.10.4 Modelling of Particulate Mercury

When modelling particulate mercury (Hg), the surface area weighting rather than mass weighting is used for deposition. The surface weighting reflects the mode of formation where volatiles condense on the surface of particulates in the flue gas cleaning system (see Column 6 of Table A8.43). Thus, the apportionment of emissions by particle size becomes a function of the surface area of the particle which is available for chemical adsorption.

Dry Particulate Deposition

Dry particulate deposition is based on a resistance scheme in which the deposition velocity is based on the predominant particle size distribution via two methods. Method 1 is used when a significant fraction (> 10%) of the total particulate mass has a diameter greater than 10 microns and the particle size distribution is reasonably well known. The method is based on the gravitational settling velocity and two resistance terms; aerodynamic resistance and quasi-laminar resistance to bulk transfer. Method 2 is used when the particle size distribution is not well known and when a small fraction (less than 10% of the mass) consists of particles with a diameter of 10 microns or larger. The deposition velocity for method 2 is given as the weighted average of the deposition velocity for the coarse mode and fine mode. In the results below method 1 has been used, based on the generalised particle-size distribution recommended by the USEPA as outlined in Table A8.43[11], as it gives similar concentrations to method 2 but significantly higher deposition results.

Wet Particulate Deposition

Wet particulate deposition physically washes out the chemically contaminated particulate from the atmosphere. Wet deposition flux depends on the fraction of the time precipitation occurs and the fraction of material removed by precipitation per unit of time by particle size. The AERMOD model formulation is based on a particle washout coefficient which is based on the collision efficiency and the mean diameter of raindrops. It is also assumed that the wet deposition flux is the same for snow as for rain.

8.10.5 Modelling Strategy

The emissions of mercury from the stack have been evaluated in terms of mass of release into both vapour and particle-bound phases. Thereafter, air dispersion and deposition modelling has been employed to translate these releases into ambient air vapour and particle phase concentrations, and wet and dry gaseous and particulate deposition amounts, in the vicinity of the release. The maximum emission scenario has been modelled as outlined in Table A8.60.

Table A8.60 Emission Scenario for Mercury

Pollutant	Scenario	Emission Concentration	Emission Rate (g/s)
Hg	Maximum	0.05 mg/m^3	0.00293
Hg	Abnormal(1)	1 mg/m^3	0.0586

(1) Abnormal operation scenario based on an emission level of 1 mg/m^3 for 3% of the time (assumed to occur for one 24-hour period once per month).

For the deposition modelling of mercury both wet and dry particulate and gaseous deposition were calculated. Results are shown in Table A8.61 - A8.64 for maximum operating conditions.

8.10.6 Modelling Results

Tables A8.61 – A8.64 detail the predicted mercury GLC for each vapour and particulate concentration and deposition scenario.

Table A8.61 Mercury Vapour Concentrations Under Maximum Operating Conditions

Oxidation State	Vapour Fraction	Vapour Emission Rate (g/sec)	Vapour Concentration (ng/m^3)
Elemental Hg	0.20	Maximum - 0.00059	0.067
Divalent Hg^{2+}	0.60	Maximum - 0.0018	0.20
Sum			**0.27 ng/m^3**

Table A8.62 Mercury Particulate Concentrations Under Maximum Operating Conditions

Oxidation State	Particulate Fraction	Particulate Emission Rate (g/sec)	Particulate Concentration (ng/m^3)
Divalent Hg^{2+}	0.20	Maximum - 0.00059	0.127

Table A8.63 Mercury Deposition Fluxes – Maximum Operating Conditions

Oxidation State	Fraction	Emission Rate (g/sec)	Annual Deposition Flux (μg/m^2/year)
Elemental Hg	Dry Gas	0.00059	19.3
	Wet Gas		0.01
	Total Gas		19.3
Divalent Hg^{2+}	Dry Gas & Particle	0.0023	140
	Wet Gas & Particle		142
	Total Gas & Particle		158
Sum of Total Deposition			**178 μg/m^2/year**

Table A8.64 Dispersion Model Summary Of Combined Vapour And Particulate Hg Concentrations Under Maximum And Abnormal Operating Conditions.

Pollutant / Scenario	Annual Mean Background (ng/m^3)	Averaging Period	Process Contribution (ng/m^3)	Predicted Emission Concentration (ng/Nm^3)	Standard (ng/Nm^3)
Hg / Maximum	8	Annual mean	0.40	8.4	1000
Hg / Abnormal	8	Annual mean	0.73	8.7	1000

8.10.7 Concentration Contours

The geographical variation in vapour mercury ground level concentrations beyond the Facility boundary is illustrated as concentration contours in Figure 8.27.

Figure 8.27 Maximum Operations: Predicted Mercury Annual Average Vapour and Particulate Concentration

8.10.8 Result Findings

Hg modelling results indicate that the ambient ground level concentrations are significantly below the WHO guideline under both typical and maximum operation of the facility. Thus, no adverse environmental effect is envisaged to occur under these conditions at or beyond the facility boundary. Emissions at maximum operations equate to ambient mercury combined concentration (both vapour and particle-bound) (including background concentrations) which are less than 1% of the annual average limit value at the boundary of the facility.

8.11 Heavy Metal Emissions and Results (excluding Mercury)

8.11.1 Modelling Approach

The emissions of heavy metals (except Hg) from the Ringaskiddy Resource Recovery Centre have been evaluated in terms of mass of release into the particulate phase only as recommended by the USEPA[10,11]. Thereafter, air dispersion and deposition modelling has been employed to translate these releases to ambient particle phase concentrations, and wet and dry particulate deposition amounts, in the vicinity of the release.

When modelling heavy metals (except Hg) the mass weighting rather than surface weighting is used for deposition as it is assumed that the metals are all in the particulate state (see Column 4 of Table A8.43). Results are shown under both maximum and abnormal operating conditions.

For the deposition modelling of heavy metals (except Hg) both wet and dry particulate deposition were calculated.

Ambient ground level concentrations (GLCs) and deposition values of Cadmium and Thallium (Cd & Tl) and the Sum of antimony (Sb), arsenic (As), lead (Pb), chromium (Cr), cobalt (Co), copper (Cu), manganese (Mn), nickel (Ni) and vanadium (V) have been investigated using the concentration limits outlined in Council Directive 2010/75/EU (see Table A8.65 and Table A8.66 respectively) and also under abnormal operations at the facility.

Table A8.65 Maximum And Abnormal Operations for Cd & Tl

Pollutant	Scenario	Concentration	Emission Rate (g/s)
Cd & Tl	Maximum 24-Hr Operation	0.05 mg/m^3	0.00293
	Abnormal Operation(1)	0.2 mg/m^3	0.0117

(1) Abnormal operation scenario based on an emission level of 0.2 mg/m^3 for 3% of the time (assumed to occur for one 24-hour period once per month).

Table A8.66 Emission Scenario for Heavy Metals Taken From Council Directive 2010/75/EU

Pollutant	Scenario	Concentration	Emission Rate (g/s)
Sum of Sb, As, Pb, Cr, Co, Cu, Mn, Ni and V	Maximum Operation	0.50 mg/m^3	0.0293
	Abnormal Operation(1)	30 mg/m^3	1.76

(1) Abnormal operation scenario based on an emission level of 30 mg/m^3 for 3% of the time (assumed to occur for one 24-hour period once per month).

Data is available from the Carranstown incinerator facility operated by Indaver in Duleek, County Meath (see Table A8.67) indicating the emission levels of these metals based on typical and maximum recorded levels over the period 2017 - 2018. This source of data has been used to identify the likely ratio of metals when emitting under both maximum and abnormal operations (Table A8.68).

Table A8.67 Actual Measured Emission Data From An Incinerator Facility operated by Indaver In Duleek, County Meath Over The Period 2017 - 2018 (mg/Nm^3) (*Non-detects reported at the detection limit).*

	2017		2018		Average	Maximum
Parameter	**Q1**	**Q2**	**Q1**	**Q2**	**2017-2018**	**2017-2018**
As	0.0002	0.0005	0.0001	0.0001	0.0002	0.0005
Co	0.0001	0.0005	0.0001	0.0001	0.0002	0.0005
Cr	0.0008	0.0168	0.0014	0.0010	0.0050	0.0168
Cu	0.0014	0.0440	0.0015	0.0020	0.0122	0.0440
Mn	0.0002	0.0017	0.0003	0.0010	0.0008	0.0017
Ni	0.0016	0.0100	0.0007	0.0024	0.0037	0.0100
Pb	0.0003	0.0016	0.0003	0.0013	0.0009	0.0016
Sb	0.0001	0.0005	0.0001	0.0001	0.0002	0.0005
V	0.0001	0.0003	0.0001	0.0001	0.0002	0.0003

Table A8.68 Ratio Of Metals Emitting Based On Actual Measured Emission Data From Indaver In Duleek, County Meath Over The Period 2017 - 2018 (mg/Nm^3)

Parameter	**Average[(1)]**	**Maximum[(1)]**	**Maximum Operation[(2)]**	**Abnormal Operation[(2)]**
	2017 - 2018 (mg/m^3)	**2017 - 2018 (mg/m^3)**	**0.50 mg/m^3**	**30 mg/m^3**
As	0.0002	0.0005	0.003	0.198
Co	0.0002	0.0005	0.003	0.198
Cr	0.0050	0.0168	0.111	6.640
Cu	0.0122	0.0440	0.290	17.391
Mn	0.0008	0.0017	0.011	0.672
Ni	0.0037	0.0100	0.066	3.953
Pb	0.0009	0.0016	0.011	0.632
Sb	0.0002	0.0005	0.003	0.198
V	0.0002	0.0003	0.002	0.119
Sum Sb/As/Pb/Cr/Co/Cu/Mn/Ni/V	0.023 mg/m^3	0.076 mg/m^3	0.50 mg/m^3	30 mg/m^3

(1) Non-detects reported at the detection limit.
(2) Based on the ratio under maximum operation.

8.11.2 Comparison with Standards And Guidelines

In the absence of statutory standards, ambient air quality guidelines can also be derived from occupational exposure limits (OEL). Guidance has issued by the UK Environment Agency entitled "*IPPC Environmental Assessment for BAT*" (Environment Agency, 2003)[29]. The guidance outlines the approach for deriving both short-term and long-term environmental assessment levels (EAL). In relation to the long-term (annual) EAL, this can be derived by applying a factor of 100 to the 8-hour OEL. The factor of 100 allows for both the greater period of exposure and the greater sensitivity of the general population. For short-term (1-hour) exposure, the EAL is derived by applying a factor of 10 to the short term exposure limit (STEL). In this case, only the sensitivity of the general population need be taken into account as there is no need for additional safety factors in terms of the period of exposure. Where STELs are not listed then a value of 3 times the 8-hour time weighted average occupational exposure limit may be used. Predicted GLCs have been compared with the applicable ambient air quality guidelines and standards for the protection of human health as set out in Table A8.69 and A8.70.

A comparison of Tables A8.67 and A8.68 with Table A8.70 indicates that Arsenic is the metal which is emitted at the most significant level relative to its annual average limit value and thus has been reported below. All other metals will have a lower effect on the ambient environment. Vanadium has also been investigated as it is emitted at the most significant level relative to the short-term limit values.

Table A8.69 Cd and Tl Ambient Air Quality Standards & Guidelines For The Protection of Human Health

Metal	Short-Term EAL (1-Hr)	Long-Term EAL (Annual)	Regulation
Cd	-	0.005 μg/m^3	WHO[3]
Cd	1.5 μg/m^3	0.005 μg/m^3	EU[1] / EAL[2]
Tl	30 μg/m^3	1.0 μg/m^3	EAL[2]

(1) Council Directive 2004/107/EC[27]
(2) Environmental Agency (2003) "IPPC H1 - Environmental Assessment & Appraisal of BAT"[29]
(3) WHO (2006) Air Quality Guidelines[23]

Table A8.70 Sb, As, Pb, Cr, Co, Cu, Mn, Ni and V Ambient Air Quality Standards & Guidelines For The Protection of Human Health

Metal	Short-Term EAL (1-Hr)	Long-Term EAL (Annual)	Regulation
Sb	150 μg/m^3	5 μg/m^3	EAL[2]
As	15 μg/m^3	0.006 μg/m^3[1]	EU[1] / EAL[2]
Pb	-	0.5 μg/m^3	EU[1]
Cr (except VI)	150 μg/m^3	5.0 μg/m^3	EAL[2]
Cr (VI)[4]	-	0.0002 μg/m^3	EAL[2]
Co	6 μg/m^3	0.2 μg/m^3	EAL[2]
Cu (fumes)	60 μg/m^3	2.0 μg/m^3	EAL[2]
Cu (dust & mists)	200 μg/m^3	10 μg/m^3	EAL[2]
Mn	1500 μg/m^3	1.0 μg/m^3	WHO[3]
Ni (inorganic)	30 μg/m^3	0.020 μg/m^3[1]	EU[1]
V	1.0 μg/m^3	5.0 μg/m^3	EAL[2]

(1) Council Directive 2004/107/EC[27]
(2) Environmental Agency (2003) "IPPC H1 - Environmental Assessment & Appraisal of BAT"[29]
(3) WHO (2000) Air Quality Guidelines for Europe[23]
(4) Environmental Agency (2011) "H1 Annex F Air Emissions v 2.2"[30]

8.11.3 Modelling Results

Air dispersion and deposition modelling was carried out for the two scenarios described in Section 8.11.1. Tables A8.71 – A8.73 detail the predicted Cd & Tl GLC and deposition value for each scenario and averaging period.

Table A8.71 Cd & Tl Particulate Concentrations Under Maximum And Abnormal Operation

Heavy Metal	Emission Rate (g/sec)	Ambient Concentration (ng/m^3)
Cd & Tl	Maximum Operation - 0.00293	0.35
	Abnormal Operation - 0.0117	0.42

(1) Abnormal operation scenario based on an emission level of 0.2 mg/m^3 for 3% of the time (assumed to occur for one 24-hour period once per month).

Table A8.72 Cadmium Deposition Fluxes – Maximum Operation

Heavy Metal	Fraction	Emission Rate (g/sec)	Annual Deposition Flux (mg/m^2)
Cd & Tl / Maximum Operation	Dry particulate	0.00293	0.21
	Wet particulate		0.81
Sum of Total Deposition			0.81 mg/m^2
			2.2 μg/m^2/day

Table A8.73 Cadmium & Thallium Particulate Concentration Summary

Pollutant / Scenario	Averaging Period	Process Contribution (ng/m^3)	Annual Mean Background (ng/m^3)	Predicted Emission Concentration (ng/Nm^3)	Standard (ng/Nm^3)(1)
Cd / Maximum	Annual mean	0.35	1	1.4	5.0
Cd / Abnormal	Annual mean	0.42	1	1.4	5.0

(1) Council Directive 2004/107/EC[23]

Tables A8.74 – A8.77 detail the predicted GLC and deposition values for each scenario for Arsenic, Nickel and Vanadium. In terms of Vanadium, emission levels are based on the ratio of the Sum of Other Metals (Mn, Sb, Sn, V, Pb, Cr, Cu, Co & Ni) as outlined in Table A8.68.

Table A8.74 Arsenic, Nickel and Vanadium Particulate Concentration Under Maximum & Abnormal Operating Conditions

Heavy Metal	Emission Rate (g/sec)	Maximum 1-hour Concentration (ng/m^3)	Annual Concentration (ng/m^3)
Arsenic	Maximum - 0.000193		0.023
Nickel	Maximum - 0.0039		0.46
Vanadium	Maximum - 0.00012	0.81	
Arsenic(1)	Abnormal - 0.0116		0.108
Nickel(2)	Abnormal - 0.232		2.16
Vanadium(3)	Abnormal - 0.0069	31.6	

(1) Abnormal operation scenario based on an emission level of 0.26 mg/m^3 for 3% of the time (assumed to occur for one 24-hour period once per month).
(2) Abnormal operation scenario based on an emission level of 3.8 mg/m^3 for 3% of the time (assumed to occur for one 24-hour period once per month).
(3) Abnormal operation scenario based on an emission level of 0.084 mg/m^3 for 3% of the time (assumed to occur for one 24-hour period once per month).

Table A8.75 Arsenic Deposition Fluxes – Maximum & Abnormal Operating Conditions

Heavy Metal	Fraction	Emission Rate (g/sec)	Annual Deposition Flux (mg/m^2)
Arsenic / Maximum	Dry particulate	0.00019	0.014
	Wet particulate		0.053
Sum of Total Deposition			0.053 mg/m^2
			0.147 $\mu g/m^2$/day
Arsenic / Abnormal(1)	Dry particulate	0.0116	0.069
	Wet particulate		0.094
Sum of Total Deposition			0.094 mg/m^2
			0.258 $\mu g/m^2$/day

(1) Abnormal operation scenario based on an emission level of 0.0104 g/sec for 3% of the time (assumed to occur for one 24-hour period once per month).

Table A8.76 Nickel Deposition Fluxes – Maximum & Abnormal Operating Conditions

Heavy Metal	Fraction	Emission Rate (g/sec)	Annual Deposition Flux (mg/m^2)
Nickel / Maximum	Dry particulate	0.0039	0.282
	Wet particulate		1.07
Sum of Total Deposition			1.07 mg/m^2
			2.93 $\mu g/m^2$/day
Nickel / Abnormal(1)	Dry particulate	0.232	1.37
	Wet particulate		1.88
Sum of Total Deposition			1.88 mg/m^2
			5.16 $\mu g/m^2$/day

(1) Abnormal operation scenario based on an emission level of 0.15 g/sec for 3% of the time (assumed to occur for one 24-hour period once per month).

Table A8.77 Dispersion Model Results – Arsenic and Vanadium

Heavy Metal / Scenario	Averaging Period	Process Contribution (ng/m^3)	Background (ng/m^3)	Predicted Emission Concentration (ng/Nm^3)	Standard (ng/Nm^3)
Arsenic / Maximum	Annual mean	0.023	1.0(1)	1.02	**6.0(4)**
Nickel / Maximum	Annual mean	0.46	9.0(2)	9.5	**20(5)**
Vanadium / Maximum	Maximum One-Hour	0.81	2.0(3)	2.8	**1000(6)**
Arsenic / Abnormal	Annual mean	0.11	1.0(1)	1.1	**6.0(4)**
Nickel / Abnormal	Annual mean	2.2	9.0(2)	11.2	**20.0(5)**
Vanadium / Abnormal	Maximum One-Hour	31.6	2.0(3)	33.6	**1000(6)**

(1) Background concentration for arsenic based on on-site monitoring
(2) Background concentration for nickel based on on-site monitoring
(3) Background concentration for vanadium based on on-site monitoring
(4) Ambient standard for arsenic which is the most stringent applicable limit value for this averaging period
(5) Ambient standard for nickel which is the most stringent applicable limit value for this averaging period
(6) Ambient standard for vanadium which is the most stringent applicable limit value for this averaging period.

Chromium (VI)

The UK Environment Agency (UKEA) has issued guidance on the release of Chromium (VI) from municipal waste incinerators(31). The UKEA has recently published a substantially lower EAL for Cr(VI) of 0.2 ng/m^3. The guidance indicates that data on the release of Cr(VI) is limited but that in relation to the data gathered to date from 13 incinerators in the UK, based on measurements of total chromium and the ratio of Cr(VI) to total chromium in Air Pollution Control (APC) residues, the range in emission data is as follows:

- Mean = $3.5*10^{-5}$ mg/Nm^3
- Minimum = $2.3*10^{-6}$ mg/Nm^3
- Maximum = $1.3*10^{-4}$ mg/Nm^3

Shown in Table A8.78 is the estimated Cr(VI) release from the Ringaskiddy Resource Recovery facility and the predicted process contribution to the ambient environment as a results of these estimated releases.

Table A8.78 Dispersion Model Results – Chromium (VI)

Heavy Metal / Scenario	Emission Concentration ($\mu g/Nm^3$)(1)	Emission Rate (mg/s)	Averaging Period	Ambient Process Contribution (ng/m^3)	Standard (ng/Nm^3)(2)
Cr(VI) / Mean	0.035	0.00205	Annual mean	0.00025	**0.02**
Cr(VI) / Maximum	0.13	0.00762	Annual mean	0.00091	**0.02**

(1) Cr(VI) emission rate taken from UKEA guidance(31)
(2) Ambient standard for Cr(VI) taken from H1 Annex F(30)

The results indicate that under typical conditions the Cr(VI) emissions from the facility are likely to lead to an ambient Cr(VI) concentration which is less than 0.15% of the EAL. Assuming maximum emissions of Cr(VI) for a full year at maximum operations leads to an ambient Cr(VI) concentration which is 0.5% of the EAL. Thus, Cr(VI) emissions from the facility are insignificant and will not increase existing background levels of this pollutant by a significant amount.

8.11.4 Concentration Contours

The geographical variations in heavy metal ground level concentrations beyond the Facility boundary are illustrated as a concentration contours in Figures 8.28 and 8.29. The content of the figures are described below.

Figure 8.28 Maximum Operation: Predicted Cd Annual Average Concentration

Figure 8.29 Maximum Operation: Predicted Ni Annual Average Concentration

8.11.5 Result Findings

Cd and Tl

Modelling results indicate that the ambient ground level concentrations will be below the relevant air quality standards for the protection of human health for cadmium under maximum and abnormal operations of the facility. Emissions at maximum operations equate to an ambient Cd and Tl concentration (including background concentration) which is 28% of the annual target value for Cd close to the facility boundary (the comparison is made with the Cd limit value as this is more stringent than that for Tl).

Sum of As, Ni, Sb, Pb, Cr, Co, Cu, Mn and V

Modelling results indicate that the ambient ground level concentrations are below the relevant air quality standards for the protection of human health for arsenic, nickel and vanadium (the metals with the most stringent limit values) under maximum and abnormal emissions from the facility. Thus, no adverse effect on public health or the environment is envisaged to occur under these conditions at or beyond the facility boundary. Emissions at maximum operations equate to ambient As and Ni concentrations (including background concentrations) which are 17% and 48% of the annual limit value respectively at the worst-case receptor whilst emissions at maximum operations equate to ambient V concentrations (including background concentrations) which are only 0.3% of the maximum 1-hour limit value at the worst-case receptor. Emissions under abnormal operations equate to ambient As and Ni concentrations (including background concentrations) which are 18% and 56% of the annual limit value respectively at the worst-case receptor whilst emissions at maximum operations equate to ambient V concentrations (including background concentrations) which are 0.4% of the maximum 1-hour limit value at the worst-case receptor.

8.11.6 Summary Of Effects

Based on the emission guidelines outlined in Council Directive 2010/75/EU, detailed air dispersion modelling has shown that the most stringent ambient air quality standards for the protection of human health are not exceeded either as a result of operating under maximum or abnormal operating conditions.

The modelling results indicate that the maximum long-term ambient GLC occurs at or near the facility's southern and south-east boundaries. The spatial effect of the facility is limited with concentrations falling off rapidly away from the maximum peak. Concentrations fall off rapidly away from this maximum and for the short-term averaging periods, at the nearest residential receptors, concentrations will be less than 23% of the short-term limit values under the maximum operating scenario (not including background concentrations). The annual average concentration has an even more dramatic decrease in maximum concentration away from the facility with concentrations from emissions at the proposed Facility accounting for less than 1% of the limit value (not including background concentrations) at worst case sensitive receptors near the facility under the maximum operating scenario for the facility.

In the surrounding areas of Cobh, Carrigaline and Monkstown levels are significantly lower than most background sources with the concentrations from emissions at the proposed facility accounting for less than 1% of the annual limit values for the protection of human health for all pollutants under maximum operations of the facility.

8.12 CALPUFF Assessment

The CALPUFF modelling system has been recommended by the USEPA as a Guideline Model for source-receptor distances of greater than 50km and for use on a case-by-case basis in complex flow situations within 50km(1). CALPUFF has some important advantages over steady-state Gaussian models such as AERMOD in areas of complex meteorology. Firstly, AERMOD, being a steady state straight line plume model cannot respond to the terrain-induced spatial variability in wind fields. Secondly, as AERMOD is based on a single-station wind observation, the wind fields do not vary spatially within the modelling domain. Thirdly, AERMOD cannot treat calm conditions and does not calculate concentrations during these hours. Because of these limitations, CALPUFF would be expected to more accurately reflect the meteorological and dispersion characteristics of the modelling domain and thus lead to more accurate ambient air concentrations. As shoreline fumigation was also raised as a possible concern in the previous application and AERMOD does not have the capability to model this phenomenon, CALPUFF (version 6.42) was selected as the most appropriate model which could assess all possible meteorological conditions within the one air dispersion model.

8.12.1 MM5 / CALMET Set-Up

Meteorological data is an important input into the air dispersion model. The local airflow pattern will be influenced by the geographical location. Important features will be the location of hills and valleys or land-water-air interfaces and whether the existing and proposed facilities are located in simple or complex terrain.

Meteorological data for the assessment was based on various sources of information. Firstly, the Fifth Generation Penn State/NCAR (National Centre for Atmospheric Research) Mesoscale Model (known as MM5) was used for the years 2006 and 2007. The model output consists of hourly values of wind speed, wind direction, temperature and pressure on a grid size of 80 km x 80 km centred in Ringaskiddy. The data had 18 vertical levels with a base level of 15 m and a horizontal resolution of 12 km.

CALMET meteorological pre-processor used the three-dimensional MM5 data along with all available surface observations within the 80km x 80km grid. As no upper air observation stations were located within or near to the modelling domain, upper air data was obtained from MM5 and extrapolation of surface observations. One synoptic meteorological station operated by Met Éireann was identified near the site – Cork Airport. Data collection of greater than 90% for all parameters is required for air dispersion modelling. Cork Airport fulfils this requirement. A second surface station operated by Indaver as part of the current application was available for the year 2007 and thus was also used in the assessment. Buoy data for the stations M3 and M5 for 2006 and 2007 was obtained from the Marine Institute.

The CALMET modelling domain covered an area of 80km x 80km centred in Ringaskiddy. The CALMET wind field data had 11 vertical levels with a base level of 10m and a horizontal resolution of 1 km. The eleven vertical levels are at 20, 40, 80, 160, 320, 650, 1000, 1500, 2200, 3000 and 4000 metres.

The horizontal resolution of 500 metres was used to resolve the terrain variations in the region. Terrain data was obtained from the Shuttle Radar Topography Mission (SRTM) which is a digital elevation data set that spans the globe from 60° north latitude to 56° south latitude. It has a horizontal grid spacing of 1 arc-seconds (approximately 30m) and is shown in Figure 8.30 for the CALMET modelling domain.

Land use data from the U.S. Geological Survey (USGS) and the European Commission's Joint Research Centre (JRC) based on a 1-km resolution Global Land Cover Characteristics (GLCC) database was processed to generate a gridded field of dominant land use categories and land-use weighted values of surface and vegetation properties for each grid cell. The predominant land use in the CALMET domain is shown in Figure 8.31.

Gridded MM5 meteorological fields which were purchased from TRC (Lowell, MA, USA), were used to define the initial guess fields for the CALMET simulations. The MM5 simulations were made for the periods January to December 2006 and January to December 2007, the same period selected for the CALMET/CALPUFF runs. The MM5 data were produced at a horizontal resolution of 12 km and at 18 vertical sigma levels.

Two stages are involved in developing the CALMET wind field. The first step, the Step 1 wind field, CALMET adjusts the initial guess field to reflect slope flows and blocking effects. Slope flows are a function of the local slope and altitude of the nearest crest. The crest is defined as the highest peak within a radius TERRAD around each grid point. A value of TERRAD of 15 km was considered most appropriate for the computational domain. The Step 1 field produces a flow field consistent with the fine-scale CALMET terrain resolution (0.5 km).

In the second step, the Step 2 wind field, observations are incorporated into the Step 1 wind field to produce a final wind field. The philosophy behind the Step 2 wind field is to ensure that observational data strongly influences the final wind field in the region of the observational stations whilst the MM5 data is strongly weighted in the region were no observational data is available. Parameters R1 at the surface and R2 aloft determine the weighting of the Step 1 (MM5 data) and observational data. In the current application, relatively small values (5 km) for R1 and R2 were selected because the two meteorological stations (Cork Airport and the On-site Station) in the vicinity of the proposed facility and existing facilities are located quite close to each other (at a distance of less than 15 km), and each of these stations should have an important weighting in the vicinity of each station.

A second set of parameters defines the area of influence of each station (parameters RMAX1 at the surface and RMAX2 aloft). Since the initial guess field is driven by the MM5 winds and terrain effects are expected to be important, RMAX1 and RMAX2 were set to 10 km in order to give greater weight to the surface station and RMIN=0.1 km. As the buoys (M3 and M5) are located at a distance of up to 60 km off-shore, RMAX3 which defines the radius of influence of the buoy was set to 100km.

8.12.2 CALPUFF Set-Up

Emissions from the proposed site have been modelled using the CALPUFF dispersion model (Version 6.42) which has been developed by Earth Tech (now part of Exponent) and has been approved by the U.S. Environmental Protection Agency (USEPA)[(1)] for long-range transport and on a case-by-case basis for near-field (less than 50km) applications involving complex meteorological conditions. The model is a non-steady-state Lagrangian puff model used to assess pollutant concentrations associated with a wide range of sources including industrial sources.

A receptor grid measuring 80 km by 80 km with the site at the centre was mapped out with terrain information at each receptor, derived from Shuttle Radar Topography Mission (SRTM) with 30 m resolution as input into the model.

8.12.3 CALPUFF Modelling Results

The main study conclusions are presented below for each substance in turn with a graphical summary of results in comparison to the previously obtained AERMOD results presented in Figures 8.6 and 8.7 and in Table 8.79. Modelling was undertaken for both 2006 and 2007 with the worst-case result for either year reported for each averaging period.

NO_2 & NO_X

NO_2 modelling results indicate that the ambient ground level concentrations will be below the relevant air quality standards for the protection of human health for nitrogen dioxide under maximum and abnormal operation of the facility. Thus, no adverse effect on public health or the environment is envisaged to occur under these conditions at or beyond the facility boundary. Emissions at maximum operations lead to ambient NO_2 concentrations (including background concentrations) which are 67% of the maximum ambient 1-hour limit value (measured as a 99.8^{th}%ile) and 32% of the annual average limit value at the respective worst-case receptors.

SO_2, CO, PM_{10} & $PM_{2.5}$

Modelling results indicate that ambient ground level concentrations will be below the relevant air quality standards for the protection of human health for sulphur dioxide, carbon monoxide and PM_{10} under maximum and abnormal operation of the facility. Results will also be below the air quality standard for $PM_{2.5}$ under maximum and abnormal operation of the facility. Thus, no adverse effect on public health or the environment is envisaged to occur under these conditions at or beyond the facility boundary. Emissions at maximum operations equate to ambient concentrations (including background concentrations) ranging from 10% - 58% of the respective limit values at the worst-case receptors.

TOC, HCl & HF

Modelling results indicate that the ambient ground level concentrations will be below the relevant air quality guidelines for the protection of human health for TOC (assumed pessimistically to consist solely of benzene), HCl and HF under maximum and abnormal operation of the facility. Thus, no adverse effect on public health or the environment is envisaged to occur under these conditions at or beyond the facility boundary. Emissions at maximum operations equate to ambient concentrations (including background concentrations) for HCl and TOC of only 18% and 21% respectively of the ambient limit values.

HF modelling results indicate that emissions at maximum operations equate to ambient HF concentrations (including background concentrations) which will be 6% of the maximum ambient 1-hour limit value and 2% of the annual limit value.

PCDD / PCDFs (Dioxins/Furans)

Currently, no internationally recognised ambient air quality concentration or deposition standards exist for PCDD/PCDFs (Dioxins/Furans). The EU, USEPA and WHO recommended approach to assessing the risk to human health from Dioxins/Furans entails a detailed risk assessment analysis involving the determination of the effect of Dioxins/Furans in terms of the TDI (Tolerable Daily Intake) or TWI (Tolerable Weekly Intake) approach. The EU currently proposes a maximum TWI of between 14 pg WHO-TEQ/kg of body weight per day.

Background levels of Dioxins/Furans occur everywhere and existing levels in the surrounding area have been extensively monitored as part of this study. Monitoring

results indicate that the existing levels are similar to rural areas in the UK and Ireland. The contribution from the facility in this context is minor, with levels at the worst-case receptor to the south of the Facility, under maximum and abnormal operation, accounting for only a small fraction of existing levels. Levels at the nearest residential receptor will be minor, with the annual contribution from the proposed facility accounting for less than 1% of the existing background concentration under maximum operating conditions.

PAHs

PAHs modelling results indicate that the ambient ground level concentrations will be below the relevant air quality target value for the protection of human health under maximum and abnormal operation of the Facility. Thus, no adverse effect on public health or the environment is envisaged to occur under these conditions at or beyond the facility boundary. Emissions at maximum operations equate to ambient benzo[*a*]pyrene concentrations (excluding background concentrations) which are only 0.5% of the EU annual average target value at the worst-case receptor.

Hg

Hg modelling results indicate that the ambient ground level concentrations will be below the relevant air quality standards for the protection of human health under maximum and abnormal operation of the facility. Thus, no adverse effect on public health or the environment is envisaged to occur under these conditions at or beyond the facility boundary. Emissions at maximum operations equate to ambient mercury concentrations (including background concentrations) which are only 0.8% of the annual average limit value at the worst-case receptor.

Cd and Tl

Modelling results indicate that the ambient ground level concentrations will be below the relevant air quality standard for the protection of human health for cadmium under maximum and abnormal operation from the facility. Emissions at maximum levels equate to ambient Cd and Tl concentrations (including background concentrations) which are 25% of the EU annual target value for Cd close to the facility boundary (the comparison is made with the Cd limit value as this is more stringent than that for Tl).

Sum of As, Sb, Pb, Cr, Co, Cu, Ni, Mn and V

Modelling results indicate that the ambient ground level concentrations will be below the relevant air quality standards for the protection of human health for arsenic (As), Nickel (Ni) and vanadium (V) (the metals with the most stringent limit values) under maximum and abnormal operation emissions from the facility (based on the ratio of metals measured at a Waste to Energy facility in Carranstown, County Meath). Thus, no adverse effect on public health or the environment is envisaged to occur under these conditions at or beyond the facility boundary. Ambient concentrations have been compared to the annual target value for As and Ni and the maximum 1-hour limit value for V as these represent the most stringent limit values for the suite of metals. Emissions at maximum operations equate to ambient As and Ni concentrations (including background concentrations) which are 17% and 47% of the EU annual target value respectively at the worst-case receptor whilst emissions at maximum operations equate to ambient V concentrations (including background concentrations) which are only 0.7% of the maximum 1-hour limit value at the worst-case receptor.

Table A8.79 CALPUFF Modelling Results Under Maximum Operations (μg/m^3).

Pollutant	**NO_2**		**NO_x**	**SO_2**			**PM_{10}**		**$PM_{2.5}$**	**CO**	**TOC**	**HCl**	
Averaging Period	1-hr	Annual	Annual	1-hr	24-hr	Annual	24-hr	Annual	Annual	8-Hr	Ann	1-hr	Annual
Baseline & Site Traffic Concentration (Year 2023)	24	12	17	25.6	19.7	10	28.9	16	14	1000	1	4.4	2.2
Process Emissions	109.5	0.73	1.0	41.4	3.6	0.15	0.2	0.05	0.05	49.0	0.048	144	0.048
Predicted Environmental Concentration (Year 2023)	133.5	12.7	18.0	67.0	23.3	10.2	29.1	16.1	14.1	1049	1.05	148	2.3
Ambient Air Quality Standard	**200**	**40**	**30**	**350**	**125**	**20**	**50**	**40**	**25**	**10000**	**5.0**	**800**	**20**

Table A8.79(continued) CALPUFF Modelling Results Under Maximum Operations (μg/m^3).

Pollutant	**HF**		**Dioxins (fg/m^3)**	**PAHs**	**Hg**	**Cd (ng/m^3)**	**As (ng/m^3)**	**Ni (ng/m^3)**	**V**
Averaging Period	1-hr	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Maximum 1-Hr
Annual Baseline & Site Traffic Concentration (Year 2023)	0.64	0.32	23	0.54	0.008	1	1	9	0.002
Process Emissions	9.6	0.0048	0.71	0.005	0.0002	0.24	0.02	0.32	0.005
Predicted Environmental Concentration (Year 2023)	10.2	0.33	23.7	0.55	0.009	1.24	1.02	9.32	0.007
Ambient Air Quality Standard	**160**	**16**	**N/A**	**1,000**	**1**	**5**	**6**	**20**	**1**

8.13 National Emissions Ceilings

In 1999, Ireland signed the Gothenburg Protocol to the 1979 UN Convention on Long Range Transboundary Air Pollution. The initial objective of the Protocol was to control and reduce emissions of Sulphur Dioxide (SO_2), Nitrogen Oxides (NO_X), Volatile Organic Compounds (VOCs) and Ammonia (NH_3). To achieve the initial targets Ireland was obliged, by 2010, to meet national emission ceilings of 42 kt for SO_2 (67% below 2001 levels), 65 kt for NO_X (52% reduction), 55 kt for VOCs (37% reduction) and 116 kt for NH_3 (6% reduction). In 2012, the Gothenburg Protocol was revised to include national emission reduction commitments for the main air pollutants to be achieved in 2020 and beyond and to include emission reduction commitments for $PM_{2.5.}$ In relation to Ireland, 2020 emission targets are 25 kt for SO_2 (65% below 2005 levels), 65 kt for NO_X (49% reduction), 43 kt for VOCs (25% reduction), 108 kt for NH3 (1% reduction) and 10 kt for $PM_{2.5}$ (18% reduction).

European Commission Directive 2001/81/EC[32], the National Emissions Ceiling Directive (NECD), prescribes the same emission limits as the 1999 Gothenburg Protocol. A National Programme for the progressive reduction of emissions of these four transboundary pollutants has been in place since April 2005[33]. Data available from the EU indicates that Ireland currently complies with the emissions ceilings for SO_2 and $PM_{2.5}$ but is failing to comply with the ceilings for NO_X, NH_3 and NMVOC[34]. Directive (EU) 2016/2284 "*On the Reduction of National Emissions of Certain Atmospheric Pollutants and Amending Directive 2003/35/EC and Repealing Directive 2001/81/EC*" was published in December 2016[35]. The Directive will apply the 2010 NECD limits until 2020 and establish new national emission reduction commitments which will be applicable from 2020 and 2030 for SO_2, NO_X, NMVOC, NH_3, $PM_{2.5}$ and CH_4. In relation to Ireland, 2020-29 emission targets are for SO_2 (65% below 2005 levels), for NO_X (49% reduction), for VOCs (25% reduction), for NH_3 (1% reduction) and for $PM_{2.5}$ (18% reduction). In relation to 2030, Ireland's emission targets are for SO_2 (85% below 2005 levels), for NO_X (69% reduction), for VOCs (32% reduction), for NH_3 (5% reduction) and for $PM_{2.5}$ (41% reduction).

The effect of the facility on emissions of SO_2, NO_X and VOCs has been assessed. Results, outlined in Table A8.80, indicate that the effect of the Facility on Ireland's obligations under the Gothenburg Protocol is slight. The overall effect of the development is to increase SO_2 levels by 0.41% of the ceiling levels to be complied with in 2020, NO_X levels by 0.64% of the ceiling levels, VOC levels will be increased by 0.05% of the ceiling limits whilst $PM_{2.5}$ levels will be increased by 0.23% of the ceiling limits.

Table A8.80 Effect of Ringaskiddy WTE Facility on the Ireland's National Emission Ceiling Obligations.

Year	Scenario	SO_2 (tonnes/ annum)	VOC (tonnes/ annum)	NO_X (tonnes/ annum)	$PM_{2.5}$ (tonnes/ annum)
2023	**Facility In Operation (8760 Hours)**	103	21	412	21
Emission Ceiling (kilo-tonnes) In 2020		24.9(1)	42.8(1)	64.8(1)	9.0(1)
Effect of Facility (%) (National)		**0.41%**	**0.05%**	**0.64%**	**0.23%**

Note 1 Directive (EU) 2016/2284 "On the Reduction of National Emissions of Certain Atmospheric Pollutants and Amending Directive 2003/35/EC and Repealing Directive 2001/81/EC"

8.14 Conclusions

Based on the emission guidelines outlined in Council Directive 2010/75/EU, detailed air dispersion modelling has shown that the most stringent ambient air quality standards for the protection of human health are not exceeded either as a result of operating under maximum or abnormal operating conditions.

The modelling results, using both the USEPA regulatory model AERMOD and the more advanced CALPUFF model, indicate that the maximum ambient GLC occurs at or near the facility's southern and south-eastern boundaries. The spatial effect of the facility is limited with concentrations falling off rapidly away from the maximum peak. For example, the short-term limit values at the nearest residential receptor will be less than 19% of the short-term ambient air quality limit values. The annual average concentration has an even more dramatic decrease in maximum concentration away from the facility with concentrations from emissions at the proposed facility accounting for less than 1% of the limit value (not including background concentrations) at worst case sensitive receptors near the facility.

In the surrounding areas of Cobh, Carrigaline and Monkstown, levels are significantly lower than most background sources with the concentrations from emissions at the proposed facility accounting for less than 1% of the annual limit values for the protection of human health for all pollutants under maximum operations of the facility.

In terms of Ireland's obligations under the Gothenburg Protocol and the POPs Convention, the effect of the facility will not be significant.

8.15 References

(1) USEPA (2017) Guidelines on Air Quality Models, Appendix W to Part 51, 40 CFR Ch.1
(2) USEPA (2004) Minimum Meteorological Data Requirements For AERMOD – Study & Recommendations", 1998, USEPA
(3) USEPA (2018) AERMOD Description of Model Formulation
(4) USEPA (2018) AERMAP Users Guide
(5) USEPA (2019) AERSURFACE User's Guide
(6) Alaska Department of Environmental Conservation (2008) ADEC Guidance re AERMET Geometric Means (http://dec.alaska.gov/air/ap/modeling.htm)
(7) Schulman, L.L; Strimaitis, D.G.; Scire, J.S. (2000) Development and evaluation of the PRIME plume rise and building downwash model. Journal of the Air & Waste Management Association, 50, 378-390.
(8) Paine, R & Lew, F. "Consequence Analysis for Adoption of PRIME: an Advanced Building Downwash Model" Prepared for the EPRI, ENSR Document No. 2460-026-450 (1997).
(9) EPA (2010) Guidance Note On Air Dispersion Modelling – AG04
(10) USEPA (2004) Estimating Exposure to Dioxin-Like Compounds Volume IV, Chapter 3 Evaluating Atmospheric Releases of Dioxin-Like Compounds from Combustion Sources (Draft)
(11) USEPA (2005) Human Health Risk Assessment Protocol, Chapter 3: Air Dispersion and Deposition Modelling, Region 6 Centre for Combustion Science and Engineering
(12) Auer Jr, (1978) Correlation of Land Use and Cover with Meteorological Anomalies, *Journal of Applied Meteorology* 17(5):636-643
(13) UK DEFRA (2016) Part IV of the Environment Act 1995: Local Air Quality Management, LAQM. TG(16)
(14) European Commission (2000) Assessment of Dietary Intake of Dioxins & Related PCBs by the Population of EU Member States (SCOOP Task 3.2.5)
(15) AEA Technology (1999) Compilation of EU Dioxin Exposure & Health Data Task 2 – Environmental Levels
(16) WHO (1989) Polychlorinated dibenzo-p-dioxins and dibenzofurans, EHC 810.
(17) USEPA (2004) Estimating Exposure to Dioxin-Like Compounds Volume I, Chapter 1 Introduction (Draft)
(18) Database of Sources of Environmental Releases of Dioxin-Like Compounds in the United States (1998, USEPA (CD-ROM))
(19) USEPA (2004) Estimating Exposure to Dioxin-Like Compounds Volume IV, Chapter 5 Demonstration of Methodology (Draft)
(20) Chemistry of the Upper & Lower Atmosphere, Finlayson-Pitts & Pitts (1999), Academic Press
(21) Harrison et al, (1996) Source apportionment of atmospheric polycyclic aromatic hydrocarbons collected from an urban location in Birmingham, UK *Environmental Science & Technology*; 30 (825-832)
(22) USEPA (1993) Exposure & Risk Assessment for Benzo[a]pyrene and other Polycyclic Aromatic Hydrocarbons, Volume 1: Summary
(23) World Health Organisation (2006) Air Quality Guidelines - Global Update 2005 (and previous Air Quality Guideline Reports 1999 & 2000)
(24) UK DETR (2000) Polycyclic Aromatic Hydrocarbons
(25) Farant & Gariepy (1998) Relationship between benzo[a]pyrene and individual polycyclic aromatic hydrocarbons in a Soderberg primary aluminium smelter *American Industrial Hygiene Association Journal* 59 (758-765)
(26) EPA (2018) Air Quality Monitoring Report 2017 (& earlier reports)
(27) European Commission (2004) Council Directive 2004/107/EC Relating To As, Cd, Hg, Ni and PAHs In Ambient Air
(28) USEPA (2000) Implementation Issues: Mercury Transport & Fate, Combustion Risk Assessments in Region 6
(29) Environmental Agency (2003) "IPPC H1 - Environmental Assessment & Appraisal of BAT"
(30) Environmental Agency (2011) "H1 Annex F Air Emissions v 2.2"
(31) Environment Agency (2012) "Releases From Municipal Waste Incinerators – Guidance To Applicants On Impact Assessment For Group 3 Metals Stack"
(32) European Commission (2001) Council Directive 2001/81/EC Relating To National Emission Ceilings for Certain Atmospheric Pollutants
(33) DEHLG (2003) Strategy to Reduce Emissions of Trans-boundary Pollution by 2010 to Comply with National Emission Ceilings - Discussion Document
(34) EPA (2018) Ireland's Transboundary Gas Emissions
(35) EU (2016) Directive (EU) 2016/2284 "On the Reduction of National Emissions of Certain Atmospheric Pollutants and Amending Directive 2003/35/EC and Repealing Directive 2001/81/EC"
(36) USEPA (2018) User's Guide to the AERMOD Meteorological Preprocessor (AERMET)
(37) UK DEFRA (2007) Design Manual for Roads and Bridges Vol 11 Chapter 3 (Spreadsheet)