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 15181). The aim of the study was to assess the impact 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 impact 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;
- Impact on public health and the environment in the unlikely event of "abnormal" operating conditions;
- The cumulative impact 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 emission levels at the 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 impact 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 impacts 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 2010 - 2014 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, 2010 - 2014 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 impact 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 impact 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.

Baseline Air Quality Assessment

An extensive baseline survey was carried out in the region of the proposed facility over the period from August 2014 to July 2015. 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 and between 2006 - 2008.

PM_{10} concentrations measured during the monitoring campaigns averaged 20 $\mu g/m^3$, which is below the annual limit value of 40 $\mu g/m^3$. 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.

The average $PM_{2.5}$ concentration measured over the period May / June 2008 is 7 $\mu g/m^3$ which is significantly below the annual average EU limit value of 25 $\mu g/m^3$ which is applicable in 2015.

Nitrogen dioxide (NO_2) concentrations measured over the 2008 monitoring period were below both the 1-hour and annual EU limit values. The annual average NO_2 concentration averaged 6 $\mu g/m^3$ over the three month period. The 99.8^{th}%ile of 1-hour concentrations peaked at 38 $\mu g/m^3$ in 2008. Long term NO_2 concentrations at a further nine locations in the region of the facility were significantly lower than the annual average limit value. The average NO_2 concentration measured over the three month period at each location ranged from 4 -

14 $\mu g/m^3$ which is between 10 - 35% of the EU annual limit value of 40 $\mu g/m^3$. The results indicated a weak NO_2 spatial concentration gradient in the region. Updated 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.

Levels of sulphur dioxide (SO_2), benzene, hydrogen fluoride (HF) and hydrogen chloride (HCl) were all significantly below their respective limit values in 2008. Updated SO_2 diffusion monitoring results amounting to six months of data over the period August 2014 to May 2015 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. Similarly, updated benzene diffusion monitoring results amounting to six months of data over the period August 2014 to July 2015 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.

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) measured were significantly below their respective annual limit values both in 2008 and 2014-2015. Updated 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.

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 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.

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 impact 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 63% 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 61% 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 impact 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 impact 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 22% 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 0.7% 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 impact 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 impact 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 0.8% 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 impact 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 impact 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 38% 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 0.1% 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 44% 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 0.2% 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 impact of the development is to increase SO_2 levels by 0.25% of the ceiling levels to be complied with in 2020, NO_X levels by 0.38% of the ceiling levels, VOC levels will be increased by 0.03% of the ceiling limits whilst $PM_{2.5}$ levels will be increased by 0.14% 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 impact 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 17% 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.

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 impact 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 impacts 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 impact 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 2010 - 2014 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, 2010 - 2014 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 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 (2010 - 2014) is the most recent data set available. 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. Secondly, 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 2010 - 2014 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 2010 - 2014. 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 66 hours in 2012 (0.8% of the time). The number of missing hours are also very low with an average of 2 missing hours / year over the period 2010 – 2014 (0.1% of the time).

8.2.3 Modelling Methodology

Emissions from the proposed facility have been modelled using the AERMOD dispersion model (Version 15181) 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 1100°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 15181). 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, 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	1.18	0.89
Gaseous & vaporous organic substances expressed as total organic carbon (TOC)	20 mg/m^3	10 mg/m^3	0.79	0.59
Hydrogen Chloride (HCl)	60 mg/m^3	10 mg/m^3	2.37	1.78
Hydrogen Fluoride (HF)	4 mg/m^3	1.0 mg/m^3	0.16	0.119
Sulphur Dioxide (SO_2)	200 mg/m^3	50 mg/m^3	7.89	5.94
Nitrogen Oxides (as NO_2)	400 mg/m^3	200 mg/m^3	15.8	11.9
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	0.0020	0.0015
Thallium and its compounds, expressed as Tl				
Mercury and its compounds, expressed as Hg	0.05 mg/m^3	0.05 mg/m^3	0.0020	0.0015
Antimony and its compounds, expressed as Sb	Total 0.5 mg/m^3	Total 0.50 mg/m^3	0.020	0.015
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	0.0040	0.0030
Average Value	**Emission Concentration**	**Emission Concentration**	**Emission Rate (g/s)**	**Emission Rate (g/s)**
Carbon Monoxide	100 mg/m^3	50 mg/m^3	3.95	1.49

(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 August 2014 to July 2015. This supplements the extensive baseline surveys undertaken in November 2006 to February 2007 and from April 2008 to July 2008. 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 August 2014 to July 2015 focused on NO_2, PM_{10}, benzene, SO_2 and heavy metals over a year long period in order to capture any possible seasonal factors. 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

<u>NO_2</u>

Monitoring of nitrogen dioxide in the vicinity of Ringaskiddy over the period August 2014 to May 2015 was carried out using passive diffusion tubes. 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, passive diffusion tube monitoring over six one-month periods at ten locations in the area (see Figure 8.1) was carried out. 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, by ESG (a UKAS accredited laboratory).

<u>SO_2</u>

In order to assess the spatial variation in sulphur dioxide levels in the area, SO_2 was monitored using passive diffusion tubes over six one-month periods at six locations over the period August 2014 to May 2015 (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 ESG.

Benzene

In order to assess the spatial variation in benzene levels in the area, benzene was monitored using passive diffusion tubes over six one-month periods at six locations over the period August 2014 to May 2015 (see Figure 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 Chromasorb 106. Following sampling, the tubes were analysed by Gas Chromatography, at ESG.

PCDD/PCDFs

Sampling for PCDDs and PCDFs was carried out over four 3-4 day periods extended over one month at the on-site monitoring station in 2008. Sampling was carried out in accordance with the requirements of the United States Environmental Protection Agency (US EPA) methodology. The sampling method was taken from the Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air. Method TO9 describes a method for the sampling of PCDDs and PCDFs in ambient air using high resolution gas chromatography/mass spectrometry.

Sampling of the ambient air was achieved using a high volume air sampler. Air was drawn through a fine porosity quartz filter and adsorbent cartridge containing polyurethane foam to trap the particulate and volatile fractions respectively. In order to obtain a detection limit in ambient air of approximately one femtogram (fg), a sample volume of at least $500m^3$ was required.

Analysis for PCDDs and PCDFs was by high-resolution gas chromatography/mass spectrometry (GC/MS) and was carried out by Scientific Analysis Laboratories (SAL), Manchester. SAL Ltd are UKAS accredited for the analysis of PCDDs and PCDFs. Extraction, clean-up and analysis procedures followed USEPA protocols and the full quality assurance and quality control regime set out in EPA Method 1613 was followed.

HCl & HF

Gaseous HF and HCl were monitored over four 4-7 day periods extended over one month at the on-site monitoring station in 2008. HF and HCl were sampled using sequential filtration onto pre-cleaned 47mm diameter, 0.45µm nominal pore size nylon membrane filters. Particles and aerosols, including salt which may interfere with the gaseous measurement, were removed from the airstream using a 47mm diameter, 1µm pore size teflon filter. The filters were housed in a single multi-stage open-face teflon holder designed to minimise any losses onto the sampler surfaces. The teflon cassette contained a Teflon filter upstream of a nylon filter to ensure quantitative collection of the acid gases.

Ambient air was sampled through the cassette assembly using a sampling pump set at a flowrate of approximately 5 litres per minute (l/min). The actual volume sampled was recorded on a digital dry gas meter. Following sampling, the nylon filters were extracted with eluent in a sonic bath and chloride (Cl^-) and fluoride (F^-) concentrations determined on the solution by ion chromatography (IC). An equivalent mass of HCl and HF was then determined from the molecular masses. The methodology therefore assumes that all the gaseous chloride and fluoride present in the air is in the form of HCl and HF respectively. Analysis was carried out by Scientific Analysis Laboratories, Manchester.

$PM_{2.5}$

The $PM_{2.5}$ monitoring program, focused on assessing 24-hour average concentrations over a one-month at the on-site monitoring station (see Figure 8.1) in 2008. $PM_{2.5}$ sampling was carried out by means of an 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 >2.5 µg. The remaining particles (<2.5 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 (Bureau Veritas Laboratories, Glasgow). The gravimetric results allowed a calculation of the average $PM_{2.5}$ concentration over each 24-hour period.

PM_{10}

The PM_{10} monitoring program, using a PM_{10} continuous monitor, focused on assessing 24-hour average concentrations over the period August 2014 to July 2015 at a monitoring station located on-site in Ringaskiddy, County Cork (see Figure 8.1). PM_{10} sampling was carried out by means of an 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 (Bureau Veritas, UK). The gravimetric results allowed a calculation of the average PM_{10} concentration over each 24-hour period. The results, which are shown in Table A8.16, can be directly compared with the 24-hour limit value (which is set as a 90th%ile), and the long-term average can be indicatively compared with the annual limit value.

Heavy Metals

Sampling for heavy metals over the period August 2014 to July 2015 was conducted using the same methodology as for PM_{10}. PTFE filters were utilised as they have low background heavy metal concentrations. Following sampling and re-weighing, the PTFE filters were acid digested in batches of 5 - 7 samples and the metals suite determined by inductively coupled plasma (ICP) by Bureau Veritas, UK.

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 2008, 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 5.6 $\mu g/m^3$ which is 14% of the annual NO_2 limit value (see Figure 8.9). The 2008 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 4 - 14 $\mu g/m^3$ which is between 10 - 35% 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.

Updated results at 15 locations (as opposed to 10 locations in the 2008 survey) indicated compliance with the NO_2 annual limit value over a larger geographical area. Updated 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 and A8.7. The 2008 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 as shown in Table A8.6. The average SO_2 concentration measured over the three month period at each location ranged from 0.6 - 1.4 $\mu g/m^3$ which is between 3 - 7% of the EU annual limit value of 20 $\mu g/m^3$.

Updated 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 and A8.9. The 2008 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 as shown in Table A8.8. The average benzene concentration measured over the three month period at each location ranged from 0.3 - 0.4 $\mu g/m^3$ which is between 6 - 8% of the EU annual limit value of 5 $\mu g/m^3$.

Updated benzene diffusion monitoring results amounting to six months of data over the period August 2014 to May2015, 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 region have been monitored over four one-week periods in April - May 2008. Monitoring was carried out over four 4-5 (approx.) day periods, the results of which are detailed in Tables A8.10 and A8.11. A summary of the results for the one-month period is detailed in Table A8.12.

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

HCl and HF were measured over four sets of 3-4 day periods at the on-site monitoring station during April - June 2008. The results are detailed in Table A8.13. The average concentrations measured during the one-month period in 2008 were 1.2 μg/m^3 (HCl) and < 0.05 μg/m^3 (HF). The average HCl levels can be indicatively compared to the hourly EAL for HCl of 800 μg/m^3 and the long-term of EAL of 20 μg/m^3 whereas the average HF level can be indicatively compared to the annual UK DEFRA Limit value for HF of 16 μg/m^3. Hence, measured levels of HCl and HF were considerably lower than the relevant limit values.

$PM_{2.5}$

Daily concentrations of $PM_{2.5}$ measured in 2008 using the sequential $PM_{2.5}$ sampler are shown in Table A8.14. The average $PM_{2.5}$ concentration measured over the one-month period is 7 μg/m^3 which is significantly below the annual average EU limit value of 25 μg/m^3 which is applicable in 2015.

PM_{10}

Daily concentrations of PM_{10} measured, in 2006 – 2007, using the sequential PM_{10} sampler are shown in Table A8.15. The 24-hour PM_{10} concentrations measured over the three-month period are significantly below the 24-hour EU limit value of 50 μg/m^3 which has been applicable since 2005.

No exceedances of the 24-hour limit value were recorded over the three months of this monitoring campaign. The 90th%ile, which means the 36th highest value measured over a full year is compared to the limit value. The standard allows for compliance with the ambient air quality standard to be maintained provided no more than 35 exceedances of the 24-hour limit value occur in any one year. Since no exceedances were recorded over the three-months of this monitoring survey, 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 in 2006 – 2007 is 6 μg/m^3 which is only 12% of the EU annual limit value of 40 μg/m^3, which has been applicable since 2005.

Updated 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 μg/m^3, which is below the annual limit value of 40 μg/m^3 as shown in Figure 8.10 and Table A8.16. 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.

Metals

Ambient concentrations of the suite of metals were measured over 12 sets of 5-7 day periods spread over three-months at the fixed monitoring station during the period November 2006 - February 2007. The results for each sample are detailed in Tables A8.17 and A8.18 and in 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 upper range average levels reaching only 0.01 - 2% of these limits (see Tables A8.17 and A8.18).

Updated 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 A8.19 - A8.21).

Table A8.3 Summary of Continuous NO_2 Monitoring Results at On-Site Monitoring Station (Year 2008)

Monitoring Period	Details	
March 2008	Total No. Days Sampling	26
	No. Hourly Averages >200 μg/m^3	0
	Monthly Average	6.5 μg/m^3
April 2008	Total No. Days Sampling	30
	No. Hourly Averages >200 μg/m^3	0
	Monthly Average	6.6 μg/m^3
May 2008	Total No. Days Sampling	31
	No. Hourly Averages >200 μg/m^3	0
	Monthly Average	4.0 μg/m^3
June 2008	Total No. Days Sampling	11
	No. Hourly Averages >200 μg/m^3	0
	Monthly Average	5.5 μg/m^3
March - May 2008 Monitoring Period	*Total No. Days Sampling*	*98*
	No. Hourly Averages >200 μg/m^3	*0*
	99.8th%ile of 1-hour Averages	*39.3 μg/m^3*
	Monitoring Period Average	*5.6 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 Using Passive Diffusion Tubes (March - June 2008).

Location	**NO_2 (µg/m^3) 04/03/08 – 01/04/08**	**NO_2 (µg/m^3) 01/04/08 - 02/05/08**	**NO_2 (µg/m^3) 02/05/08 - 05/06/08**	**NO_2 Average (µg/m^3)**	***Adjusted NO_2 Average (µg/m^3)***
M1- On-Site Monitoring Station	9	8	6	8	6
M2 – Car Park East of Site	10	10	8	9	7
M3 – Nearest Residential	13	11	8	11	8
M4 – Main Residential	11	14	11	12	9
M5 – Ringaskiddy Village	15	16	14	15	11
M6 – N28/R613 Junction	19	19	18	19	14
M7 – South of Haulbowline Island	10	8	6	8	6
M8 – National School	4	7	4	5	4
M9 – Loughbeg	7	8	6	7	5
M10 – Opposite Site Entrance	13	10	3	9	6
		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. Chemiluminescent average for equivalent monitoring period = 5.7 µg/m^3. Thus the diffusion tube bias is 5.7/7.7 = 0.74

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

Location	**NO_2 (µg/m^3) 14/08/14 – 15/09/14**	**NO_2 (µg/m^3) 15/09/14 - 20/10/14**	**NO_2 (µg/m^3) 20/10/14 – 21/11/14**	**NO_2 (µg/m^3) 14/01/15 – 13/02/15**	**NO_2 (µg/m^3) 13/02/15 – 16/03/15**	**NO_2 (µg/m^3) 31/03/15 – 01/05/15**	**NO_2 Average (µg/m^3)**	***Adjusted NO_2 Average (µg/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 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 0.81.

Table A8.6 Average SO_2 Concentrations Measured in Ringaskiddy Using Passive Diffusion Tubes (March - June 2008).

Location	**SO_2 (µg/m^3) 04/03/08 - 01/04/08**	**SO_2 (µg/m^3) 01/04/08 - 02/05/08**	**SO_2 (µg/m^3) 02/05/08 - 05/06/08**	**SO_2 Average (µg/m^3)**
M1- On-Site Monitoring Station	1.2	0.82	<0.1	0.7
M3 - Nearest Residential	1.5	1.5	1.2	1.4
M4 - Main Residential	Note 1	0.98	0.15	0.6
M5 - Ringaskiddy Village	1.4	1.1	1.1	1.2
M8 - National School	1.3	1.3	0.75	1.1
			Limit Value	*20 µg/m$^{3\ Note\ 2}$*

Note 1 Sample tube tampered with during monitoring.

Note 2 EU Council Directive 2008/50/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 (March - June 2008).

Location	**Benzene (µg/m^{3}) 04/03/08 - 01/04/08**	**Benzene (µg/m^{3}) 01/04/08 - 02/05/08**	**Benzene (µg/m^{3}) 02/05/08 - 05/06/08**	**Benzene Average (µg/m^{3})$^{\text{Note 1}}$**
M1- On-Site Monitoring Station	<0.2	0.2	0.7	0.4
M3 - Nearest Residential	0.6	0.3	<0.2	0.4
M4 - Main Residential	Note 2	0.3	<0.2	0.3
M5 - Ringaskiddy Village	0.4	<0.2	0.3	0.3
M8 - National School	0.5	<0.2	0.2	0.3
			Limit Value	*5 µg/m^{3} Note 3*

Note 1 Average calculated assuming non detects are equal to the detection limit.
Note 2 Sample tube tampered with during monitoring.
Note 3 EU Council Directive 2008/50/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).

PCDD Congeners	**I-TEF**[Note 1]	**Sampling Period 1: 21/04/08 - 25/04/08**			**Sampling Period 2: 02/05/08 - 06/05/08**		
		Ambient Concentration (fg/m^3) [Note 2]	**Lower Limit TEQ**[Note 3] **(fg/m^3)**	**Upper Limit TEQ**[Note 4] **(fg/m^3)**	**Ambient Concentration (fg/m^3)** [Note 2]	**Lower Limit TEQ**[Note 3] **(fg/m^3)**	**Upper Limit TEQ**[Note 4] **(fg/m^3)**
2,3,7,8-TCDD	1.0	*1.514*	1.5137	1.5137	*1.718*	-	1.7185
1,2,3,7,8-PeCDD	0.5	5.178	2.5892	2.5892	4.419	2.2095	2.2095
1,2,3,4,7,8-HxCDD	0.1	4.063	0.4063	0.4063	*1.718*	-	0.1718
1,2,3,6,7,8-HxCDD	0.1	4.382	0.4382	0.4382	3.601	0.3601	0.3601
1,2,3,7,8,9-HxCDD	0.1	3.824	0.3824	0.3824	*1.146*	-	0.1146
1,2,3,4,6,7,8-HpCDD	0.01	41.43	0.4143	0.4143	*2.046*	-	0.0205
OCDD	0.001	143.4	0.1434	0.1434	24.55	0.0245	0.0245
PCDF Congeners	**I-TEF**[Note 1]						
2,3,7,8-TCDF	0.1	7.967	0.7967	0.7967	7.283	0.7283	0.7283
1,2,3,7,8-PeCDF	0.05	5.099	0.2549	0.2549	6.137	0.3069	0.3069
2,3,4,7,8-PeCDF	0.5	11.15	5.577	5.577	9.001	4.5007	4.5007
1,2,3,4,7,8-HxCDF	0.1	19.92	1.9917	1.9917	6.301	0.6301	0.6301
1,2,3,6,7,8-HxCDF	0.1	10.36	1.0357	1.0357	3.355	0.3355	0.3355
1,2,3,7,8,9-HxCDF	0.1	15.93	0.5258	0.5258	*2.864*	-	0.2537
2,3,4,6,7,8-HxCDF	0.1	5.258	1.5934	1.5934	2.537	0.2864	0.2864
1,2,3,4,6,7,8-HpCDF	0.01	74.09	0.7409	0.7409	8.183	0.0818	0.0818
1,2,3,4,7,8,9-HpCDF	0.01	9.560	0.0956	0.0956	*2.782*	-	0.0278
OCDF	0.001	127.5	0.1275	0.1275	9.820	0.0098	0.0098
		Total TEQ	**18.6**	**18.6**	**Total TEQ**	**9.0**	**11.8**

[Note 1] Annex 1, Council Directive 2010/75/EU.

[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 Average PCDD/PCDF Concentrations Measured at the On-Site Monitoring Station (Sampling Periods 3 & 4).

PCDD Congeners	**I-TEF$^{\text{Note 1}}$**	**Sampling Period 3: 08/05/08 - 13/05/08**			**Sampling Period 4: 19/05/08 - 23/05/08**		
		Ambient Concentration (fg/m^3) $^{\text{Note 2}}$	**Lower Limit TEQ$^{\text{Note 3}}$ (fg/m^3)**	**Upper Limit TEQ$^{\text{Note 4}}$ (fg/m^3)**	**Ambient Concentration (fg/m^3) $^{\text{Note 2}}$**	**Lower Limit TEQ$^{\text{Note 3}}$ (fg/m^3)**	**Upper Limit TEQ$^{\text{Note 4}}$ (fg/m^3)**
2,3,7,8-TCDD	1.0	0.6530	0.6530	0.6530	*1.281*	-	1.2808
1,2,3,7,8-PeCDD	0.5	4.505	2.2527	2.2527	2.481	1.2407	1.2407
1,2,3,4,7,8-HxCDD	0.1	6.073	0.6073	0.6073	*1.521*	-	0.1521
1,2,3,6,7,8-HxCDD	0.1	6.530	0.6530	0.6530	2.001	0.2001	0.2001
1,2,3,7,8,9-HxCDD	0.1	3.591	0.3591	0.3591	*1.201*	-	0.1201
1,2,3,4,6,7,8-HpCDD	0.01	25.47	0.2547	0.2547	7.124	0.0712	0.0712
OCDD	0.001	43.75	0.0437	0.0437	21.61	0.0216	0.0216
PCDF Congeners	**I-TEF$^{\text{Note 1}}$**						
2,3,7,8-TCDF	0.1	8.489	0.8489	0.8489	4.323	0.4323	0.4323
1,2,3,7,8-PeCDF	0.05	8.489	0.4244	0.4244	3.922	0.1961	0.1961
2,3,4,7,8-PeCDF	0.5	11.75	5.8767	5.8767	7.284	3.6422	3.6422
1,2,3,4,7,8-HxCDF	0.1	9.795	0.9795	0.9795	7.364	0.7364	0.7364
1,2,3,6,7,8-HxCDF	0.1	3.461	0.3461	0.3461	4.162	0.4162	0.4162
1,2,3,7,8,9-HxCDF	0.1	*4.636*	-	0.2285	*3.442*	-	0.2722
2,3,4,6,7,8-HxCDF	0.1	2.285	0.4636	0.4636	2.722	0.3442	0.3442
1,2,3,4,6,7,8-HpCDF	0.01	12.41	0.1241	0.1241	8.805	0.0881	0.0881
1,2,3,4,7,8,9-HpCDF	0.01	*2.351*	-	0.0235	*2.882*	-	0.0288
OCDF	0.001	16.98	0.0170	0.0170	16.01	0.0160	0.0160
		Total TEQ	**13.9**	**14.2**	**Total TEQ**	**7.4**	**9.3**

Note 1 Annex 1, Council Directive 2010/75/EU.

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 A8.12 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 A8.13 Average HCl & HF Concentrations Measured at On-Site Monitoring Station (April - June 2008)

Sampling Period	**HCl (µg/m^3)**	**HF (µg/m^3)**
21/04/08 - 02/05/08	0.22	<0.05
19/05/08 - 23/05/08	0.52	<0.05
23/05/08 - 27/05/08	1.1	<0.05
05/06/08 - 09/06/08	2.7	<0.05
Average	***1.2***	***<0.05***

Table A8.14 PM$_{2.5}$ Concentrations Measured at On-Site Monitoring Station (May - June 2008)

Date	**PM$_{2.5}$ (µg/m^3)**	**Date**	**PM$_{2.5}$ (µg/m^3)**
09/05/08	2.8	25/05/08	9.1
10/05/08	5.7	26/05/08	7.7
11/05/08	9.1	27/05/08	6.2
12/05/08	6.7	28/05/08	7.9
13/05/08	7.7	29/05/08	7.4
14/05/08	8.5	30/05/08	7.7
15/05/08	8.8	31/05/08	8.0
16/05/08	10.5	01/06/08	6.3
17/05/08	4.5	02/06/08	7.5
18/05/08	6.2	03/06/08	7.4
19/05/08	6.0	04/06/08	7.6
20/05/08	10.5	05/06/08	7.7
21/05/08	17.8	06/06/08	7.9
22/05/08	7.2	07/06/08	6.3
24/05/08	11.5	**Mean**	**7**
Limit Values	*25*[Note 1]	***Limit Values***	***25***[Note 1]

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

Table A8.15 Results of PM_{10} monitoring carried out at an on-site location in Ringaskiddy, Co. Cork (2006 – 2007).

Sampling Date	**PM_{10} ($\mu g/m^3$)**	**Sampling Date**	**PM_{10} ($\mu g/m^3$)**	**Sampling Date**	**PM_{10} ($\mu g/m^3$)**
08-Nov-06	5	02-Jan-07	6	31-Jan-07	7
09-Nov-06	7	03-Jan-07	4	01-Feb-07	5
10-Nov-06	7	04-Jan-07	6	02-Feb-07	5
12-Nov-06	3	05-Jan-07	< 1	03-Feb-07	8
13-Nov-06	6	06-Jan-07	< 1	04-Feb-07	8
14-Nov-06	5	07-Jan-07	8	05-Feb-07	8
15-Nov-06	3	08-Jan-07	8	06-Feb-07	3
16-Nov-06	2	09-Jan-07	10	07-Feb-07	11
17-Nov-06	3	10-Jan-07	5	08-Feb-07	7
18-Nov-06	5	11-Jan-07	12	09-Feb-07	-(2)
19-Nov-06	4	12-Jan-07	3	10-Feb-07	-(2)
13-Dec-06	-(1)	13-Jan-07	4	11-Feb-07	-(2)
15-Dec-06	-(1)	14-Jan-07	5	12-Feb-07	-(2)
16-Dec-06	-(1)	15-Jan-07	6	13-Feb-07	-(2)
17-Dec-06	-(1)	16-Jan-07	9	14-Feb-07	-(2)
18-Dec-06	-(1)	17-Jan-07	7	15-Feb-07	-(2)
19-Dec-06	-(1)	18-Jan-07	4	16-Feb-07	-(2)
20-Dec-06	6	19-Jan-07	4	17-Feb-07	-(2)
21-Dec-06	7	20-Jan-07	7	18-Feb-07	-(2)
22-Dec-06	8	21-Jan-07	< 1	19-Feb-07	-(2)
23-Dec-06	6	22-Jan-07	1	20-Feb-07	-(2)
24-Dec-06	6	23-Jan-07	3	21-Feb-07	-(2)
25-Dec-06	9	24-Jan-07	4	22-Feb-07	-(2)
26-Dec-06	10	25-Jan-07	7	23-Feb-07	-(2)
27-Dec-06	6	26-Jan-07	5	24-Feb-07	-(2)
28-Dec-06	11	27-Jan-07	3	25-Feb-07	-(2)
30-Dec-06	4	28-Jan-07	3	26-Feb-07	-(2)
31-Dec-06	11	29-Jan-07	6	27-Feb-07	-(2)
01-Jan-07	3	30-Jan-07	4		
Mean			**6**		
No. Exceedances of 24-hour Limit Value			**0**		
Limit Values			**40(3), 50(4)**		

(1) Filter misplaced in laboratory.
(2) Filter weighing error in laboratory.
(3) EU Council Directive 2008/50/EC - (as an annual average).
(4) EU Council Directive 2008/50/EC - (as a 90th percentile of 24 hour averages).

Table A8.16a 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.

Table A8.16b 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)
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 A8.17 Levels of heavy metals measured at an on-site location in Ringaskiddy during the period 08/11/06 – 27/02/07.

Species	**Period 1** **08/11/06 - 13/11/06 (ng/m^3)**	**Period 2** **14/11/06 - 19/11/06 (ng/m^3)**	**Period 3** **20/12/06 - 26/12/06 (ng/m^3)**	**Period 4** **27/12/06 - 02/01/07 (ng/m^3)**	**Period 5** **03/01/07 - 11/01/07 (ng/m^3)**	**Period 6** **12/01/07 - 18/01/07 (ng/m^3)**	**Period 7** **19/01/07 - 25/01/07 (ng/m^3)**	**Limit Values (ng/m^3)(1)**
Antimony	< 0.069	< 0.069	< 0.006	< 0.006	< 0.069	< 0.060	< 0.060	5000
Arsenic	< 0.069	< 0.069	< 0.060	< 0.060	< 0.069	< 0.060	< 0.060	6(2)
Cadmium	< 0.069	< 0.069	0.23	0.054	< 0.069	0.012	0.018	5(2)
Chromium	< 0.069	< 0.069	3.4	4.9	< 0.069	< 0.060	< 0.060	5000
Cobalt	< 0.069	< 0.069	< 0.060	< 0.060	< 0.069	< 0.060	< 0.060	200
Copper	0.076	< 0.069	1.0	3.3	0.13	< 0.060	< 0.060	2000
Lead	14.4	6.5	0.94	1.8	20.6	17.6	6.5	500
Manganese	< 0.069	< 0.069	1.1	0.80	< 0.069	< 0.060	< 0.060	150
Mercury	< 0.069	< 0.069	< 0.060	< 0.060	< 0.069	< 0.060	< 0.060	1000
Nickel	0.097	< 0.069	< 0.060	< 0.060	< 0.069	0.077	< 0.060	20(2)
Thallium	< 0.014	< 0.014	< 0.012	< 0.012	< 0.014	< 0.012	< 0.012	1000
Vanadium	< 0.069	< 0.069	0.52	< 0.060	< 0.069	< 0.060	< 0.060	1000

(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 08/11/06 – 27/02/07.

Species	**Period 8** **26/01/07 - 01/02/07 (ng/m^3)**	**Period 9** **02/02/07 - 08/02/07 (ng/m^3)**	**Period 10** **09/02/07 - 15/02/07 (ng/m^3)**	**Period 11** **16/02/07 - 22/02/07 (ng/m^3)**	**Period 12** **23/02/07 - 27/02/07 (ng/m^3)**	**Lower Range Average (ng/m^3)(1)**	**Upper Range Average (ng/m^3)(2)**	**Limit Values (ng/m^3)(3)**
Antimony	0.006	0.012	< 0.060	< 0.060	< 0.060	**0.001**	**0.045**	5000
Arsenic	< 0.060	< 0.060	< 0.060	< 0.060	< 0.060	**ND**	**0.062**	6(4)
Cadmium	0.006	< 0.006	0.11	0.006	< 0.006	**0.037**	**0.055**	5(4)
Chromium	< 0.060	< 0.060	< 0.060	< 0.060	< 0.060	**0.70**	**0.75**	5000
Cobalt	< 0.060	< 0.060	< 0.060	< 0.060	< 0.060	**ND**	**0.062**	200
Copper	0.10	< 0.060	0.11	< 0.060	< 0.060	**0.12**	**0.42**	2000
Lead	10.8	19.4	7.4	3.3	9.2	**9.9**	**9.9**	500
Manganese	< 0.060	< 0.060	< 0.060	< 0.060	< 0.060	**0.16**	**0.21**	150
Mercury	< 0.060	< 0.060	< 0.060	< 0.060	< 0.060	**N.D.**	**0.062**	1000
Nickel	< 0.060	< 0.060	< 0.060	0.13	0.071	**0.031**	**0.073**	20(4)
Thallium	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	**N.D.**	**0.012**	1000
Vanadium	< 0.060	< 0.060	< 0.060	< 0.060	< 0.060	**0.043**	**0.10**	1000

(1) Values at detection limit have been taken to equal to zero.
(2) Values at detection limit have been taken to equal to the detection limit
(3) Annual average limit values set by the EU, WHO, TA Luft Guidelines or a derived as an Environmental Assessment Level.
(4) EU Directive 2004/107/EC

Table A8.19 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 A8.20 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 A8.21 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 has 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 emissions 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 is outlined in Table A8.22. Full details of emission concentrations and mass emissions are given in Appendix 8.6.

Table A8.22 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	418	142,000 – Maximum	14.0
					106,900 – Nominal	10.5

(1) Normalised to 11% O_2, dry, 273K.
(2) Actual, 418K

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 A8.23. 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 A8.23 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 2006 – 2008 & Year 2014 - 2015	9	13	9	20	12	-	1	1.2	0.05	0.0013 pg/m^3	0.71 ng/m^3	0.001	0.001	0.001	0.002	0.007
Annual Background Concentration - Year 2020	9	13	9	20	12	450	1	1.2	0.05	0.0013 pg/m^3	0.71 ng/m^3	0.001	0.001	0.001	0.002	0.007
Facility Traffic - Year 2020(3)	0.6	1.2	-	0.1	0.1	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 2020)	**12**	**17**	**10**	**20**	**12**	**500**	**1.0**	**1.2**	**0.05**	**0.0014 pg/m^3**	**0.71 ng/m^3**	**0.001**	**0.001**	**0.001**	**0.002**	**0.007**

(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 A8.24.

Table A8.24 Emission Scenario for Nitrogen Dioxide

Pollutant	Scenario	Concentration	Emission Rate (g/s)
NO_2	Maximum 1-Hr Operation	400 mg/m^3	15.8
	Maximum 24-Hr Operation	200 mg/m^3	7.89
	Abnormal Operation$^{(1)}$	400 mg/m^3	15.8

(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 A8.25. 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 A8.25 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 μg/m^3 NO_2
		Annual limit for protection of human health	0% After 2010	40 μg/m^3 NO_2
		Critical level for protection of vegetation	None	30 μg/m^3 NO + NO_2

8.5.4 Modelling Results

Modelling was carried out for the scenarios described in Section 8.5.2. Table A8.26 details the predicted annual average and maximum one-hour NO_2 GLC for each scenario at the worst-case locations whereas Table A8.27 details the spatial variation in nitrogen dioxide concentrations at specific locations in the surrounding region. Table A8.26 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 A8.26 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)	1.2	12	13.2	40	3.1%
	99.8th%ile of 1-hr means(4)	72.1	N/A(4)	125.3	200	36.0%
NO_2 / Abnormal Operation	Annual Mean(3)	1.3	12	13.3	40	3.3%
	99.8th%ile of 1-hr means(4)	72.1	N/A(4)	125.3	200	36.0%
NO_X / Maximum	Annual Average (In NHA / SPA Only)	1.2	17	18.2	30	4.0%
NO_X / Abnormal Operation	Annual Average (In NHA / SPA Only)	1.25	17	18.3	30	4.2%

(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 A8.27 Dispersion Model Results – Nitrogen Dioxide Maximum Operation, Specific Receptors

Pollutant / Location	**Averaging Period**	**Process Contribution ($\mu g/m^3$)**	**Background Concentration ($\mu g/m^3$)(1)**	**Predicted Emission Concentration ($\mu g/Nm^3$)**	**Standard(2) ($\mu g/Nm^3$)**	**Facility emissions as a % of ambient limit value**
NO_2 Maximum / Worst-case Residential Receptor	Annual Mean(3)	0.26	12	12.3	40	0.6
	99.8th%ile of 1-hr means(4)	33.8	N/A(4)	105.6	200	17
NO_2 Typical / Ringaskiddy School	Annual Mean(3)	0.11	12	12.1	40	0.3
	99.8th%ile of 1-hr means(4)	11.6	N/A(4)	105.3	200	5.8
NO_2 Typical / Ringaskiddy Centre	Annual Mean(3)	0.11	12	12.1	40	0.5
	99.8th%ile of 1-hr means(4)	22.4	N/A(4)	105.4	200	11
NO_2 Typical / Cobh	Annual Mean(3)	0.17	12	12.2	40	0.4
	99.8th%ile of 1-hr means(4)	12.8	N/A(4)	105.4	200	6.4
NO_2 Typical / Carrigaline	Annual Mean(3)	0.03	12	12.03	40	0.1
	99.8th%ile of 1-hr means(4)	4.3	N/A(4)	105.1	200	2.1
NO_2 Typical / Crosshaven	Annual Mean(3)	0.12	12	12.1	40	0.3
	99.8th%ile of 1-hr means(4)	15.6	N/A(4)	105.3	200	7.8

(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 impact 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 63% 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 impact 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 17% 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 0.6% of the limit value (not including background concentrations) at worst case sensitive receptors near the facility. Thus, the results indicate that the potential impact 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 0.5% 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 61% 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 A8.28.

Table A8.28 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	7.89
	Maximum 24-Hr Operation	50 mg/m^3	1.97
	Abnormal 24-Hr Operation(1)	200 mg/m^3	7.89
CO	Maximum 1-Hr Operation	150 mg/m^3	5.92
	Maximum 24-Hr Operation	50 mg/m^3	1.97
	Abnormal 24-Hr Operation(2)	200 mg/m^3	7.89
Total Dust	Maximum 1-Hr Operation	30 mg/m^3	1.18
	Maximum 24-Hr Operation	10 mg/m^3	0.40
	Abnormal 24-Hr Operation(3)	30 mg/m^3	1.18

(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 A8.29. 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 A8.29 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 A8.30 – A8.33 detail the predicted SO_2, CO, PM_{10} and $PM_{2.5}$ GLC for each scenario.

Table A8.30 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	35.7	N/A$^{(3)}$	45.1	350
	99.2th%ile of 24-hr means	5.23	N/A$^{(3)}$	14.6	125
SO_2 / Abnormal Operation$^{(2)}$	99.7th%ile of 1-hr means	35.7	N/A$^{(3)}$	45.1	350
	99.2th%ile of 24-hr means	5.54	N/A$^{(3)}$	14.9	125
SO_2 / Maximum	Annual Average (In NHA / SPA Only)	0.30	4.7	5.0	20
SO_2 / Abnormal	Annual Average (In NHA / SPA Only)	0.34	4.7	5.0	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 A8.31 Dispersion Model Results – Carbon Monoxide

Pollutant / Scenario	Averaging Period	Process Contribution (µg/m^3)	Background (µg/m^3)(1)	Predicted Emission Concentration (µg/Nm^3)	Standard(2) (µg/Nm^3)
CO / Maximum	Rolling Eight Hour	26.1	1,000	1,026	10,000
CO / Abnormal Operation(3)	Rolling Eight Hour	34.8	1,000	1,035	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 A8.32 Dispersion Model Results – Total Dust (referenced to PM$_{10}$)

Pollutant / Scenario	Averaging Period	Process Contribution (µg/m^3)	Background (µg/m^3)	Predicted Emission Concentration (µg/Nm^3)	Standard(1) (µg/Nm^3)
PM$_{10}$ / Maximum	90th%ile of 24-hr means	0.30	N/A(3)	28.1	50
	Annual mean	0.08	20	20.1	40
PM$_{10}$ / Abnormal Operation(2)	90th%ile of 24-hr means	0.30	N/A(3)	28.1	50
	Annual mean	0.09	20	20.1	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 A8.33 Dispersion Model Results – Total Dust (referenced to PM$_{2.5}$)

Pollutant / Scenario	Averaging Period	Process Contribution (µg/m^3)	Background (µg/m^3)	Predicted Emission Concentration (µg/Nm^3)	Limit Value(1) (µg/Nm^3)
PM$_{2.5}$ / Maximum	Annual mean	0.08	12	12.1	25
PM$_{2.5}$ / Abnormal Operation(2)	Annual mean	0.09	12	12.1	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 impact 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 10% 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 13% of the maximum ambient 1-hour limit value (measured as a 99.7th%ile) and 12% 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 1.5% 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 25% 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 impact 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 is 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 impact 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 56% of the maximum ambient 24-hour limit value (measured as a 90th%ile) with the contribution from the proposed facility equating to 0.6% of the limit value. Emissions at maximum operations equate to ambient PM_{10} concentrations which are 50% of the 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.

$PM_{2.5}$

$PM_{2.5}$ 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 impact 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 48% of the proposed annual average limit value at the worst-case receptor, with the contribution from the proposed facility equating to less than 0.4% 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 A8.34.

Table A8.34 Emission Scenario for TOC, HCl and HF

Pollutant	Scenario	Concentration	Emission Rate (g/s)
TOC	Maximum 1-Hr Operation	30 mg/m^3	0.79
	Maximum 24-Hr Operation	10 mg/m^3	0.39
	Abnormal Operation(1)	30 mg/m^3	0.79
HCl	Maximum 1-Hr Operation	60 mg/m^3	2.37
	Maximum 24-Hr Operation	10 mg/m^3	0.39
	Abnormal Operation(2)	60 mg/m^3	2.37
HF	Maximum 1-Hr Operation	4 mg/m^3	0.16
	Maximum 24-Hr Operation	1 mg/m^3	0.04
	Abnormal Operation(3)	4 mg/m^3	0.16

(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 A8.35). 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 impact 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 A8.35).

Table A8.35 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 A8.36 – A8.38 details the predicted TOC, HCl and HF GLC for each scenario.

Table A8.36 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	0.083	1	1.1	5
TOC / Abnormal Operation(2)	Annual Average	0.090	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 A8.37 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	15.7	2.4	18.1	800
HCl / Maximum	Annual	0.083	1.2	1.3	20
HCl / Abnormal Operation(2)	Maximum 1-hour	15.7	2.4	18.1	800
HCl / Abnormal Operation(2)	Annual	0.099	1.2	1.3	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 A8.38 Dispersion Model Results – HF

Pollutant / Scenario	Averaging Period	Process Contribution (μg/m^3)	Annual Mean Background (μg/m^3)	Predicted Emission Concentration (μg/Nm^3)	Standard (μg/Nm^3)$^{(1)}$
HF / Maximum	Maximum 1-hr	1.04	0.1	1.1	160
	Annual Average	0.0083	0.05	0.058	16
HF / Abnormal Operation$^{(2)}$	Maximum 1-hr	1.04	0.1	1.1	160
	Annual Average	0.0093	0.05	0.059	16

(1) UK DEFRA

(2) 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).

8.7.4 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 impact 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 22% 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 impact 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% of the maximum ambient 1-hour limit value and 6% 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 impact 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 0.7% of the maximum ambient 1-hour limit value and 0.4% 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 A8.39). 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 A8.40). 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 A8.33 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 impacts 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 A8.41 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:

$$\boxed{\Phi = c\Theta / (\rho^{o}_{L} + c\Theta)}$$

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:

$$\boxed{\Phi = C_p(TSP) / (C_g + C_p(TSP))}$$

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 A8.42. Other relevant data used in the calculations and the derived particle fraction at 10ºC is also shown in Table A8.42.

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 A8.43.

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 A8.39 and the vapour – particle partitioning from Table A8.40, the vapour concentrations of the respective dioxin congeners was determined as outlined in Table A8.45 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 A8.45 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 A8.44). 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 A8.44(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 A8.39 and the vapour – particle partitioning from Table A8.40 were used to give the particulate concentrations of the respective dioxin congeners as determined in Table A8.46 and diagrammatically in Figure 8.23. Results are shown under maximum operating conditions.

For the particle-bound deposition, the congener profile from Table A8.39 and the vapour – particle partitioning from Table A8.40 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 A8.47 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 impact of Dioxins/Furans in terms of the EU TWI (Tolerable Daily 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 7 (Population And Human Health)).

Table A8.39 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 A8.40 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 A8.41 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	0.00088	0.0023	0.054
1,2,3,7,8-PeCDD	0.00681	0.0090	0.303
1,2,3,4,7,8-HxCDD	0.01168	0.0031	0.105
1,2,3,6,7,8-HxCDD	0.02355	0.0062	0.128
1,2,3,7,8,9-HxCDD	0.02836	0.0075	0.240
1,2,3,4,6,7,8-HpCDD	0.20633	0.0054	0.111
OCDD	0.31520	0.0008	0.019
2,3,7,8-TCDF	0.03103	0.0082	0.038
1,2,3,7,8-PeCDF	0.00623	0.0008	0.049
2,3,4,7,8-PeCDF	0.01633	0.0215	1.066
1,2,3,4,7,8-HxCDF	0.04845	0.0128	0.756
1,2,3,6,7,8-HxCDF	0.01605	0.0042	0.322
1,2,3,7,8,9-HxCDF	0.00322	0.0008	0.000
2,3,4,6,7,8-HxCDF	0.05353	0.0141	0.538
1,2,3,4,6,7,8-HpCDF	0.08777	0.0023	0.185
1,2,3,4,7,8,9-HpCDF	0.02675	0.0007	0.021
OCDF	0.11783	0.0003	0.011
Total PCDD/PCDF	**1.0**	**0.1 ng/m^3**	**3.95 ng/sec**

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

Table A8.42 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 x 10^{-4}	1.87 x 10^{-5}	0.763
1,2,3,7,8-PeCDD	1.74 x 10^{-5}	2.47 x 10^{-6}	0.961
1,2,3,4,7,8-HxCDD	3.96 x 10^{-6}	4.98 x 10^{-7}	0.992
1,2,3,6,7,8-HxCDD	3.96 x 10^{-6}	4.98 x 10^{-7}	0.992
1,2,3,7,8,9-HxCDD	3.96 x 10^{-6}	4.98 x 10^{-7}	0.992
1,2,3,4,6,7,8-HpCDD	1.02 x 10^{-6}	1.18 x 10^{-7}	0.998
OCDD	2.77 x 10^{-7}	2.91 x 10^{-8}	0.9995
2,3,7,8-TCDF	1.23 x 10^{-4}	2.01 x 10^{-5}	0.75
1,2,3,7,8-PeCDF	3.64 x 10^{-5}	5.46 x 10^{-6}	0.917
2,3,4,7,8-PeCDF	2.17 x 10^{-5}	3.11 x 10^{-6}	0.951
1,2,3,4,7,8-HxCDF	10.09 x 10^{-6}	1.09 x 10^{-6}	0.982
1,2,3,6,7,8-HxCDF	10.09 x 10^{-6}	1.09 x 10^{-6}	0.982
1,2,3,7,8,9-HxCDF	4.99 x 10^{-6}	6.49 x 10^{-7}	0.989
2,3,4,6,7,8-HxCDF	4.99 x 10^{-6}	6.49 x 10^{-7}	0.989
1,2,3,4,6,7,8-HpCDF	2.24 x 10^{-6}	2.77 x 10^{-7}	0.995
1,2,3,4,7,8,9-HpCDF	1.31 x 10^{-6}	1.56 x 10^{-7}	0.9974
OCDF	2.60 x 10^{-7}	2.71 x 10^{-8}	0.9995

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

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

Table A8.43 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 A8.44 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 A8.45 – A8.50 details 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 A8.45 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	1.29E-02	2.72E-03	7.28E-04	8.26E-06
1,2,3,7,8-PeCDD	0.039	1.18E-02	2.49E-03	6.67E-04	7.56E-06
1,2,3,4,7,8-HxCDD	0.008	8.40E-04	1.77E-04	4.74E-05	5.38E-07
1,2,3,6,7,8-HxCDD	0.008	1.03E-03	2.17E-04	5.79E-05	6.57E-07
1,2,3,7,8,9-HxCDD	0.008	1.92E-03	4.05E-04	1.08E-04	1.23E-06
1,2,3,4,6,7,8-HpCDD	0.002	2.22E-04	4.68E-05	1.25E-05	1.42E-07
OCDD	0.0005	9.37E-06	1.98E-06	5.28E-07	6.00E-09
2,3,7,8-TCDF	0.25	9.52E-03	2.01E-03	5.37E-04	6.09E-06
1,2,3,7,8-PeCDF	0.083	4.09E-03	8.63E-04	2.31E-04	2.62E-06
2,3,4,7,8-PeCDF	0.049	5.22E-02	1.10E-02	2.95E-03	3.34E-05
1,2,3,4,7,8-HxCDF	0.018	1.36E-02	2.87E-03	7.67E-04	8.70E-06
1,2,3,6,7,8-HxCDF	0.018	5.79E-03	1.22E-03	3.26E-04	3.70E-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	5.92E-03	1.25E-03	3.34E-04	3.79E-06
1,2,3,4,6,7,8-HpCDF	0.005	9.25E-04	1.95E-04	5.21E-05	5.92E-07
1,2,3,4,7,8,9-HpCDF	0.0026	5.55E-05	1.17E-05	3.13E-06	3.55E-08
OCDF	0.0005	5.66E-06	1.19E-06	3.19E-07	3.62E-09
Sum			**0.026 fg/m^3**	**0.007 ng/m^2**	**0.00008 ng/m^2**
Equivalent Daily Deposition Flux				**0.019 pg/m^2/day**	**0.0021 pg/m^2/day**

Table A8.46 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	4.16E-02	8.98E-03
1,2,3,7,8-PeCDD	0.961	2.91E-01	6.29E-02
1,2,3,4,7,8-HxCDD	0.992	1.04E-01	2.25E-02
1,2,3,6,7,8-HxCDD	0.992	1.27E-01	2.75E-02
1,2,3,7,8,9-HxCDD	0.992	2.38E-01	5.14E-02
1,2,3,4,6,7,8-HpCDD	0.998	1.11E-01	2.39E-02
OCDD	0.9995	1.87E-02	4.05E-03
2,3,7,8-TCDF	0.75	2.86E-02	6.17E-03
1,2,3,7,8-PeCDF	0.917	4.52E-02	9.76E-03
2,3,4,7,8-PeCDF	0.951	1.01E+00	2.19E-01
1,2,3,4,7,8-HxCDF	0.982	7.42E-01	1.60E-01
1,2,3,6,7,8-HxCDF	0.982	3.16E-01	6.82E-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	5.33E-01	1.15E-01
1,2,3,4,6,7,8-HpCDF	0.995	1.84E-01	3.97E-02
1,2,3,4,7,8,9-HpCDF	0.9974	2.13E-02	4.60E-03
OCDF	0.9995	1.13E-02	2.44E-03
Sum			**0.826 fg/m^3**

Table A8.47 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	4.16E-02	1.20E-03	1.93E-03	1.94E-03
1,2,3,7,8-PeCDD	2.91E-01	8.42E-03	1.35E-02	1.36E-02
1,2,3,4,7,8-HxCDD	1.04E-01	3.01E-03	4.84E-03	4.85E-03
1,2,3,6,7,8-HxCDD	1.27E-01	3.68E-03	5.92E-03	5.93E-03
1,2,3,7,8,9-HxCDD	2.38E-01	6.88E-03	1.11E-02	1.11E-02
1,2,3,4,6,7,8-HpCDD	1.11E-01	3.20E-03	5.14E-03	5.15E-03
OCDD	1.87E-02	5.41E-04	8.71E-04	8.73E-04
2,3,7,8-TCDF	2.86E-02	8.25E-04	1.33E-03	1.33E-03
1,2,3,7,8-PeCDF	4.52E-02	1.31E-03	2.10E-03	2.11E-03
2,3,4,7,8-PeCDF	1.01E+00	2.93E-02	4.71E-02	4.72E-02
1,2,3,4,7,8-HxCDF	7.42E-01	2.14E-02	3.45E-02	3.46E-02
1,2,3,6,7,8-HxCDF	3.16E-01	9.13E-03	1.47E-02	1.47E-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	5.33E-01	1.54E-02	2.48E-02	2.48E-02
1,2,3,4,6,7,8-HpCDF	1.84E-01	5.32E-03	8.55E-03	8.57E-03
1,2,3,4,7,8,9-HpCDF	2.13E-02	6.15E-04	9.90E-04	9.92E-04
OCDF	1.13E-02	3.27E-04	5.26E-04	5.27E-04
Sum		**0.111 ng/m^2**	**0.178 ng/m^2**	**0.178 ng/m^2**
Equivalent Daily Deposition Flux		**0.303 pg/m^2/day**	**0.487 pg/m^2/day**	**0.488 pg/m^2/day**

Table A8.48 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	14	Annual Average	0.85	14.9
PCCD/PCDFs / Abnormal Operation	14	Annual Average	0.98	15.0

(1) Baseline results for dioxins given as sum of cumulative impacts (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 A8.49 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	0.51	30.5
PCCD/PCDFs / Abnormal	Annual Average	30	0.58	30.6

Table A8.50 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 Impact 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 A8.51 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 A8.50). 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 10% of the existing background concentration under maximum and abnormal operating conditions.

Shown in Table A8.49 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 A8.51).

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 7 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 five sites in Ireland over the period 2009 - 2014(26). Shown in Table A8.52 are B[*a*]P concentrations at these sites. Annual average background concentrations of B[*a*]P in this network ranged from 0.10 - 0.71 ng/m^3 over the period 2009 - 2014. Shown in Table A8.53 are B[*a*]P deposition rates at two sites in Ireland. Annual average background deposition rates of B[*a*]P ranged from 1.2 – 6.9 ng/m^2/day over the period 2009 - 2014.

Table A8.52 Annual average B[a]P concentration at selected sites in Ireland In 2009 - 2014(26)

Year	**B[a]P Annual Mean Concentration (ng/m^3) in 2009 - 2014**				
	Rathmines	**Winetavern Street**	**Heatherton Park**	**Galway**	**Kilkitt**
	Zone A		Zone B	Zone C	Zone D
2009	0.4	0.3	0.5	0.5	0.1
2010	1.0	0.7	1.0	0.5	0.2
2011	0.25	0.44	0.97	0.14	0.14
2012	0.16	0.21	0.18	0.13	0.04
2013	0.17	0.15	0.46	0.19	0.07
2014	0.26	-	1.16	0.38	0.05
Average	0.37	0.36	0.71	0.31	0.10

Table A8.53 Annual average B[a]P deposition rate at selected sites in Ireland In 2011 - 2014(26)

Year	**B[a]P Annual Mean Deposition (ng/m^2/day) in 2011 - 2014**	
	Rosemount, UCD	**Shannon Estuary**
	Zone A	Zone D
2011	2.4	1.2
2012	1.7	1.9
2013	1.7	1.9
2014	6.9	6.0
Average	3.2	2.8

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 A8.54.

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 A8.44). 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 A8.56. 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 A8.44(10,11). For the deposition modelling of B[*a*]P both wet and dry particulate deposition were calculated. Results are shown in Table A8.57 for maximum operating conditions.

Table A8.54 Emission Scenario for B[*a*]P

Pollutant	Scenario	Emission Concentration	Emission Rate (mg/s)
B[*a*]P	Maximum Operation	1.0 μg/m^3	0.0395

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 A8.55.

Table A8.55 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 A8.56 – A8.58 details the predicted B[*a*]P GLC for the particulate concentration and deposition scenarios.

Table A8.56 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 - 40	8.5

Table A8.57 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	68	1.14
	Wet particulate		1.84
	Total particulate		1.84
Sum of Total Particulate Deposition			**1.8 μg/m^2**
			5.0 ng/m^2/day

Table A8.58 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	710	Annual mean	8.5	719	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 impact 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 0.9% 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 approached 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 A8.59.

Table A8.59 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 physiochemical 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 A8.60.

Table A8.60 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 A8.44). 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 A8.44(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 A8.61.

Table A8.61 Emission Scenario for Mercury

Pollutant	**Scenario**	**Emission Concentration**	**Emission Rate (g/s)**
Hg	Maximum	0.05 mg/m^3	0.00197
Hg	Abnormal(1)	1 mg/m^3	0.0395

(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 A8.62 - A8.65 for maximum operating conditions.

8.10.6 Modelling Results

Tables A8.62 – A8.65 detail the predicted mercury GLC for each vapour and particulate concentration and deposition scenario.

Table A8.62 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 - 0.00040	0.084
Divalent Hg^{2+}	0.60	Maximum - 0.0012	0.25
Sum			**0.34 ng/m^3**

Table A8.63 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 - 0.00040	0.085

Table A8.64 Mercury Deposition Fluxes – Maximum Operating Conditions

Oxidation State	**Fraction**	**Emission Rate (g/sec)**	**Annual Deposition Flux (µg/m^2/year)**
Elemental Hg	Dry Gas	0.00040	17
	Wet Gas		0.01
	Total Gas		17
Divalent Hg^{2+}	Dry Gas & Particle	0.0016	203
	Wet Gas & Particle		108
	Total Gas & Particle		216
Sum of Total Deposition			**233 µg/m^2/year**

Table A8.65 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	1	Annual mean	0.42	1.4	1000
Hg / Abnormal	1	Annual mean	0.74	1.7	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 impact 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 0.2% 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 A8.44). 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 Cadium 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 A8.66 and Table A8.67 respectively) and also under abnormal operations at the facility.

Table A8.66 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	0.0020
	Abnormal Operation(1)	0.2 mg/m^3	0.0079

(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 A8.67 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	0.020
	Abnormal Operation(1)	30 mg/m^3	1.18

(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 A8.68) indicating the emission levels of these metals based on typical and maximum recorded levels over the period 2013 - 2014. This source of data has been used to identify the likely ratio of metals when emitting under both maximum and abnormal operations (Table A8.69).

Table A8.68 Actual Measured Emission Data From An Incinerator Facility operated by Indaver In Duleek, County Meath Over The Period 2013 - 2014 (mg/Nm^3) (*Italics = below limit of detection).*

Parameter	**2013**				**2014**				**Average**	**Maximum**
	Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**2013-2014**	**2013-2015**
As	0.0019	0.0009	0.0013	0.0009	*0.0005*	0.0008	0.0005	0.0005	**0.0009**	**0.0019**
Co	0.0008	0.0004	0.0006	0.0005	*0.0005*	*0.0037*	*0.0005*	*0.0004*	**0.0009**	**0.0037**
Cr	0.0066	0.0009	0.0268	0.0307	0.0075	0.0040	0.0058	0.0098	**0.0115**	**0.0307**
Cu	0.0014	0.0007	0.0044	0.0023	0.0023	0.0039	0.1340	0.0193	**0.0210**	**0.1340**
Mn	0.0014	0.0007	0.0023	0.00627	0.0039	0.0007	0.0018	0.0005	**0.0022**	**0.0063**
Ni	0.0024	0.0012	0.0032	0.0203	0.0075	0.0036	0.0272	0.0172	**0.0103**	**0.0272**
Pb	0.0037	0.0012	0.0023	0.0084	0.0020	0.0026	0.0009	0.0016	**0.0028**	**0.0084**
Sb	0.0024	0.0012	0.0016	0.0006	0.0006	0.0025	*0.0006*	0.0005	**0.0013**	**0.0025**
V	0.0006	0.0003	0.0004	0.0004	0.0004	0.0004	0.0005	0.0003	**0.0004**	**0.0006**
Cd	0.0024	0.0012	0.0016	0.0008	0.0007	0.0007	0.0008	*0.0004*	**0.0011**	**0.0024**
Sum Cd+Tl	0.004	0.0018	0.002	0.001	0.0010	0.0010	0.0010	0.0008	**0.0016**	**0.0040**
Hg	0.0005	0.0002	0.0003	0.0003	*0.0004*	*0.0003*	0.0004	0.0004	**0.0004**	**0.0005**
Dioxins (ng/m^3)		0.0011	0.0097			0.0026		0.0004	**0.0035**	**0.0097**

Table A8.69 Ratio Of Metals Emitting Based On Actual Measured Emission Data From Indaver In Duleek, County Meath Over The Period 2013 - 2014 (mg/Nm^3)

Parameter	**Average(1)**	**Maximum(1)**	**Maximum Operation(2)**	**Abnormal Operation(2)**
	2013 - 2014 (mg/m^3)	**2013 - 2014 (mg/m^3)**	**0.50 mg/m^3**	**30 mg/m^3**
As	0.0009	0.0019	0.0044	0.26
Co	0.0009	0.0037	0.0086	0.52
Cr	0.0115	0.0307	0.0713	4.28
Cu	0.0210	0.1340	0.311	18.67
Mn	0.0022	0.0063	0.0146	0.87
Ni	0.0103	0.0272	0.0632	3.79
Pb	0.0028	0.0084	0.0195	1.17
Sb	0.0013	0.0025	0.0059	0.35
V	0.0004	0.0006	0.0014	0.08
Cd	0.0011	0.0024		
Sum Cd+Tl	0.0016	0.0040		
Hg	0.0004	0.0005		
Sum Sb/As/Pb/Cr/Co/Cu/Mn/Ni/V	0.11 mg/m^3	0.56 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, 2002)(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 A8.70 and A8.71.

A comparison of Tables A8.68 and A8.69 with Table A8.71 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 impact 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 A8.70 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 A8.71 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 A8.72 – A8.74 details the predicted Cd & Tl GLC and deposition value for each scenario and averaging period.

Table A8.72 Cd & Tl Particulate Concentrations Under Maximum And Abnormal Operation

Heavy Metal	Emission Rate (g/sec)	Ambient Concentration (ng/m^3)
Cd & Tl	Maximum Operation - 0.00197	0.42
	Abnormal Operation - 0.00789	0.47

(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 A8.73 Cadmium Deposition Fluxes – Maximum Operation

Heavy Metal	Fraction	Emission Rate (g/sec)	Annual Deposition Flux (mg/m^2)
Cd & Tl / Maximum Operation	Dry particulate	0.00197	0.33
	Wet particulate		0.58
Sum of Total Deposition			0.58 mg/m^2
			1.6 µg/m^2/day

Table A8.74 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	0.42	1	1.4	5.0
Cd / Abnormal	Annual mean	0.47	1	1.5	5.0

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

Tables A8.75 – A8.78 details 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 A8.69.

Table A8.75 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 - 0.000174		0.037
Nickel	Maximum - 0.00025		0.54
Vanadium	Maximum - 0.000055	0.48	
Arsenic(1)	Abnormal - 0.0104		0.129
Nickel(2)	Abnormal - 0.15		1.84
Vanadium(3)	Abnormal - 0.0033	19.9	

(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 A8.76 Arsenic Deposition Fluxes – Maximum & Abnormal Operating Conditions

Heavy Metal	Fraction	Emission Rate (g/sec)	Annual Deposition Flux (mg/m^2)
Arsenic / Maximum	Dry particulate	0.000174	0.029
	Wet particulate		0.051
Sum of Total Deposition			0.051 mg/m^2
			0.141 μg/m^2/day
Arsenic / Abnormal(1)	Dry particulate	0.0104	0.101
	Wet particulate		0.086
Sum of Total Deposition			0.108 mg/m^2
			0.296 μg/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 A8.77 Nickel Deposition Fluxes – Maximum & Abnormal Operating Conditions

Heavy Metal	Fraction	Emission Rate (g/sec)	Annual Deposition Flux (mg/m^2)
Nickel / Maximum	Dry particulate	0.0025	0.411
	Wet particulate		0.735
Sum of Total Deposition			0.735 mg/m^2
			2.02 μg/m^2/day
Nickel / Abnormal(1)	Dry particulate	0.15	1.44
	Wet particulate		1.23
Sum of Total Deposition			1.55 mg/m^2
			4.24 μg/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 A8.78 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	0.037	1.0(1)	1.04	**6.0(4)**
Nickel / Maximum	Annual mean	0.54	7.0(2)	7.54	**20(5)**
Vanadium / Maximum	Maximum One-Hour	0.48	4.0(3)	4.5	**1000(6)**
Arsenic / Abnormal	Annual mean	0.13	1.0(1)	1.1	**6.0(4)**
Nickel / Abnormal	Annual mean	1.8	7.0(2)	8.8	**20.0(5)**
Vanadium / Abnormal	Maximum One-Hour	19.9	4.0(3)	23.9	**1000(6)**

(1) Background concentration for arsenic based on on-site monitoring
(2) Background concentration for arsenic 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 A8.79 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 A8.79 Dispersion Model Results – Arsenic and Vanadium

Heavy Metal / Scenario	Emission Concentration (μg/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	0.00138	Annual mean	0.00029	**0.02**
Cr(VI) / Maximum	0.13	0.00513	Annual mean	0.0011	**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 typically 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 to 8.29. The content of the figure is 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 impact 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 38% 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 0.1% 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 44% 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 0.2% of the maximum 1-hour limit value at the worst-case receptor.

8.11.6 Summary Of Impacts

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 impact 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 17% 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 7.2.1) 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 100 km x 100 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 100km x 100km grid. As no upper air observations station 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 Eireann 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 100km x 100km 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 7.2.1) which has been developed by Earth Tech (now part of TRC Companies, Inc) 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 100 km by 100 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. The model receptor grid entailed a total of 49,980 receptor points at which ambient ground levels concentrations were determined for each pollutant (inner grid at 25 m resolution, middle at 100 m resolution and outer grid at 500 m grid resolution as shown in Figure 8.5).

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 8.80. 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 impact 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 99.8^{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 impact 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% - 50% 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 impact 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 14% 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 5% of the maximum ambient 1-hour limit value and 0.3% 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 impact 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 impact 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 impact 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 0.1% 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 impact 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 37% 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 0.5% of the maximum 1-hour limit value at the worst-case receptor.

Table A8.80 CALPUFF Modelling Results Under Maximum Operations ($\mu g/m^3$).

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
Annual Baseline & Site Traffic Concentration (Year 2020)	24	12	17	20.7	12.8	10	28.1	20	12	500	1	2.4	1.2
Process Emissions	113.0	0.8	1.1	41.4	4.6	0.3	0.5	0.05	0.05	35.0	0.053	111.8	0.053
Predicted Environmental Concentration (Year 2020)	83	12.6	17.8	52.2	15.4	10.3	28.2	20.1	12.1	535	1.04	114.2	1.25
Ambient Air Quality Standard	**200**	**40**	**30**	**350**	**125**	**20**	**50**	**40**	**25**	**10000**	**5.0**	**800**	**20**

Table A8.80(continued) CALPUFF Modelling Results Under Maximum Operations ($\mu g/m^3$).

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 2020)	0.100	0.05	14	0.620	0.001	1	1	7	0.0026
Process Emissions	7.45	0.0053	0.53	0.005	0.0003	0.27	0.02	0.34	0.003
Predicted Environmental Concentration (Year 2020)	7.55	0.055	14.5	0.625	0.001	1.27	1.02	7.34	0.005
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). COM (2013) 917 Final is the “*Proposal for a Council Decision for the acceptance of the Amendment to the 1999 Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution to Abate Acidification, Eutrophication and Ground-level Ozone*”(32).

European Commission Directive 2001/81/EC(33), 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(34). The most recent data available from the EU in 2010 indicated that Ireland complied with the emissions ceilings for SO_2, VOCs and NH_3 but failed to comply with the ceiling for NO_X(35). COM (2013) 920 Final is the *“Proposal for a Directive on the reduction of national emissions of certain atmospheric pollutants and amending Directive 2003/35/EC’*(36)*.* The proposal 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 (83% below 2005 levels), for NO_X (75% reduction), for VOCs (32% reduction), for NH_3 (7% reduction), for $PM_{2.5}$ (35% reduction) and for CH_4 (7% reduction).

The impact of the facility on emissions of SO_2, NO_X and VOCs has been assessed. Results, outlined in Table A8.81, indicate that the impact of the Facility on Ireland's obligations under the Gothenburg Protocol is slight. The overall impact of the development is to increase SO_2 levels by 0.25% of the ceiling levels to be complied with in 2020, NO_X levels by 0.38% of the ceiling levels, VOC levels will be increased by 0.03% of the ceiling limits whilst $PM_{2.5}$ levels will be increased by 0.14% of the ceiling limits.

Table A8.81 Impact 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)**
2020	**Facility In Operation (8760 Hours)**	62	12	249	12
Emission Ceiling (kilo-tonnes) In 2020		24.9(1)	42.8(1)	64.8(1)	9.0(1)
Impact of Facility (%) (National)		**0.25%**	**0.03%**	**0.38%**	**0.14%**

(1) Proposal for a Council Decision for the acceptance of the Amendment to the 1999 Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution to Abate Acidification, Eutrophication and Ground-level Ozone. (COM2013) 917 Final

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 impact 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 17% 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 impact of the facility will not be significant.

8.15 References

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