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Company Name:	Oxigen Environmental Ltd. (Ireland)
Waste Licence No.:	W0144-01
EPA Compliance Investigation Reference	CI 373
EPA Action Reference:	A014757

RE: Request for Technical Amendment to Update Waste Licence (W0144-01), Oxigen Environmental Ltd., Coes Road, Dundalk Co Louth

Dear Sir / Madam,

Oxigen Environmental Ltd. (henceforth Oxigen) hereby applies for a Technical Amendment to Waste Licence W0144-01, in order to enable the early installation and operation of a proposed odour abatement system at the Oxigen site at Coes Road, Dundalk, Co Louth (the "Site").

On the basis of the discussions with the Agency to date, Oxigen requests a Technical Amendment to its Waste Licence to reflect the following primary changes to the Site:

- Amend Schedule C (Emission Limits) and Schedule D (Monitoring) of the Waste Licence to include the proposed emission point A1-1 from installation of an Odour Abatement System and associated stack. The proposed odour abatement system will treat odourous air from the Municipal Waste Processing Building (MWPB) and discharge the treated air through a new suitably sized stack (A1-1);

- Oxigen propose to trial a pilot plant bio-scrubber odour abatement system at their facility in Coes Road in order to optimise the scrubber settings. Oxigen require Agency approval to commission the trial system in advance of the emission point being formally approved through the licence review process;

- Oxigen are also considering a carbon-based odour abatement system as proposed by the EPA during a meeting held with Oxigen on 21st December 2016. Both the bio-scrubber and carbon-based odour abatement system options are assessed within this Technical Amendment application.

The following sections present the background and context for this submission and the rationale for the proposed changes. This submission has been prepared by AWN Consulting on behalf of Oxigen Environmental Ltd.

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1.0 BACKGROUND & CONTEXT

1.1 Background

The Oxigen Environmental waste transfer station and recycling facility at Coes Road, Dundalk, Co. Louth has a waste licence issued by the EPA (Licence Number WW0144-01). The waste licence was originally granted to Sean Rooney Limited t/a Bambi Bins & Wheel Bin Services Limited on 06/02/2002 and was subsequently transferred to Oxigen Environmental Limited on 02/02/2010.

The waste licence allows for processing of up to 35,000 tonnes of household (black bin) waste, 5,000 tonnes of commercial waste, 30,000 tonnes of industrial non-hazardous solids and 20,000 tonnes of construction and demolition waste at this facility annually, giving a total waste acceptance maximum of 90,000 tonnes.

The Site consists of two buildings: the Municipal Waste Processing Building (MWPB) where putrescible waste and mixed dry recyclables are handled, and the Commercial Waste Processing Building (CWPB) where Construction & Demolition (C&D) waste is handled.

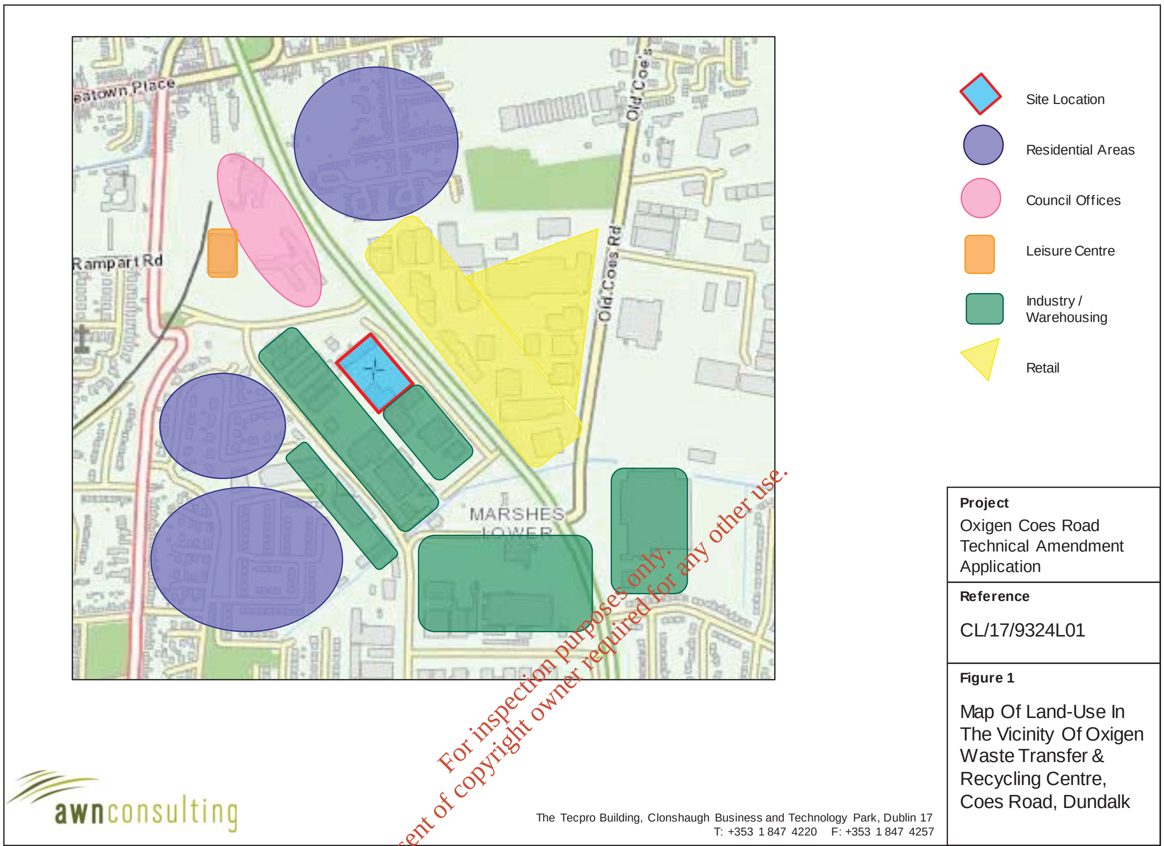
In order to prevent odour nuisance from the Site, Oxigen has committed to install appropriate odour abatement infrastructure at the MWPB to contain and treat any odorous emissions arising from the licensed waste activities.

Planning permission was granted on 20/06/2016 for the proposed installation of a negative air abstraction system, odour treatment system, and 20 meter high stack by Louth County Council (see Appendix A).

In addition to planning permission, installation of the odour abatement system requires an amendment to the existing waste licence by the EPA. This application for a Technical Amendment to waste licence WW0144-01 is being submitted based on discussions between Oxigen and the EPA during a meeting held on 21st December 2016. Oxigen are also in the process of preparing an EPA Licence Review Application to address a number of other matters. This is currently tentatively scheduled for end of Q2 2017.

1.2 Site Location

The Site is located in a zoned industrial area on the eastern outskirts of Dundalk town. The nearest residential receptors are located 100m south-west of the site boundary with additional residential receptors located 160m north of the site boundary. Other nearby buildings include a retail building, a leisure facility and council offices as shown in Figure 1.



1.3 Process Description

Waste handling activities at the Site consist of accepting and bulk loading of commercial, industrial and municipal waste for transfer to other recycling depots or other disposal outlets. In addition, where possible, recyclable waste (cardboard, glass, metal, timber, plastic) is recovered from the waste streams and sent for further recycling. Oxigen achieved a 95% recovery rate for waste processed at the Site in 2015 (from Oxigen's *Annual Environmental Report 2015* for Coes Road).

Currently, all waste tipping and processing of household and commercial waste and storing of segregated recyclables is carried out inside the MWPB. The municipal (black bin) waste is currently processed in a 40ft compactor and is subsequently sent for recovery or to a licensed landfill for disposal where appropriate. Brown bin (kitchen and garden) waste is tipped onto the MWPB floor and after inspection for contamination is bulked up into 40ft trailers for transfer off-site to a composting facility.

The MWPB was upgraded in 2015 by constructing a lean two extension to the building. The extension creates an additional space in front of doors 7 and 8 thereby allowing for the doors to remain fully closed while waste processing is ongoing within the building.

Other recent odour control works completed with the agreement of the EPA and

Louth County Council were:

- The replacement of some of the unused roller shutter doors to the MWPB with solid concrete walls and metal cladding;
- The fitting of new steel roller shutter doors;
- Brush seals fitted to all roller shutter doors to the MWPB to contain any possible emissions;
- The blocking up of all openings and further sealing works to the MWPB followed by smoke test to ensure the integrity of the building envelope is of a satisfactory standard.

An odour misting system had been place at the facility to reduce odour and dust emissions. The system was upgraded in 2011 to include a new pumping system and stainless piping and nozzles along both sides of the MWPB. Since the upgrade works to the shed structure and sealing of all possible leaks, a mobile odour misting system operates outside the doors of the MWPB to reduce any possible odour and dust emissions escaping from door areas when opened to access the building.

Despite the recent upgrades to the facility there is the potential for odorous releases during unloading and storage of both municipal and food waste particularly when the waste has started the process of putrefaction which is enhanced in summer months. As the building is not currently under negative pressure, odour releases can occur when the doors are opened to allow trucks to off-load waste within the building.

2.0 DESCRIPTION OF PROPOSED ODOUR ABATEMENT SYSTEM OPTIONS

AWN Consulting Ltd (AWN) was commissioned to consider suitable odour abatement options in order to identify the most efficient means of ensuring that no odour nuisance will occur at nearby receptors (both residential and commercial premises).

Previous odour dispersion modelling undertaken in December 2013 and updated in March 2016 proposed installation of a bio-scrubber odour abatement system with a minimum 50% removal rate and emission of the treated air via a 20 metre stack to ensure appropriate dispersion and prevent odour nuisance at nearby receptors.

Additional odour dispersion modelling has been undertaken as part of this Technical Amendment application (see Section 3.0 below and Appendix B) in response to requests made by the EPA during the meeting held on 21st December 2016. The additional modelling work comprises:

1. Modelling and comparison of two types of abatement systems – a bio-scrubber and a carbon-based scrubber system with updated model input data;
2. Re-confirm optimum stack height for each abatement option.

In addition to air dispersion modelling of the proposed abatement system options, the EPA has also requested further information on the proposed abatement system options and the removal efficiency that each option can achieve.

2.1 Technical Information on Proposed Carbon-based Odour Abatement System

Activated Carbon systems operate on the principle of adsorption (as opposed to absorption). During adsorption, gaseous components are removed from the gas stream, by adhering to the surface of a solid particle. These systems are provided as engineered solutions by using packed beds or towers of adsorbents such as activated carbon.

Simdean Group Limited (henceforth Simdean) have provided technical information on a proposed carbon-based odour abatement system for the waste transfer facility at Coes Road. The full proposal document from Simdean can be found in Appendix C. The key information relating to this Technical Amendment application has been summarised below.

The proposed odour abatement system would extract 26,000 m^3/hr based on an assumption of 4 air changes per hour (ACH) within the MWPB. The carbon-based abatement system will achieve odour control in 4 stages:

1. Extraction

The inlet ductwork to be located and installed within the waste transfer station will be added to enable a total of 26,000 m^3/hr to be extracted from the MWPB building.

2. Removal of Particulates within the Exhaust Airstream

A reverse jet cartridge filter will be installed to ensure that the particulates are removed from the exhaust air stream. Providing the pulse jet filter is operated in accordance with the operating and maintenance instructions the unit will remove at least 99% of the dust burden below 1 micron and less and 99.9% of the dust burden when the average size of the particles is 10 microns or above entering the unit.

3. Removal of Odour with Carbon Adsorbers

The crux of the system in terms of odour control will be the carbon adsorber. Simdean have included for installing a single unit which will be capable of treating up to 26,000 m^3/hr of air from the building.

Based on the average inlet odour concentration of 3,000 OuE/m^3, with the odour comprised of basic components i.e. Ammonia and amines, and acidic components i.e. H_2S, mercaptans, sulphides and disulphides, Simdean have designed the system to provide an overall efficiency of removal of acidic and basic components of better than 90%. The total retention time within the adsorber is approximately 2 seconds.

Details of the type of activated carbon to be used within the adsorber is given below:

- General Purpose Carbon
- Base Carbon type Coal
- CTC (CCl4 Activity) 60 % w/w min
- Pellet diameter 4 mm +/- 20%
- Bulk Density 0.47 kg/l
- Ignition Temp 400 degC
- Ash 8 %
- Surface Area 950 m^2/g

Simdean estimate that the carbon is capable operating for approximately one year before replacement adsorbent beds are required. This assumption is based on an average flow rate and loading rate.

4. Dispersion of Exhaust Air

The adsorber will be provided with an exhaust stack which will discharge at a height to provide adequate dispersion of the discharged air.

A schematic for the proposed carbon-based odour abatement system is shown in Figure 2. Further information can be found in the Simdean proposal document in Appendix C.

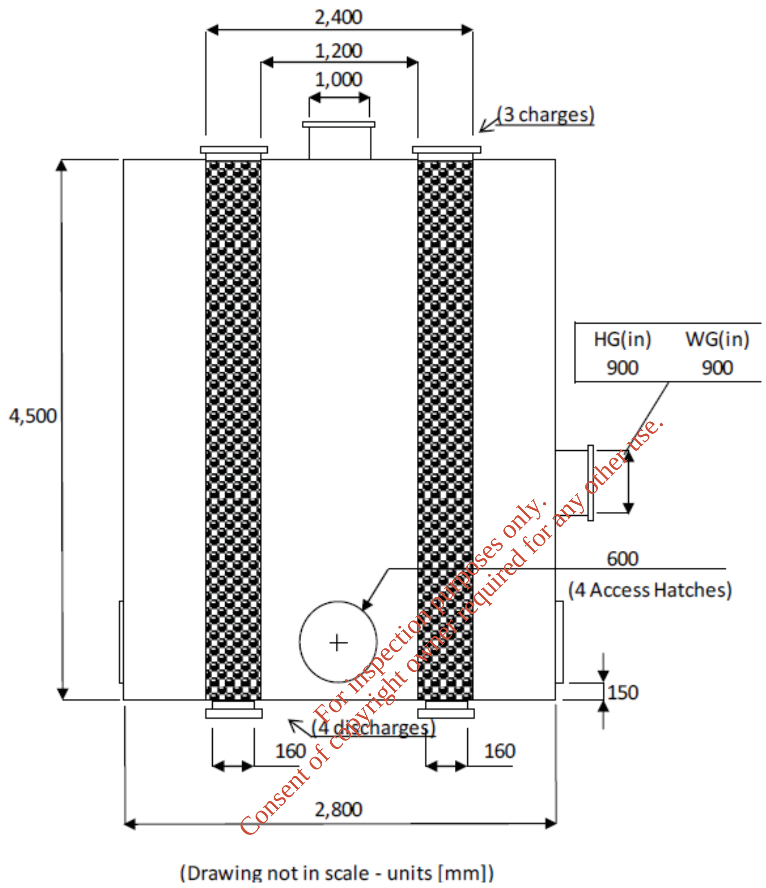


Figure 2 Schematic Layout of the Carbon Adsorber for Full Site (left) or Half Site (right) Extraction

2.1.1 *Achievable Emission Removal Efficiency*

Based on the design parameters for the carbon adsorber abatement system options proposed by Simdean, a removal efficiency of 90% or greater can be anticipated and has been assumed for odour dispersion modelling. Simdean have designed the overall adsorber system to produce odour concentrations of less than 300 OuE/m^3 at the exit of the proposed stack.

2.2 Technical Information on Proposed Bio-scrubber Odour Abatement System

In wet scrubbing processes, liquid or solid particles are removed from a gas stream by transferring them to a liquid. The liquid most commonly used is water. A wet scrubber's particulate collection efficiency is directly related to the amount of energy expended in contacting the gas stream with the scrubber liquid. Most wet scrubbing systems operate with particulate collection efficiencies over 95 percent.

MEHS have provided technical information on a proposed bio-scrubber odour abatement system for the waste transfer facility at Coes Road. The standard specification issued by Oxigen to MEHS for the bio-scrubber system can be found in Appendix D along with the Proposal document and Design Report provided by MEHS. The key information relating to this Technical Amendment application has been summarised below.

The bio-scrubber proposed by MEHS would extract 20,000 m^3/hr from the black bin shed (reducing to 5,000 m^3/hr at night time when there is no movement of waste) based on an assumption of 3 air changes per hour (ACH) within the MWPB. The bio-scrubber abatement system proposed by MEHS will achieve odour control in 3 stages:

1. Extraction

The inlet ductwork to be located and installed within the waste transfer station will be added to enable a total of 20,000 m^3/hr to be extracted.

2. Removal of Particulates and Odour by Bio-scrubber

Bio-scrubbers typically consist of two reactors, an absorption tower, where the pollutants are absorbed in a liquid phase, and a second reactor which is a type of activated sludge unit where pollutants are degraded by microorganisms growing in suspended flocs within the water to produce energy and metabolic by-products in the form of CO_2 and H_2O. The effluent from the activated sludge unit is recirculated over the absorption tower in a co- or counter current direction to the flow of the waste gas.

This degradation process by the microorganisms occurs by oxidation, and can be written as follows:

Organic Pollutant + O_2 $\rightarrow$ CO_2 + H_2O + Heat + Biomass

The proposed bio-scrubber system from MEHS will be a bio-packed column which is used for continuous contact between the liquid and the gas. The system will be located externally adjacent to the MWPB and is likely to occupy a foot-print of some 5m x 10m.

The aeration tank will be contained within the bio-scrubber unit. A schematic of a typical bio-scrubber system (with separate aeration tank) is shown in Figure 3.

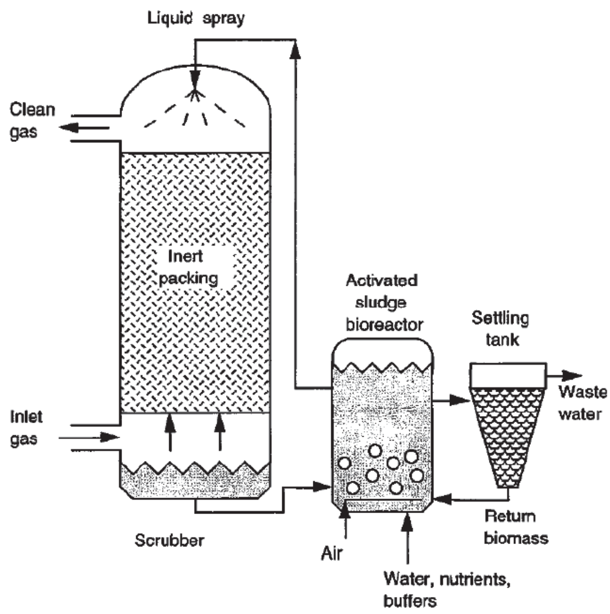


Figure 3 Schematic Layout of a Typical Bio-scrubber System (with a separate aeration tank)

Based on an average inlet odour concentration of 3,000 OuE/m^3, with the odour comprised of basic components i.e. Ammonia and amines, and acidic components i.e. H_2S, mercaptans, sulphides and disulphides, MEHS have designed the system to reduce the odour from the waste gas by 60 – 90%.

MEHS have provided typical design criteria for the proposed bio-scrubber as outlined below including the achievable removal efficiencies for each type of pollutant:

- Flow rate: 5,000 to 35,000 m^3/hr (air flow rate dependent on loading rate);
- Loadings: 40 – 120 m^3/m^2 (dependent on contaminant concentrations);
- Residence or Contact time: 4 - 10 seconds;
- Amines removal efficiency: 85 – 90%;
- Ammonia removal efficiency: 85 – 90%;
- H_2S removal efficiency: 85 – 90%;
- VOC removal efficiency: 60 – 80%.

MEHS estimate that the bio-scrubber media is capable of operating for approximately thirty years before replacement is required. This assumption is based on an average flow rate and loading rate and assumes the system is consistently maintained in line with the maintenance procedures provided (see Section 2.5 and Appendices D and F).

3. <u>Dispersion of Exhaust Air</u>

The bio-scrubber will be connected to an exhaust stack which will discharge at a height of 20m to provide adequate dispersion of the discharged air.

Further information on the proposed bio-scrubber can be found in the MEHS documents in Appendix D.

2.2.1 *Achievable Emission Removal Efficiency*

Based on the design parameters for the bio-scrubber abatement system options proposed by MEHS, a minimal removal efficiency of 50% or greater can be anticipated and has been assumed for odour dispersion modelling. Odour concentrations at the exit of the proposed stack are therefore conservatively estimated to be less than 1,500 OuE/m^3.

2.3 Amendments to Building

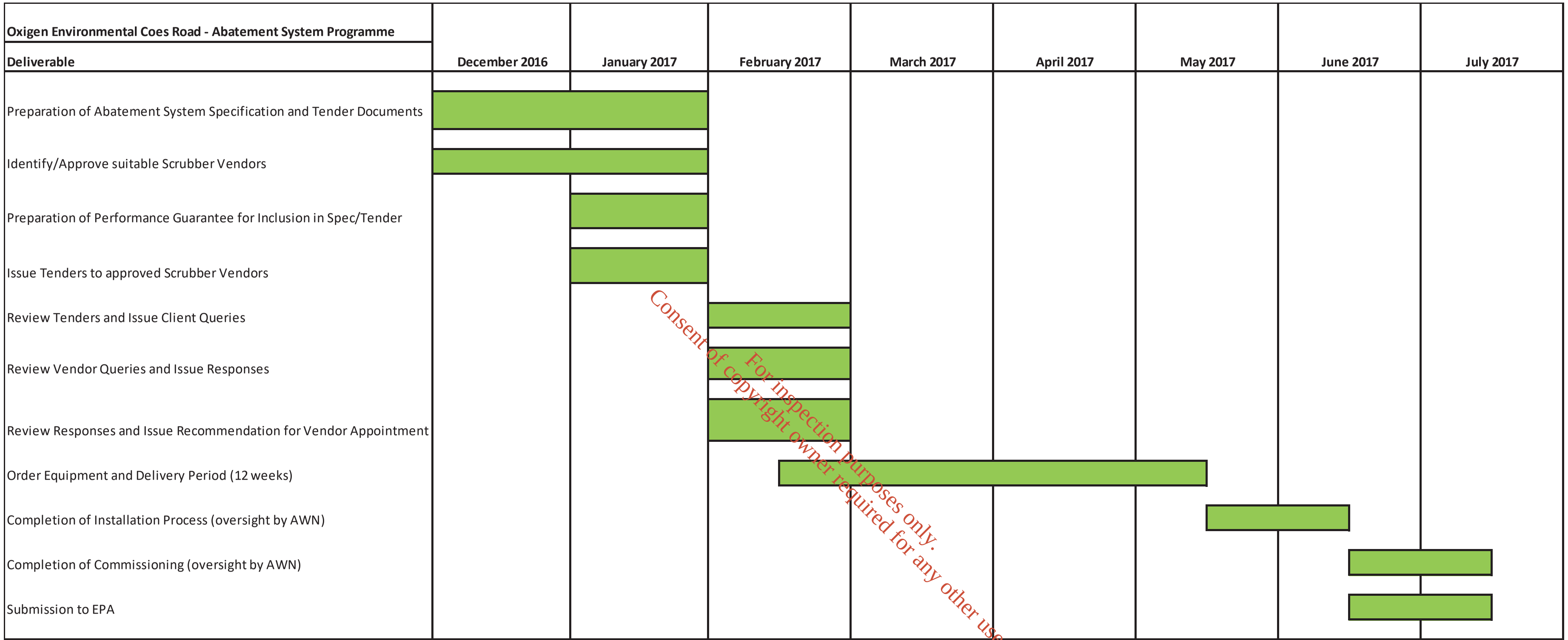
It is likely that odour emissions mainly occur from the MWPB (municipal waste processing building) with a minor contribution from the C & D waste building due to potential contamination of the waste with MSW. It is likely that other minor sources of odour will occur on-site such as transport vehicles and skips, however the major source remains the MWPB.

In order to facilitate the installation of an odour abatement system, the MWPB will be fully sealed and will be operated under sufficient negative pressure to ensure that fugitive odour release will be minimal. An extract system will be installed in the building, directing extracted air to the abatement system, thereby maximising odour capture.

2.4 Timeline for Odour Abatement System Installation

The proposed timeline for procurement, installation and commissioning of the proposed abatement system is outlined in Table 1.

Table 1 Estimated Timeline for Procurement, Installation and Commissioning of the Proposed Abatement System at Oxigen Coes Road [Note 1]



Note 1 – Oxigen will work with suppliers to further expedite this timeline in order to ensure the odour abatement system is installed and commissioned at the earliest feasible date

2.5 Management & Maintenance of Odour Abatement System

2.5.1 *Carbon-based Odour Abatement System*

Simdean have provided a document on the typical maintenance and training procedures required to ensure the proposed carbon-based odour abatement system runs efficiently. The maintenance document is attached as Appendix E and a summary of the key points is provided below:

Installation & Commissioning

Simdean will ensure that all necessary pre-installation tests and procedures are carried out as follows:

- Visual inspection;
- Sign off to QA plan;

Simdean Envirotec will ensure that all necessary documentation is signed by Oxigen prior to take over. This documentation is as follows:

- Completion certificate;
- Performance test certificate;

Simdean Envirotec will ensure that all necessary activities have been completed before Oxigen takeover of the system. These activities are as follows:

- Commissioning;
- Client training;
- Issuance of takeover certificate.

Regular Maintenance & Management

The following checks will be conducted on a daily basis:

1. Perform a daily "sniff check" of the odour present at the exhaust stack of the unit. This can be achieved using the "sniff tubes" fitted to both the carbon adsorber unit and the exhaust stack. There should be a notable reduction in odour detected at the exhaust stack compared to the adsorber unit if the system is running correctly;
2. Perform a minimum of a daily check of the SCADA screens to ensure that the system is operating correctly. Any alarms or failures on the system can be provided as email alerts to the relevant factory personnel. This feature will be set up during commissioning of the abatement system;
3. Complete entries to an Odour Log on a daily basis noting whether there are any odours present at the boundary of the facility;

The carbon-based odour control system is virtually maintenance free. To keep it running efficiently, the other proprietary items of equipment will be regularly inspected and serviced in line with the procedures outlined in the Simdean maintenance document (see Appendix E) as well as following guidance provided in detailed maintenance and operation manuals which will be furnished to Oxigen by Simdean upon proceeding with installation of the system.

The carbon adsorber unit is fitted with a temperature sensor, a resistance thermometer, a pressure monitor and odour sensing pipework. These systems automatically regulate the abatement system and should be checked regularly to ensure the system is functioning correctly.

Regular inspection and servicing will be required for the following system components:

- System exhaust fan;
- Dust collector;
- Air compressor.

A proposed maintenance schedule has been provided by Simdean for the carbon-based abatement system and can be found in table format at the end of Appendix E.

Changeout of Scrubber Media

It is estimated that the adsorber could operate for approximately one year continuously before replacement adsorbent beds are required. This assumption is based on an average flow rate and loading rate.

A permanent steelwork structure will be installed below the adsorber housing to allow ease of maintenance and replacement of the carbon within the adsorber.

The procedures involved in changing out the carbon from the adsorber are provided in Appendix E.

Training

Simdean will provide one session of training to nominated Oxigen staff during the commissioning of the abatement system. Training will ensure that Oxigen staff understand the requirements for optimal operation and maintenance of the system.

2.5.2 *Bio-scrubber Abatement System*

Installation & Commissioning

As part of the commissioning and validation, the following monitoring will be undertaken:

- Air Monitoring (Gastec tubes)
- Scrubber water sampling and analysis
- Differential Pressure checks
- Air flow monitoring
- pH monitoring
- Alkalinity testing

In order to ensure a smooth commissioning and handover period, MEHS have included for 2-months of the above monitoring within their proposal. Trained Oxigen staff will then take over the monitoring to ensure continued maintenance of the bio-scrubber system.

The appropriate nutrients essential to the various bacteria in the bio-scrubber will be identified prior to commissioning by sampling and running lab scale tests on samples of the waste leachate. A dosing pump would be installed to allow dosing of nutrients and bacteria selected for particulate odorous compounds.

Regular Maintenance & Management

The proposed bacterial mix is part of a product called MEHS-Treat OC, MEHS-Treat AB and MEHS-Treat NR. The Bio-scrubber maintenance from a chemical and bacteriological view point has developed to the point that the composition is managed by adding various bacterial, feed and nutrient products to the scrubber on a weekly and as required basis. The addition of the products is based on chemical and bacterial results and observations from routine checks.

The chemical and micro-biological parameters of the recirculation water in the bio-scrubber will be monitored on a regular basis for the following parameters

- Total Bacterial Count
- Total Nitrogen
- Ammonia
- BOD / COD
- Suspended Solids
- Volatile Organic Matter (measure of bacterial mass)
- Alkalinity

Adequate access has been engineered into the Bio-scrubber unit to create a minimum of work when cleaning or servicing is required. The recommended frequency for routine maintenance of the bio-scrubber components is provided as a Table in Appendix F. Visual inspections will be regularly conducted and recorded to ensure bio-scrubber system is functioning optimally.

Abatement efficiency will be regularly monitored (on a daily basis as a minimum) by checking the inlet and outlet gas streams. A semi-quantitative analysis such as sniff testing can be performed on grab samples of gas taken at sampling points which will be installed on the inlet and outlet. An annual odour audit will be conducted each year to establish the effectiveness of the odour control system and determine any remedial actions required.

A comprehensive record keeping system will be established addressing the operation, maintenance, and performance of the bio-scrubber. The records will allow Oxigen to ascertain the effectiveness of their scrubber maintenance and management programme and determine the extent of deterioration of system components. This will allow early detection of potential issues and help prevent equipment failures. Suggested operational data to be recorded on a daily, weekly and annual basis are listed in Tables 4-1 to 4-4 of the MEHS Design Report in Appendix D. Section 5.0 of the MEHS Design Report in Appendix D also outlines the standard operating and maintenance procedures required for the bio-scrubber system in detail.

<u>Changeout of Scrubber Media</u>

MEHS estimate that the bio-scrubber media is capable of operating for approximately thirty years before replacement is required. This assumption is based on an average flow rate and loading rate and assumes the system is consistently maintained in line with the maintenance procedures outlined.

<u>Training</u>

MEHS will provide training to nominated Oxigen staff during the commissioning of the abatement system. Training will ensure that Oxigen staff understand the requirements for optimal operation and maintenance of the system.

3.0 ODOUR MODELLING STUDY

Odour dispersion modelling was conducted by AWN to determine the impact from the site to off-site receptors with each odour abatement system in place. Modelling was conducted for both the bio-scrubber system and the carbon-based scrubber system. The odour dispersion modelling report can be found in Appendix B and a brief summary of the results is provided below.

Both abatement system options were assessed to determine the optimum stack height required and the residual odour impact at off-site receptors.

3.1 Odour Modelling Results

The dispersion modelling results show that the 98^{th}%ile of mean hourly odour concentrations are in compliance with the UK guideline level at all off-site receptors modelled. Results at the worst-case boundary receptors were 68% of the UK guideline odour limit value for the carbon-based scrubber scenario and 91% for the bio-scrubber scenario.

The predicted odour concentrations at the air sensitive receptors (ASRs) are well below the concentrations at the site boundary. The 98^{th}%ile of mean hourly odour concentrations complies with the UK guideline level for all abatement scenarios modelled. The worst-case odour concentration at an ASR for the bio-scrubber scenario was 17% of the UK guideline level. The worst-case odour concentration at an ASR for the carbon-scrubber scenario was 9% of the UK guideline level.

The dispersion modelling results were also compared with the more stringent New Zealand guideline level of 1.0 OU_E/m^3 for the 99.5^{th}%ile of hourly mean concentrations. The results show that the 99.5^{th}%ile of mean hourly odour concentrations exceeds the New Zealand guideline level at the worst-case boundary receptors for both abatement scenarios modelled. However, the predicted 99.5^{th}%ile of hourly odour concentrations at the ASRs are well below the site boundary concentrations. The 99.5^{th}%ile of mean hourly odour concentrations at the worst-case ASRs is 49% of the New Zealand guideline value for the bio-scrubber and 30% for the carbon-based scrubber scenario.

The modelling results demonstrate that the odour impact off-site decreases rapidly with distance from the proposed stack and that odour nuisance at the ASRs will likely be insignificant for both abatement options modelled. The bio-scrubber system requires a 20m stack to achieve adequate dispersion of odour while the carbon-based scrubber system requires a 12m stack.

In summary, both abatement system options will achieve compliance with the UK odour nuisance criterion (expressed as the 98^{th}%ile of hourly mean concentrations) for all off-site receptors. The more stringent New Zealand odour nuisance criterion (expressed as the 99.5^{th}%ile of hourly mean concentrations) was exceeded at the boundary receptors for both scenarios modelled but results for the closest ASRs (residential receptors) were well below the New Zealand guideline value.

4.0 PROPOSED AIR & ODOUR MONITORING

4.1 Proposed ELVs for Bio-scrubber

Table 2 outlines the details of the proposed bio-scrubber emission point A1-1 and Table 3 provides the requested emission limit values (ELVs) for the proposed stack. The resulting worst case ambient ground level odour concentration predicted to occur beyond the site boundary is also provided in Table 5. Results of the dispersion modelling demonstrate that ambient odour concentrations are predicted to be within guideline values for the proposed odour ELV.

Table 2 : Details of Proposed Bioscrubber Emission Point A1-1

Emission Point Reference:	A1-1 (Bio-scrubber)
Location (Irish Grid):	306003.57 E, 307035.41 N (Approximate Location)
Minimum Discharge Height:	20m
Volume to be Emitted:	20,000m^3/hr (based on 3 ACH and Half-site Extraction) Note – Volume flow to reduce to 5,000 m^3/hr between 10pm and 5am Monday to Saturday and 24 hours

Table 3 : Requested ELVs for Pollutants and Resulting Highest Predicted Ambient GLC

Stack reference	**Pollutant Emitted**	**Requested Emission Limit Value (ELV) (g/hr)**	**Highest predicted ground level concentration (GLC) beyond the site boundary as a % of relevant ambient air quality standard / guideline** Note 1
			98th%ile of 1-Hour Mean Values
A1-1 Odour Abatement System (Bio-scrubber)	Ammonia	50 ppm	NA
	Amines	5 ppm	NA
	Hydrogen Sulphide & Mercaptans	5 ppm	NA
	Condensable VOCs	5 mg/m^3	NA
	Total VOCs (as C)	10 mg/m^3	NA
	Odour	1,500 OU$_E$/m^3	91%

Note 1 Scenario modelled assumed reduced odour emissions between 10pm and 5am on Monday to Saturday and all day on Sundays when the volume flow of the bio-scrubber would be reduced as the facility is closed.

4.2 Proposed ELVs for Carbon-based Scrubber

Table 4 outlines the details of the proposed carbon-based scrubber emission point A1-1 and Table 5 provides the requested emission limit values (ELVs) for the proposed stack. The resulting worst case ambient ground level odour concentration predicted to occur beyond the site boundary is also provided in Table 5. Results of the dispersion modelling demonstrate that ambient odour concentrations are predicted to be within guideline values for the proposed odour ELV.

Table 4: Details of Proposed Carbon-based Scrubber Emission Point A1-1

Emission Point Reference:	A1-1 (Carbon-based Scrubber)
Location (Irish Grid)	306003.57 E, 307035.41 N (Approximate Location)
Minimum Discharge Height:	12m
Volume to be Emitted:	26,000 m^3/hr (based on 4 ACH and Half-site extraction)

Table 5: Requested ELVs for Pollutants and Resulting Highest Predicted Ambient GLC

Stack reference	Pollutant Emitted	Requested Emission Limit Value (ELV) (g/hr)	Highest predicted ground level concentration (GLC) beyond the site boundary as a % of relevant ambient air quality standard / guideline
			98th%ile of 1-Hour Mean Values
A1-1 Odour Abatement System (Carbon-based Scrubber)	Ammonia	50 ppm	NA
	Amines	5 ppm	NA
	Hydrogen Sulphide & Mercaptans	5 ppm	NA
	Condensable VOCs	5 mg/m^3	NA
	Total VOCs (as C)	10 mg/m^3	NA
	Odour	1,500 OU_E/m^3	68%

4.3 Control of Emissions

The odour abatement system will be periodically monitored to ensure that the removal efficiency is maintained and these reports will be available for inspection. Oxigen is committed to reducing the environmental impact from the facility in Coes Road and this is demonstrated through continual improvements in the operation of the facility in relation to odour abatement.

4.3.1 *Bio-scrubber Abatement System*

Details of the control parameters and recommend monitoring to be conducted for the bio-scrubber system are outlined in Table 6.

Table 6 : Control of Emissions to Air for Emission Point A1-1 (Bio-scrubber) [Note 1]

Control parameter	**Monitoring to be carried out**	**Frequency**
Inlet Gas	Inlet Gas Temperature	Daily
Outlet Gas	Outlet Gas Temperature	
Total Static Pressure	Total Static Pressure Drop	
Scrubber Pressure	Scrubber Pressure Drop	
Mist Eliminator	Static Pressure at Mist Eliminator	
Scrubber Liquor	Liquor Recirculation Rate m3/hr	
	Liquor pH	
	Makeup Rate (litres/hr)	
	Nozzle Pressure Purge Rate (Pa)	
	Liquor Alkalinity (mg/l CaCO3)	
	Nutrient Addition mls/day	
	MEHS NR Addition Rate (mls/day)	
	MEHS AB Addition Rate (mls/day)	
	Bicarbonate Addition Rate (mls/day)	
	Liquor Temperature (OC)	
	Scrubbing Solution (Total Bacterial Count)	
	Liquor Dissolved Oxygen	
	Liquor Ammonia	
Inlet Gas	Inlet Amines & Ammonia	
	Inlet Mercaptans & H2S	
Outlet Gas	Outlet Amines & Ammonia	
	Outlet Mercaptans & H2S	
Fan	Vibration on Fan	Weekly
	Fan Motor Bearings Lubrication	
	Fan Pump bearing	
	VSD check	
Pump	Pump motor bearing	
	Lubrication of pump	
	VSD check	
Liquor Heater	Liquor heater check	
Aeration System	Aeration system Check	
Blower	Blower check	
Dosing Pumps	Dosing Pumps Check	
Ph Probe	pH Probe Check	
Ductwork	Duct Leakage·	Annually
	Duct Excessive Flexing	
Dampers	Dampers Operation	
	Dampers Alignment	
Nozzles	Nozzle Plugging	
	Nozzle Wear	
Pipes	Plugging of Pipes	
	Leaking of Pipes	
	Check Pressure Gauge Operation	
Main Body of Scrubber	Material Feed Build-up	
	Abrasion / Corrosion	
Flow Meter	Accuracy	

[Note1] – Equipment required for monitoring to be finaised with supplier before Licence Review Application

4.3.2 *Carbon-based Scrubber Abatement System*

Details of the control parameters and recommend monitoring to be conducted for the carbon-based scrubber system are outlined in Table 7.

Table 7: Control of Emissions to Air for Emission Point A1-1 (Carbon-based scrubber) Note 1

Control parameter	Monitoring to be carried out	Frequency
Exhaust Fans & Ducting	Verify Speed and ampage of fan on control panel	Daily
	Inspect impellor for signs of excessive vibration, corrosion or solids build up Inspect external housing for signs of corrosion or wear	Quarterly
	Duct Volume Control Dampers , blow down face of damper to remove dust build up	Monthly
Reverse Jet Filter	Compare pressure drops across filter shown on digital (Delta Pulse) and analogue (CMR Sensors) to check for continuity	Daily
	Empty dust bins below hoppers	Monthly
	Open Access Doors and check for any damage to cartridges	Monthly
Carbon Adsorber	Check pressure drop across adsorber and compare with output on SCADA system	Daily
	Perform olfactory test on outlet gas (Check sniff tubes)	Daily (as a minimum)
	Check for settling of Carbon within the adsorber. Remove top access panels and top up when necessary	Quarterly

Note1 – Equipment required for monitoring to be finaised with supplier before Licence Review Application

4.4 Monitoring and Sampling

The proposed stack for the Odour Abatement System (Stack A1-1) will be monitored for Total Ammonia, Amines, Hydrogen Sulphide (H_2S), Total Mercaptans, Total VOCs (as carbon), Condensable VOCs and Odour according to the frequencies and methodologies shown in Table 8.

All emissions monitoring will be carried out in line with the requirements of *EPA Air Monitoring Guidance Note AG2* and the methods employed are in line with those specified in the EPA *Index of Preferred Methods.* Where an external contract laboratory is used for analysis, the laboratory will be accredited to ISO17025 (for the parameter being analysed).

Stack sampling will follow best practice guidance from the EPA and will be conducted only by fully qualified personnel.

Table 8 : Monitoring of Emissions to Air from Emission Point A1-1

Parameter	**Monitoring Frequency**	**Analysis Method / Technique**
Total Ammonia	Biannually	Procedural requirements of IS EN 14791 (Isokinetic sampling where water droplets are present, otherwise Non-Isokinetic sampling) or TGN M22 (Instrumental sampling)
Amines	Biannually	IS EN 13649 or TGN M22 (Instrumental sampling)
Hydrogen Sulphide	Biannually	US EPA M11 (Non-Isokinetic sampling) or IS EN 13649 (Non- Isokinetic sampling)
Mercaptans	Weekly	Colorimetric Indicator Tube
Condensable VOCs	Biannually	IS EN 14791 (Isokinetic sampling where water droplets are present, otherwise Non-Isokinetic sampling)
Total VOCs (as C)	Biannually	IS EN 14181 Any certified analyser Or IS EN 12619 FID analyser
Odour (OU_E/m^3)	Quarterly	IS EN 13725 (Manual sampling) Odour bag / Analysis by olfactometry and odour panel
Odour (Semi-quantitative)	Daily (as a minimum)	Sniff testing of grab samples of gas taken at sampling points which will be installed on the scrubber inlet and outlet
Gas Velocity & Volume Flow	Quarterly	IS EN 13284-1

4.4.1 *Monitoring and Sampling Ports*

A suitable sampling platform and sampling ports will be installed for the new stack and scrubber system and will meet the requirements specified in EPA Guidance Note on Site Safety Requirements for Air Emissions Monitoring (AG1).

For clarity, the specific requirements from AG1 which the ports will comply with are re-produced below. Oxigen will ensure the supplier can meet the stipulated requirements before procuring the abatement system.

<u>Ports for Volumetric Flow Measurement</u>

The following requirements should be met when installing sample ports in stacks for which the licence has stipulated a maximum volume flow rate:

- *Sampling ports must be downstream of any abatement equipment;*
- *The best available sampling plane must be chosen. The sampling plane should be positioned in a length of straight duct of uniform cross section. This plane should be located at least 5 duct diameters downstream of the nearest obstruction and at least 2 duct diameters upstream of the nearest obstruction. If the sampling plane is positioned in a stack which is discharging to the open air, the distance between the sampling plane and the stack top should be at least 5 duct diameters. Every effort should be made to locate the sampling ports away from sources of turbulence such as fans, duct bends and duct junctions. Where suitable sample planes exist in both vertical and horizontal sections of ductwork, the former should be chosen.*

- *Having established the best available sampling plane, the exact position of the sampling ports within that plane must be decided. For smaller ducts, a single sampling port may be all that is practicable, but generally the recommended number of sampling ports is for:*
    - *Circular ducts of diameter 1.5m; two ports positioned on the same sample plane but separated by an angle of 90o;*
    - *Circular ducts of diameter 1.5m; four ports positioned on the same sample plane and separated by an angle of 90o;*
    - *Rectangular ducts; the number of ports will depend on the size of the duct (2 to 4 for most ducts) and the ports should be equally spaced.*
- *The required size of the sampling port can vary depending on the pitot tube to be used, but in most cases a 15mm circular hole drilled directly into the duct wall will suffice. If a more serviceable fixture is desired, then a 1 to 1½ inch BSP parallel-threaded socket should be welded to the duct wall.*

Ports for Gaseous Pollutant Measurement

Gases, unlike particulates, are not subject to momentum forces when moving in a gas stream. The following requirements should be met when installing sampling ports in stacks which are licensed for gaseous pollutants:

- *Sampling ports must be downstream of any abatement equipment;*
- *The composition of the gas should be homogeneous across the area of the sampling plane (i.e. the waste gas should be thoroughly mixed);*
- *A single port is usually sufficient for the collection of gas samples.*

Additional Ports for Semi-quantitative Measurement

In addition to the ports required for volume flow and gaseous pollutant monitoring, Oxigen are also requiring the abatement system supplier to provide ports on the inlet and outlet to the scrubber that can be easily used to take frequent grab samples (daily frequency as a minimum). The grab sample will be assessed by sniff testing to ensure the abatement system is operating at the expected efficiency. This approach also allows early detection in the unlikely event of system failure.

5.0 IMPACT ON DISCHARGE TO SEWER

The subject planning application does not currently propose to change the “Emission Limit Value” for the existing discharge to sewer as already approved under the existing waste licence W0144-01 as per table C3 shown below.

The volumes of excess water discharged from bio-scrubber will be dependent on the final specification from the supplier. Consultation is ongoing with Irish Water to confirm whether any further assessment on impact to discharge to sewer will be required for the bio-scrubber abatement option.

C.3 Emission Limits for Emissions to Sewer:

Emission Point Reference No. **FS1 - location to be agreed with the Sanitary Authority & the Agency.**

Volume to be emitted: Maximum in any one day: **720 m^3**

Maximum rate per hour: **360 m^3/hr**

Parameter	**Emission Limit Value**		
	Grab Sampl e	**Daily Mean Concentr**	**Daily Mean Loadin**
BOD	3000	-	-
COD	4500	-	-
Suspended	3000	-	-
pH	6 - 9	6 - 9	-
Temperature	30°C	30°C	-

We trust the information above and attached provides suitable clarification. For each document identified above, including this letter, please find attached 2 copies in hard copy format and 1 electronic copy of all documents on CD-ROM. The content of the electronic files on the accompanying CD ROM is a true copy of the originals.

Please feel free to contact me with any queries regarding this application or to request further information.

Yours sincerely,

Claire Lynch
Senior Environmental Consultant

Dr. Fergal Callaghan
Director (EHS)

encl.

Appendix A	*Planning Permission for Proposed Abatement System & Stack Installation*
Appendix B	*Odour Dispersion Modelling Report*
Appendix C	*Specification of Carbon-based Odour Abatement System (Simdean)*
Appendix D	*Specifications, Proposal and Design Report for Bio-scrubber Odour Abatement System (MEHS)*
Appendix E	*Maintenance Procedures for Carbon-based Odour Abatement System (Simdean)*
Appendix F	*Maintenance Procedures for Bio-scrubber Odour Abatement System (MEHS)*

APPENDIX A

Planning Permission for Proposed Abatement System & Stack Installation

LOUTH COUNTY COUNCIL
Planning Section, Town Hall, Crowe Street, Dundalk, County Louth A91 W20C
Tel:042/9335457 Fax:042/9320080

PLANNING AND DEVELOPMENT ACT, 2000 (as amended)

NOTIFICATION OF GRANT OF PERMISSION

TO: Oxigen Environmental
Merrywell Industrial Estate
Ballymount Road Lower
Dublin 22

20/06/2016

Register Reference Number: 16210

Date Application Received: 07/04/2016

Description of Development: Permission for the following development consisting of: a) Lean-to extension of 95m2 to the front of the existing Waste Recycling Building; b) Installation of Odour Abatement Plant to the existing Waste Recycling Building to include a 20m high stack; c) Associated site services all at the Existing Oxigen Waste Recycling Facility, Coe`s Road, Dundalk, Co. Louth. The existing Waste Recycling Facility operates under an EPA Waste Licence Ref: WO144-01.

Application Type: PERMISSION

Name of Applicant:
Oxigen Environmental

Location Address:
Coes Road
Dundalk
Co. Louth

Permission is hereby granted for the development described above, subject to the 10 conditions set out in the Schedule attached.

pp S. McLerny
Anne D. Callan,
Administrative Officer

NOTES

1. Unless otherwise specified in this decision and subject to certain exceptions, a permission will, on the expiration of a period of five years beginning on the date of grant, cease to have effect as regards:
(a) in case the development is not commenced during that period, the entire development, and
(b) in case the development is commenced during that period, so much of the development as is not completed within that period.

2. A grant of Outline Permission will cease to have effect on the expiration of a period of three years beginning on the date of grant, unless a subsequent application for permission has been made within that period.

3. A grant of Outline Permission does not authorise the carrying out of any development. A subsequent grant of Permission must be obtained before development commences.

LOUTH COUNTY COUNCIL

REFERENCE NO. 16/210

CONDITIONS

(1) The works shall be carried out in strict accordance with the documents, plans and details lodged with the Planning Authority on 7th April 2016, save for the conditions attached below.

Reason: In order to regulate the development.

(2) Prior to the commencement of the development hereby permitted, the applicant/developer shall submit details of all external materials, colours and finishes, for the written approval of the Planning Authority. Details shall include manufacturers name, material name and colour type.

Reason: In the interests of visual amenities.

Infrastructure:
(3) Within 6 months of the grant of this permission, the following shall be agreed with the Planning Authority:

- Details of all proposed mitigatory flood resilience measures e.g. internal floors to have a waterproof finish applied to provide protection to the floor itself and allow for ease of cleaning after a flood event, any proposed surface water outfall manholes to be fitted with a non-return valve etc.

Reason: In the interests of protecting property from flooding and in the interests of orderly development.

(4) The applicant/developer shall make all necessary arrangements to apply for and obtain a Road Opening License(s) from Louth County Council in respect of all openings in public areas and shall pay Road Opening License Fees and road restoration costs. The applicant shall abide by the conditions as set out in the said license(s).

Reason: In the interests of traffic safety and orderly development.

(5) The applicant/developer shall be responsible for the full cost of repair in respect of any damage caused to the adjoining public road/footpath arising from the construction work and shall either make good any such damage forthwith to the satisfaction of Louth County Council or pay to the Council the cost of making good any such damage on a demand thereof being issued by the Council.

Reason: In the interests of traffic safety and orderly development.

(6) All necessary measures, as may be determined by the Planning Authority, shall be taken by the developer/contractor/servants/agents to prevent the spillage or deposit of clay, rubble or other debris on adjoining public roads or footpaths during the course of the development works. The developer shall

ensure that all vehicles leaving the development are free from any material that would be likely to deposit on the road and in the event of any such deposition; immediate steps shall be taken to remove the material from the road surface. The developer shall be responsible for the full cost of carrying out of road/footpath cleaning work.

Reason: In the interests of traffic safety and orderly development.

Environment:

(7) Prior to the commencement of development, the developer shall submit a formal Project Construction and Demolition Waste Management Plan to the local authority for written agreement prior to Commencement Notice stage. This plan shall, inter alia, include the information recommended in sections 3.2, 3.3 and 3.4 of the document titled "Best Practice Guidelines on the Preparation of Waste Management Plans for Construction and Demolition Projects" published by the Department of the Environment, Heritage and Local Government.

Reason: In the interests of public health.

(8) On-site construction works shall be limited to the hours of 08:00-20:00 hours Monday-Friday and 08:00- 16:00 on Saturday, and shall exclude Sundays and Bank Holidays. Cognisance should be taken of the requirements of BS 5228 Part 1 1997 (Noise and Vibration control on construction and open sites).

Reason: In the interests of public health.

(9) (a) The developers shall, if directed by the Planning Authority, monitor and record noise levels – Leq's and any other levels which may be requested by the Planning Authority (L max etc) during construction stage.

(b) The developer shall if directed by the Planning Authority, monitor and record the total dust emissions arising from all on site operations associated with the proposed development during construction stage.

(c) The number and locations of the monitoring and recording stations for sound and dust deposition necessary to comply with the requirements of Part (a) and (b) of this condition shall be in accordance with the requirements of the Planning Authority for such monitoring of sound and dust deposition.

(d) The Planning Authority shall be afforded access at all reasonable times in order to inspect, examine and check or to have inspected, examined and checked, all apparatus and equipment used or required to carry out monitoring of noise.

(e) The developers shall pay a sum of money to Louth County Council, if demanded, as a contribution towards the costs incurred by the said Council in carrying out, or in having carried out, check monitoring and recording of any, or all, of the matters required to be monitored and recorded by part (a) and (b) of this condition. The amount of contribution and the arrangements for payment of such contribution shall be as agreed between the developers and the Planning Authority.

Reason: In the interests of public health.

(10) In accordance with the Council's Development Contribution Scheme 2010 made under the provisions of section 48 of the Planning and Development Act 2000 the developer shall pay a contribution to the Planning Authority, in the amounts specified below (or such increased amount in accordance with the changes on an annual basis to the Wholesale Price Index for building and construction published by the Central Statistics Office) towards the costs already incurred or to be incurred by the Planning Authority on the provision of each of the public facilities listed below, which will benefit development in the area of the Planning Authority. Unless otherwise agreed in writing with the Planning Authority before development is commenced the said contribution shall be paid in full before such commencement.

(a)	Public Piped Services -	€ 1405.05
(b)	Roads-	€ 2850.00
(c)	Recreation & Amenity	€ 920.55
	Total -	**€5,175.60**

(Five thousand, one hundred and seventy five euro and sixty cent)

Reason: The provision of these facilities in the area will facilitate the proposed development and it is considered reasonable that the developer should contribute towards their cost.

Important Notes for Applicants

1. It should be clearly understood that the granting of Planning Permission does not relieve the developer of the responsibility of complying with any requirements under other Codes of legislation affecting the proposal.

2. A person shall not be entitled solely by reason of a grant of Planning Permission to carry out any development.

3. A grant of Planning Permission does not entitle a person to construct a development that would oversail, overhang or otherwise physically impinge upon an adjoining property without the permission of the adjoining property owner.

REFERENCE NO:16/210

Irish Water Standard Notes

1. Where the applicant proposes to connect to a public water/wastewater network operated by IW, the applicant must sign a connection agreement with IW prior to the commencement of the development and adhere to the standards and conditions set out in that agreement.

2. In the interest of Public Health and Environmental Sustainability, Irish Water Infrastructure capacity requirements and proposed connections to the Water and Waste Water Infrastructure will be subject to the constraints of the Irish Water Capital Investment Programme.

APPENDIX B

Odour Dispersion Modelling Report

awnconsulting

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ODOUR MODELLING AND ABATEMENT STUDY OF THE OXIGEN WASTE TRANSFER STATION, COES ROAD, DUNDALK

Technical Report Prepared For

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Merrywell Industrial Estate,
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Dublin 22

Technical Report Prepared By

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Our Reference

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Record of Approval

Details	Written by	Checked by
Signature		
Name	Claire Lynch	Dr. Avril Challoner
Title	Senior Environmental Consultant	Environmental Consultant
Date	30/01/17	30/01/17

EXECUTIVE SUMMARY

AWN Consulting Ltd (AWN) was commissioned by Oxigen Environmental Coes Road Waste Transfer Station And Recycling Facility in Dundalk, County Louth to consider suitable odour abatement options in order to identify the most efficient means of ensuring that no odour nuisance will occur at nearby receptors (both residential and commercial premises).

This air modelling report takes into account the proposed odour abatement system for which planning permission was provided by Louth County Council on 20/06/16. There are two proposed options for the abatement system; a bio-scrubber system and a carbon-based scrubber system. Both scenarios have been assessed to determine the optimum stack height and ensure no odour nuisance will occur beyond the site boundary.

The following assumptions were made when conducting the air dispersion modelling:

- In order to facilitate the installation of an odour abatement system, the building will be operated under sufficient negative pressure to ensure that fugitive odour release will be minimal and that odorous air will be extracted via the abatement system;

- All abatement options considered require dispersion of the treated air via a stack. The stack diameter was adjusted in order to achieve a minimum velocity of 20 m/s for the bio-scrubber option and 15 m/s for the carbon-based option as advised by the abatement system suppliers. These minimum efflux velocities ensure that the momentum of the plume is maximised;

- The stack height was modelled at 20m for the bio-scrubber option as this was the optimum height determined in the previous air modelling report (13_6839AR02_1). For the carbon-based option, the stack height was increased in increments from an initial height of 10m to a maximum height of 20m to determine the optimum stack height for the facility to ensure no odour nuisance beyond the site boundary;

- The following residual odour concentrations after abatement were assumed based on removal efficiency information from the abatement system suppliers:

    - o Residual odour concentration of 1,500 OU_E/m^3 for the bio-scrubber system;
    - o Residual odour concentration of 300 OU_E/m^3 for the carbon-based system.

Assessment Results

The dispersion modelling results show that the 98th%ile of mean hourly odour concentrations are in compliance with the UK guideline level at all off-site receptors modelled reaching 68% of the UK guideline limit value for the carbon-based scrubber scenario and 91% for the bio-scrubber scenario at the worst-case boundary receptors.

The predicted odour concentrations at the air sensitive receptors (ASRs) are well below the concentrations at the site boundary. The 98th%ile of mean hourly odour concentrations complies with the UK guideline level for all abatement scenarios modelled. The worst-case odour concentration at an ASR for the bio-scrubber scenario was 17% of the UK guideline level. The worst-case odour concentration at an ASR for the carbon-scrubber scenario was 9% of the UK guideline level.

The dispersion modelling results were also compared with the more stringent New Zealand guideline level of 1.0 OU_E/m^3 for the 99.5th%ile of hourly mean concentrations. The results show that the 99.5th%ile of mean hourly odour concentrations exceeds the New Zealand guideline level at the worst-case boundary receptors for both abatement scenarios modelled. However, the predicted 99.5th%ile of hourly odour concentrations at the ASRs are well below the site boundary concentrations. The 99.5th%ile of mean hourly odour concentrations at the worst-case ASRs is 49% of the New Zealand guideline value for the bio-scrubber and 30% for the carbon-based scrubber scenario.

The modelling results demonstrate that the odour impact off-site decreases rapidly with distance from the proposed stack and that odour nuisance at the ASRs will likely be insignificant for both abatement options modelled. The bio-scrubber system requires a 20m stack to achieve adequate dispersion of odour while the carbon-based scrubber system requires a 12m stack.

In summary, both abatement system options will achieve compliance with the UK odour nuisance criterion (expressed as the 98th%ile of hourly mean concentrations) for all off-site receptors. The more stringent New Zealand odour nuisance criterion (expressed as the 99.5th%ile of hourly mean concentrations) was exceeded at the boundary receptors for both scenarios modelled but results for the closest ASRs (residential receptors) were well below the New Zealand guideline value.

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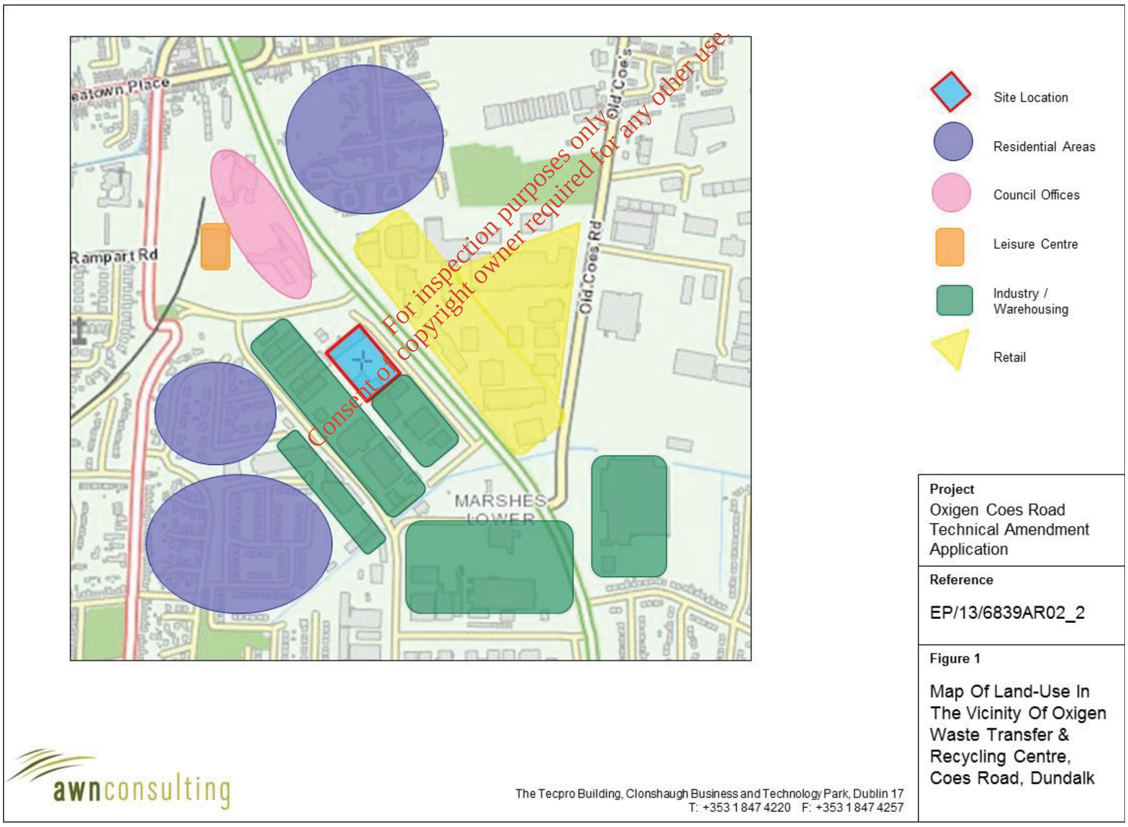
1.0 INTRODUCTION

AWN Consulting Ltd (AWN) was commissioned to consider suitable odour abatement options in order to identify the most efficient means of ensuring that no odour nuisance will occur at nearby receptors (both residential and commercial premises).

1.1. Site Location

The Oxigen Environmental waste transfer station and recycling facility at Coes Road has a waste licence issued by the EPA (Licence Number WW0144-01). The licence allows for processing of up to 35,000 tonnes of household (black bin) waste, 5,000 tonnes of commercial waste, 30,000 tonnes of industrial non-hazardous solids and 20,000 tonnes of construction and demolition waste at this facility annually giving a total waste acceptance maximum of 90,000 tonnes.

The facility is located in a zoned industrial area with nearby warehousing and industrial buildings. The nearest residential receptors are located 100m south-west of the site boundary with additional residential receptors located 160m north of the site boundary. Other nearby buildings including retail building, a leisure facility and council offices as shown in Figure 1.



Currently, all waste tipping and processing of household and commercial waste and storing of segregated recyclables is carried out inside the Municipal Waste Processing Building (MWPB). The MWPB has recently been upgraded to include the construction of a lean-to extension to the building. The extension creates an additional space in front of doors 7 and 8 thereby allowing for the doors to remain fully closed while waste processing is ongoing within the building.

Other recent odour control works completed with the agreement of the EPA and Louth County Council were:

- The replacement of some of the unused roller shutter doors to the MWPB with solid concrete walls and metal cladding;
- The fitting of new steel roller shutter doors;
- Brush seals fitted to all roller shutter doors to the MWPB to contain any possible emissions;
- The blocking up of all openings and further sealing works to the MWPB followed by smoke test to ensure the integrity of the building envelope is of a satisfactory standard.

The municipal (black bin) waste is currently processed into a 40ft compactor and is sent for recovery or to a licensed landfill for disposal where appropriate. Brown bins (kitchen and garden waste) are tipped on the MWPB floor and after inspection for contamination is bulked up into 40ft trailers for transfer off-site to a composting facility.

An odour misting system had been place at the facility to reduce odour and dust emissions which was upgraded in 2011 to include a new pumping system and stainless piping and nozzles along both sides of the MWPB. Since the upgrade works to the shed structure and sealing of all possible leaks, a mobile odour misting system operates outside the doors of the MWPB to reduce any possible odour and dust emissions escaping from door areas when opened to access the building.

Despite the recent upgrades to the facility there is the potential for odorous releases during unloading and storage of both municipal and food waste particularly when the waste has started the process of putrefaction which is enhanced in summer months. As the building is not currently under negative pressure, odour releases can occur when the doors are opened to allow trucks to off-load waste within the building.

Odour dispersion modelling for the proposed abatement scenarios was carried out using the United States Environmental Protection Agency's regulatory model AERMOD (Version 15181). The aim of the study was to assess the potential odour emissions associated with various abatement system options and to quantify the ambient predicted odour levels relative to the ambient odour guideline values for each option. The assessment was conducted using the methodology outlined in "*Air Dispersion Modelling from Industrial Installations Guidance Note (AG4) (EPA, 2010)*"(1).

This report describes the outcome of this study. The study consists of the following components:

- Review of information from odour abatement system suppliers as well as relevant literature on odour emission data and other information required for the modelling study;
- Dispersion modelling of odour emissions based on two potential abatement options;
- Presentation of predicted ground level concentrations of proposed odour impacts at the nearest sensitive receptors;
- Evaluation of the significance of these predicted concentrations, including consideration of whether these ground level odour concentrations are likely to exceed the relevant ambient odour guideline value.

Information supporting the conclusions has been detailed in the following sections. The assessment methodology and study inputs are presented in Section 2. The odour dispersion modelling results and assessment summaries are presented in

Section 3. The model formulation is detailed in Appendix I and a review of the meteorological data used is detailed in Appendix II.

2.0 MODELLING METHODOLOGY

Odour emissions from the facility have been modelled using the AERMOD dispersion model (Version 15181) which has been developed by the U.S. Environmental Protection Agency (USEPA)[2,3]. The model is a steady-state Gaussian plume model used to assess pollutant concentrations associated with industrial sources and has replaced ISCST3[4] as the regulatory model by the USEPA for modelling emissions from industrial sources in both flat and rolling terrain[5-7]. The model has more advanced algorithms and gives better agreement with monitoring data in extensive validation studies[8-11]. An overview of the AERMOD dispersion model is outlined in Appendix I.

The odour dispersion modelling input data consisted of information on the physical environment (including building dimensions and terrain features), design details from all emission sources on-site and a full year of appropriate meteorological data. Using this input data the model predicted ambient ground level odour concentrations beyond the site boundary for each hour of the modelled meteorological year. The model post-processed the data to identify the location and maximum of the worst-case ground level odour concentration. This worst-case concentration was then compared with the relevant ambient odour guideline values to assess the significance of releases from the site.

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:

- A conservative odour concentration has been selected for each abatement option modelled;
- Conservative odour guideline values have been selected for assessing the magnitude of odour impacts;
- Compliance with the odour guideline value has been determined at any building (businesses, offices, retail premises, residential) off-site irrespective of whether any sensitive receptors are currently present at these locations.

2.1 Characteristics of Odour

Odours are sensations resulting from the reception of a stimulus by the olfactory sensory system, which consists of two separate subsystems: the olfactory epithelium and the trigeminal nerve. The olfactory epithelium, located in the nose, is capable of detecting and discriminating between many thousands of different odours and can detect some of them in concentrations lower than those detectable by currently available analytical instruments[12]. The function of the trigeminal nerve is to trigger a reflex action that produces a painful sensation. It can initiate protective reflexes such as sneezing to interrupt inhalation. The olfactory system is extremely complex and peoples' responses to odours can be variable. This variability is the result of differences in the ability to detect odour; subjective acceptance or rejection of an odour due to past experience; circumstances under which the odour is detected and the age, health and attitudes of the human receptor.

Odour Intensity and Threshold

Odour intensity is a measure of the strength of the odour sensation and is related to the odour concentration. The odour threshold refers to the minimum concentration of an odorant that produces an olfactory response or sensation. This threshold is normally determined by an odour panel consisting of a specified number of people, and the numerical result is typically expressed as occurring when 50% of the panel correctly detect the odour. This odour threshold is given a value of one odour unit and is expressed as 1 OU_E/m^3. The odour threshold is not a precisely determined value, but depends on the sensitivity of the odour panellists and the method of presenting the odour stimulus to the panellists. An odour detection threshold relates to the minimum odorant concentration required to perceive the existence of the stimulus, whereas an odour recognition threshold relates to the minimum odorant concentration required to recognise the character of the stimulus. Typically, the recognition threshold exceeds the detection threshold by a factor of 2 to 10[12-13].

Odour Character

The character of an odour distinguishes it from another odour of equal intensity. Odours are characterised on the basis of odour descriptor terms (e.g. putrid, fishy, fruity etc.). Odour character is evaluated by comparison with other odours, either directly or through the use of descriptor words.

Hedonic Tone

The hedonic tone of an odour relates to its pleasantness or unpleasantness. When an odour is evaluated in the laboratory for its hedonic tone in the neutral context of an olfactometric presentation, the panellist is exposed to a stimulus of controlled intensity and duration. The degree of pleasantness or unpleasantness is determined by each panellist's experience and emotional associations. The responses among panellists may vary depending on odour character; an odour pleasant to many may be declared highly unpleasant by some.

Adaptation

Adaptation, or Olfactory Fatigue, is a phenomenon that occurs when people with a normal sense of smell experience a decrease in perceived intensity of an odour if the stimulus is received continually. Adaptation to a specific odorant typically does not interfere with the ability of a person to detect other odours. Another phenomenon known as habituation or occupational anosmia occurs when a worker in an industrial situation experiences a long-term exposure and develops a higher threshold tolerance to the odour.

2.2 Odour Guidelines

The exposure of the population to a particular odour consists of two factors; the concentration and the length of time that the population may perceive the odour. By definition, 1 OU_E/m^3 is the detection threshold of 50% of a qualified panel of observers working in an odour-free laboratory using odour-free air as the zero reference (the selection criteria result in the qualified panel being more sensitive to a particular odorant than the general population). The recognition threshold is generally about five times this concentration (5 OU_E/m^3) and the concentration at which the odour may be considered a nuisance is between 5 and 10 OU_E/m^3 based on hydrogen sulphide (H_2S)[14]. Clarkson and Misslebrook[15] proposed that a "faint odour" was an acceptable threshold criteria for the assessment of odour as a nuisance. Historically, it has been generally accepted that odour concentrations of between 5 and 10 ou/m^3

would give rise to a faint odour only, and that only a distinct odour (concentration of >10 OU_E/m^3) could give rise to a nuisance(16). However, this criteria has generally been based on waste water treatment plants where the source of the odour is generally hydrogen sulphide. In 1990, a survey of the populations surrounding 200 industrial odour sources in the Netherlands showed that there were no justifiable complaints when 98%ile compliance with an odour exposure standard of a "faint odour" (5-10 OU_E/m^3) was achieved(17).

DEFRA(18,19) in the UK has published detailed guidance on appropriate odour threshold levels based in part on the offensiveness of the odour. As shown in Table 1, a MSW transfer station is not included in the list although the odour generated could be considered similar to other waste treatment facilities such as landfills although the great majority of the waste will have a much less significant odour as the putrefaction of waste will be significantly greater in a landfill than with freshly generated waste.

EPA guidance document AG4 discusses various ambient odour guidelines in Appendix I. The most commonly adopted guidance is the UK DEFRA approach which is outlined in Table 2. DEFRA has detailed installation-specific exposure criteria based on the "annoyance potential"(18) which is defined as "the likelihood that a specific odorous mixture will give reasonable cause for annoyance in an exposed population". Industrial sources have been ranked into three categories based on their relative offensiveness which are "low", "medium" and "high" and exposure criteria assigned to each category (as shown in Table 2). The relevant exposure criteria vary from 1.5 OU_E/m^3 for highly odorous sources to 6.0 OU_E/m^3 for the least offensive odours. The relevant exposure criteria for a waste transfer facility, in circumstances where the air is extracted and treated via a bio-scrubber prior to release to atmosphere, is not included but may be assumed to be 3.0 OU_E/m^3 which should be expressed as a 98^{th}%ile and based on one hour means over a one-year period in the absence of any local factors. However, in order to ensure that a conservative approach is taken to the current assessment and in acknowledgement of the urban nature of the facility, the most stringent odour guidance level of 1.5 OU_E/m^3 (as a 98^{th}%ile) has been selected for the current assessment.

Table 1 Ranking Table For Various Industrial Sources[18]

Environmental Odour Industrial Source	Ranking UK Median	Ranking UK Mean	Ranking Dutch Mean
Bread Factory	1	2.5	1.7
Coffee Roaster	2	3.9	4.6
Chocolate Factory	3	4.6	5.1
Beer Brewery	6	7.7	8.1
Fragrance & Flavour Factory	8	8.5	9.8
Charcoal Production	8	9.2	9.4
Green Fraction composting	9	10.3	14
Fish smoking	9	10.5	9.8
Frozen Chips production	10	11	9.6
Sugar Factory	11	11.3	9.8
Car Paint Shop	12	11.7	9.8
Livestock odours	12	12.6	12.8
Asphalt	13	12.7	11.2
Livestock Feed Factory	15	14.2	13.2
Oil Refinery	14	14.3	13.2
Car Park Bldg	15	14.4	8.3
Wastewater Treatment	17	16.1	12.9
Fat & Grease Processing	18	17.3	15.7
Creamery/milk products	10	17.7	-
Pet Food Manufacture	19	17.7	-
Brickworks (burning rubber)	18	17.8	-
Slaughter House	19	18.3	17.0
Landfill	20	18.5	14.1

Table 2 Indicative Odour Standards from UK DEFRA Based On Offensiveness Of Odour[18]

Industrial Sectors	Relative Offensiveness of Odour	Indicative Criterion
Rendering Fish Processing Oil Refining Creamery WWTP Fat & Grease Processing	High	1.5 OU_E/m^3 as a 98^{th}%ile of hourly averages at the worst-case sensitive receptor
Intensive Livestock Rearing Food Processing (Fat Frying) Paint-spraying Operations Asphalt Manufacture	Medium	3.0 OU_E/m^3 as a 98^{th}%ile of hourly averages at the worst-case sensitive receptor
Brewery Coffee Roasting Bakery Chocolate Manufacturing Fragrance & Flavouring	Low	6.0 OU_E/m^3 as a 98^{th}%ile of hourly averages at the worst-case sensitive receptor

A second guidance is also suggested in AG4. This is the approach used in New Zealand[20] and would tend to be less commonly applied in Ireland than the UK guidance. The New Zealand is more stringent with the guidelines being expressed as a 99.5^{th}%ile rather than the UK guidance of 98^{th}%ile (i.e. New Zealand guidance allows 43 exceedances per year whereas the UK guidance allows 175 exceedances before the guideline is deemed to be exceeded). The New Zealand guidance is also more complex as the High Sensitivity environment (including residential) is expressed in terms of the “worst-case impacts” experienced as shown in Table 3 which is reproduced from AG4.

Table 3 Recommended Odour Modelling Guideline Values – New Zealand[20]

Sensitivity of the Receiving Environment	Examples of Land-Use Type	Concentration	Percentile (based on 1-hour means)
High (worst-case impacts under unstable / semi-unstable conditions)	High / Low Density Residential Recreational / Open Spaces Retail /Education / Business/ Cultural	1.0 OU_E/m^3 (1000 OU_E/s)	0.1% and 0.5%
High (worst-case impacts under neutral to stable conditions)		2.0 OU_E/m^3 (2000 OU_E/s)	0.1% and 0.5%
Moderate (all conditions)	Light Industry	5.0 OU_E/m^3 (2000 OU_E/s)	0.1% and 0.5%
Low (all conditions)	Heavy Industry Public Road	5 - 10 OU_E/m^3 (5000-10000 OU_E/s)	0.5%

AG4 advises that either guidance (UK DEGRA or New Zealand) is satisfactory to use and that use of both guidelines is not necessary. However, in order to provide a conservative assessment of impacts from the Coes Road facility, results of the odour modelling assessment have been assessed using the most stringent guideline values from both the UK DEFRA and New Zealand guidance documents.

2.3 Odour Dispersion Modelling Methodology

The United States Environmental Protection Agency (USEPA) approved AERMOD dispersion model[2,3] has been used to predict the ground level concentrations (GLC) of compounds emitted from the principal emission sources on-site.

The modelling incorporated the following features:

- A receptor grid was created at which concentrations would be modelled. Receptors were mapped with sufficient resolution to ensure all localised “hot-spots” were identified without adding unduly to processing time. The receptor grid was based on Cartesian grids with the site at the centre. The grid extended over a distance of 500m with concentrations calculated at 25m intervals. Boundary receptor locations were also placed along the boundary of the site, at 20m intervals and 47 specific buildings within the 500m x 500m modelling domain were marked as air sensitive receptors (ASR) giving a total of 504 calculation points for the model;

- All on-site and offsite buildings and significant process structures were mapped into the computer to create a three dimensional visualisation of the site and its emission sources. Buildings and process structures can influence the passage of airflow over the emission sources and draw plumes down towards the ground (termed building downwash). The stacks themselves can influence airflow in the same way as buildings by causing low pressure regions behind them (termed stack tip downwash). Both building and stack tip downwash were incorporated into the modelling;

- Hourly-sequenced meteorological information has been used in the model. Appropriate meteorological data for 2011 - 2015 (Dublin Airport) was selected for use in the model (see Figure 2);

- AERMOD incorporates a meteorological pre-processor AERMET PRO[21]. The AERMET PRO 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(21);

- The source and emission data, including stack dimensions, efflux velocities and emission temperatures have been incorporated into the model;
- Detailed terrain has been mapped into the model using SRTM (Shuttle Radar Topography Mission) data with 90m resolution. The site is located in relatively flat terrain. Terrain features have been mapped into the model using the terrain pre-processor AERMAP.

2.4 Terrain

The AERMOD air dispersion model has a terrain pre-processor AERMAP 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 SRTM. 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 Digital 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.

AERMOD also has the capability of modelling both unstable (convective) conditions and stable (inversion) conditions. The stability of the atmosphere is defined by the sign of the sensible heat flux. Where the sensible heat flux is positive, the atmosphere is unstable whereas when the sensible heat flux is negative the atmosphere is defined as stable. The sensible heat flux is dependent on the net radiation and the available surface moisture (Bowen Ratio). Under stable (inversion) conditions, AERMOD has specific algorithms to account for plume rise under stable conditions, mechanical mixing heights under stable conditions and vertical and lateral dispersion in the stable boundary layer.

2.5 Meteorological Data

The selection of the appropriate meteorological data has followed the guidance issued by the USEPA(3). A primary requirement is that the data used should have a data capture of greater than 90% for all parameters. Dublin Airport meteorological station, which is located approximately 65 km south of the site, collects data in the correct format and has a data collection of greater than 90%.

Long-term hourly observations at Dublin Airport meteorological station provide an indication of the prevailing wind conditions for the region (see Figure 2 for the wind profile in 2011 - 2015). Results indicate that the prevailing wind direction is from westerly to south-westerly in direction over the period 2011 – 2015. The mean wind speed is approximately 5.3 m/s over the period 1981-2010.

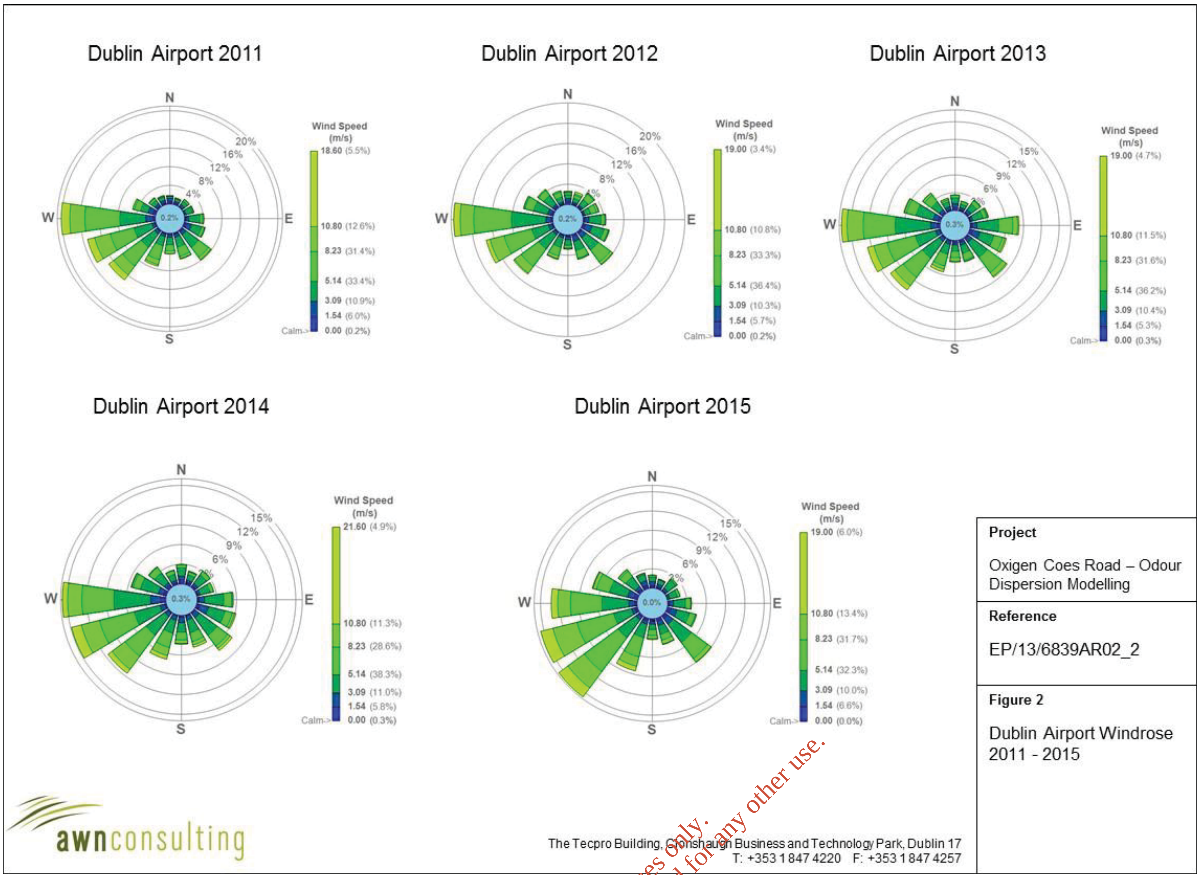


Figure 2
Dublin Airport Windrose 2011 - 2015

2.6 Odour Emission Rates From Waste Transfer Stations

An estimate of the odour emission rate within the waste transfer station has been undertaken using an odour concentration based on levels experienced at waste transfer stations or similar industries.

The facility is a MSW (black bin) and brown bin processing facility and is equipped to store and process MSW and commercial waste. There is no loading and/or unloading or handling of MSW outside the process building as the trucks drive into the process building to tip the waste. There is the potential for enhanced odorous releases during unloading and turning of the waste particularly when the MSW waste has started the process of putrefaction which is enhanced in summer months. An odour misting system is in place at the facility to reduce odour and dust emissions.

Potential Odour Process Emissions

An estimate of the likely magnitude of odour emissions from the facility can be derived from the publication “Emission Fluctuations & Site Controls At Waste Transfer Stations” by Dr. Phil Longhurst which was presented at the International Conference on Odour Management & Treatment, Cranfield University, UK (2002)[22]. A summary of the results is given in Table 4 and are based on a MSW waste transfer facility. The geometric mean of the results should give a reasonable estimate of the likely magnitude of emissions from the facility.

Table 4 Odour Emission Rates From A MSW Waste Transfer Station(22)

Survey	Samples	Odour Emission Concentration (OU_E/m^3)
September Survey	1 – waste tipping	123
	2 – waste tipping	132
	3 – bulk vehicle loading / tipping	57
	4 – bulk vehicle loading / tipping	1695
	5 – bulk vehicle loading / tipping	969
	6 – bulk vehicle loading / tipping	1409
	Geometric Mean	**359**
August Survey (11 months later)	1 – Bulk vehicle loading	588
	2 – Bulk vehicle loading	889
	3 – Bulk vehicle loading	1291
	4 – Bulk vehicle loading	2138
	5 – Bulk vehicle loading	944
	6 – Bulk vehicle loading	970
	7 – Bulk vehicle loading	1680
	8 – Bulk vehicle loading	2439
	9 – Bulk vehicle loading	1447
	Geometric Mean	**1257**

A second source of data available for a MSW waste transfer station is from a facility operated by Oxigen Environmental in Ireland. The data, in Table 5, indicates that the odour concentration, prior to abatement, is typically in the range 1600 – 1900 OU_E/m^3. Post-abatement, odour concentrations were typically between 450 – 700 OU_E/m^3 with a typical removal efficiency of 63% (based on a carbon filtration system).

Table 5 Odour Emission Rates From Oxigen MSW Waste Transfer Station In Ireland

Survey	Samples	Odour Emission Concentration (OU_E/m^3)
2011	Inlet	1,896
	Outlet	480
		724
		692
2012	Inlet	1,689
	Outlet	670
		621
		575

Other sources of data are available in the literature in relation to odour emission rates from other waste industries such as mechanical & biological treatment (MBT), composting and anaerobic digestion.

Data from 40 mechanical and biological treatment facilities in Italy was obtained by Sironi et al (2006)(23). The assessment was based on the results of odour measurements conducted over the period 2000 – 2005 at 40 waste MBT facilities in Italy treating either non-segregated organic fraction of MSW or segregated organic material and using composting but not anaerobic digestion. The capacity of the plants monitored ranged from 10,000 – 240,000 tonnes with an average capacity of 60,000 tonnes. Around 50 air samples were taken at each plant giving a total of 2,000 individual samples. The measurements were carried out in different seasons and differing weather conditions. The emission rates determined from the facilities were normalised to the tonnage of waste processed and were presented upstream of any abatement systems. Table 6 outlines the average odour concentrations, median and % deviation (which gives an indication of the scatter in the data). The “Waste Receiving” data is the most relevant process with regard to this assessment since Oxigen Coes Road is a waste transferring and recycling facility.

Table 6 Odour Average Odour Concentration Values, Median And Percent Deviation [23]

Waste Process	Geometric Mean (OU_E/m^3)	Median (OU_E/m^3)	% Deviation
Waste Receiving	2,786	3,000	11.8
Aerobic Biological Treatment	10,079	11,000	8.9
Maturation	1,701	3,899	24.1
Overscreen Storage	490	836	29.1
Final Product Storage	414	529	20.5
All Process Steps	7,903	8,234	7.8

Based on the data outlined in tables 4 to 6 above, a conservative concentration of 3,000 OU_E/m^3 was assumed for air inside the MWPB prior to abatement.

Residual Odour Emissions after Abatement

The various abatement scenarios and associated odour emissions modelled are detailed in Table 7 below. The bio-scrubber abatement option was assumed to have an emission concentration of 1,500 OU_E/m^3based on a conservative removal efficiency of 50%. A volume flow of 20,000 m^3/hr was modelled based on 3 ACH for the MWPB. The bio-scrubber abatement option was also assumed to have a decreased volume flow between 10pm and 5am on Monday to Saturday and all day on Sundays when the facility is closed. The stack height of 20m was modelled as air modelling report EP/13/6839AR02_1 determined 20m to be the optimum stack height for the bio-scrubber abatement system.

The carbon-based scrubber was assumed to have an emission concentration of 300 OUE/m^3 based on a conservative removal efficiency of 90%. The volume flow was assumed to be 26,000 m^3/hr based on 4 ACH for the MWPB. A range of stack heights between 10m and 20m were modelled for the carbon-based abatement system option to determine the optimum stack height required.

Table 7 Abatement Scenarios and Process Emissions for Oxigen Coes Road Odour Model

Scenario	Odour Concentration (OUE/m^3)	Duct Diameter (m)	Stack Height (m)	Volume Flow (m^3/hr)	Odour Emission (OU/s)
Bio_3ACH_20m_2014	1,500	0.60	20	20,000 (5,000) Note 1	8,333 Note 2
Carb_4ACH_10m_2011 / 2012	300	0.75	10	26,000	2,167
Carb_4ACH_12m_2011 / 2012	300	0.75	12	26,000	2,167
Carb_4ACH_15m_2011 / 2012	300	0.75	15	26,000	2,167
Carb_4ACH_20m_2011 / 2012	300	0.75	20	26,000	2,167

Note 1 The bio-scrubber abatement option will have a decreased volume flow (data shown in brackets) between 10pm and 5am on Monday to Saturday and all day on Sundays when the facility is closed

Note 2 The reduced nighttime and Sunday volume flows were used to calculate reduced emission factors to apply to the mass emissions for the period between 10pm and 5am on Monday to Saturday and all day on Sundays

In addition to the odour emissions from the MWPB, the C&D Waste Building was also assumed to give rise to minor fugitive odour emissions. The minor emissions from the C&D Waste Building were included in all modelling scenarios to ensure the worst-case odour impact from facility was predicted.

Odour emissions data assumed for the C&D Waste Building was based on the assumptions made in the previous odour modelling report *13_6839AR02_0 Oxigen Coes Road Odour Modelling Assessment* and is shown in Table 8.

Table 8 Odour Emissions from the C&D Waste Building at Oxigen Coes Road[Note 1]

Scenario	Odour Concentration (OU_E/m^3)	Release Height (m)	Odour Emission (OU/s)
C&D Waste Building	250	2.8	410

Note 1 See previous odour modelling report *13_6839AR02_0 Oxigen Coes Road Odour Modelling Assessment* for information on the estimation of emissions from the C&D Waste Building

Initial model runs for 5 years of meteorological data (Dublin Airport 2011 – 2015) showed that for the bio-scrubber abatement system with an associated 20m stack, the worst-case year was 2014 for both the 99.5th%ile and the 98th%ile. For the carbon-based abatement option with initial stack height of 10m, the worst-case year for the 99.5th%ile was 2011 and for the 98$^{th\%ile}$ was 2012. All subsequent runs were performed using the worst-case meteorological years.

3.0 RESULTS & DISCUSSION

3.1 Results for Odour Abatement Scenarios

Details of the 99.5^{th}%ile and 98^{th}%ile of 1-hour mean odour concentrations at the boundary of the site and at the nearest air sensitive receptor (ASR) are given in Table 9 and Figure 3 for the worst-case years for both odour abatement options modelled. A stack height of 20m (stack height for which planning permission was granted) was applied for the bio-scrubber modelling scenario. Various stack heights were modelled for the carbon-based scrubber option and the optimum stack height was determined to be 12m (see Section 3.3).

The dispersion modelling results presented in Table 9 and Figure 3 show that the 98^{th}%ile of mean hourly odour concentrations was 1.02 OU_E/m^3 for the carbon-based scrubber scenario and 1.36 OU_E/m^3 for the bio-scrubber scenario at the worst-case boundary receptors. Results indicate that both scenarios are in compliance with the UK guideline level at all receptors modelled reaching 68% of the UK guideline limit value for the carbon-based scrubber and 91% for the bio-scrubber scenario. The predicted 98^{th}%ile of hourly mean odour concentrations are shown as concentration contours for each scenario in Figures 4 – 5.

The dispersion modelling results presented in Table 9, Figure 3 and as concentration contours in Figures 4 – 5, show that predicted odour concentrations at the ASRs are well below the concentrations at the site boundary. The 98^{th}%ile of mean hourly odour concentrations ranged from 0.13 - 0.25 OU_E/m^3 at the worst-case ASRs, complying with the UK guideline level for all abatement scenarios modelled. The worst-case odour concentration at an ASR for the bio-scrubber scenario was 0.25 OU_E/m^3 reaching 17% of the UK guideline level. The worst-case odour concentration at an ASR for the carbon-scrubber was 0.13 OU_E/m^3 reaching 9% of the UK guideline level.

The dispersion modelling results were also compared with the more stringent New Zealand guideline level of 1.0 OU_E/m^3 for the 99.5^{th}%ile of hourly mean concentrations. The results presented in Table 9 and Figure 3 show that the 99.5^{th}%ile of mean hourly odour concentrations ranged from 1.34 – 1.63 OU_E/m^3 at the worst-case boundary receptors, exceeding the New Zealand guideline level for both abatement scenarios modelled. However, the predicted 99.5^{th}%ile of hourly odour concentrations at the ASRs are well below the site boundary concentrations. The 99.5^{th}%ile of mean hourly odour concentrations at the worst-case ASRs ranged from 0.30 – 0.49 OU_E/m^3, reaching at most 49% of the New Zealand guideline value for the bio-scrubber and 30% for the carbon-based scrubber scenario.

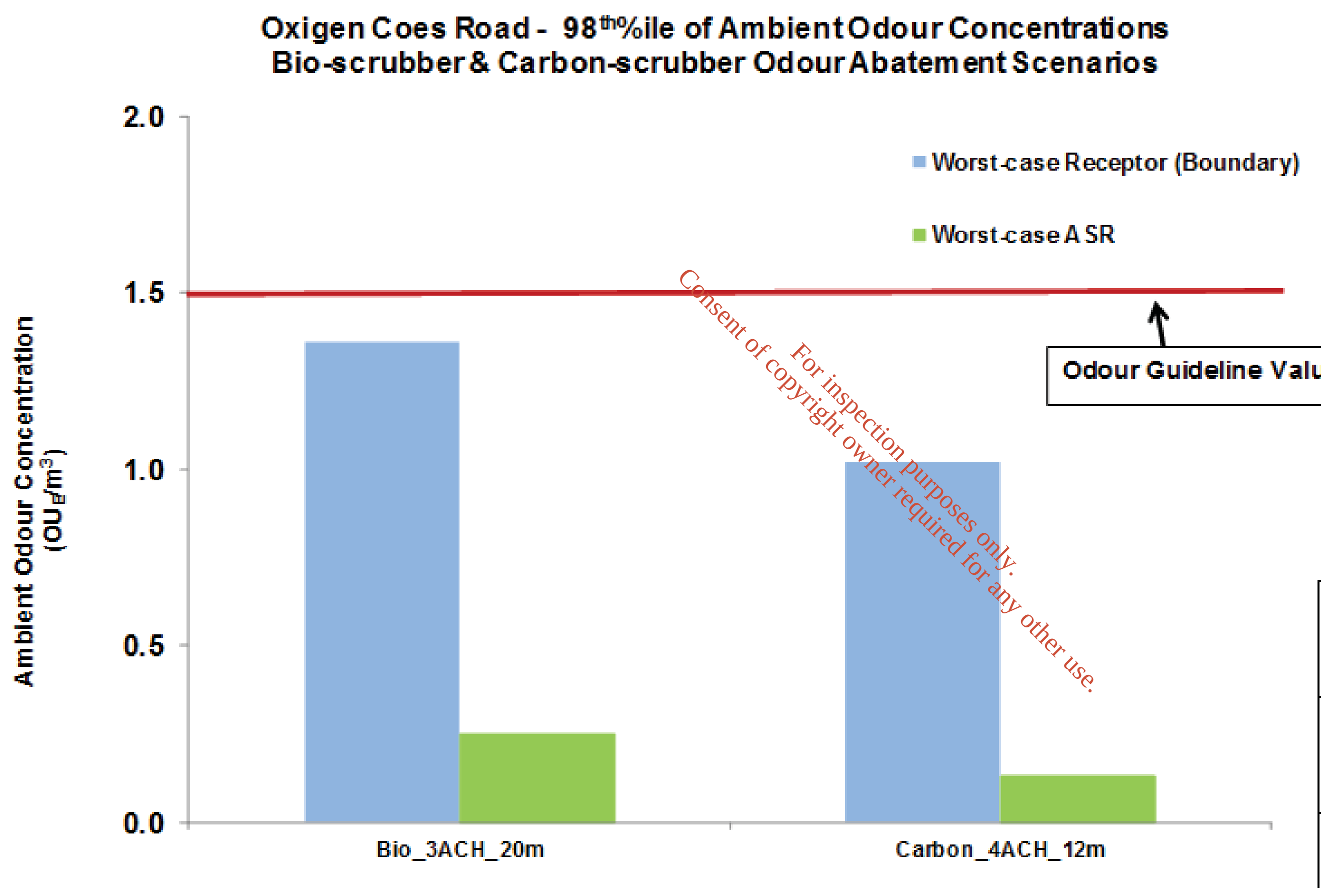
3.2 Optimum Odour Abatement Scenario

The results in Table 9 and Figure 3 demonstrate that the odour impact off-site decreases rapidly with distance from the proposed stack and that odour nuisance at the ASRs will likely be insignificant for both scenarios modelled.

Table 9 Predicted Odour Concentration At Worst-case Offsite Receptors and ASRs for Various Odour Abatement Scenarios – Oxigen Environmental Coes Road Waste Transfer & Recycling Facility (OU_E/m^3)

Model Scenario / Meteorological Year	**Predicted Odour Conc. (OU_E/m^3)**			
	Boundary Of Facility		**Nearest Residential Receptor**	
	99.5th%ile of 1-Hour Means	**98th%ile of 1-Hour Means**	**99.5th%ile of 1-Hour Means**	**98th%ile of 1-Hour Means**
Bio-scrubber, Half-Site, 3 ACH, 20m Stack / Year 2014	1.63	1.36	0.49	0.25
Carbon Scrubber, Half-Site, 4 ACH / 12m Stack / Year 2011 / 2012	1.34	1.02	0.30	0.13
Guideline Limit Values (OU_E/m^3)	*New Zealand Guidance*	*Ireland / UK Guidance*	*New Zealand Guidance*	*Ireland / UK Guidance*
	1.0	*1.5*	*1.0*	*1.5*

Red font indicates predicted concentration exceeds relevant guideline limit value



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Project

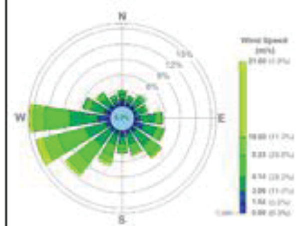
Oxigen Coes Road – Odour Abatement Modelling Study

Reference

EP/13/6839AR02_2

Figure 3

Ambient Odour Concentrations (98th%ile of 1-Hr Means) at Worst-case Receptor (OU_E/m^3) based on Two Abatement Options



Background Mapping from Google Earth

98th%ile of 1-Hour Mean Odour Concentrations

Maximum Concentration at ASR = 0.25 OU/m³

Maximum Concentration Outside Site Boundary = 1.36 OU/m³

Boundary Of Facility

N

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Reference

EP/13/6839AR02_2

Figure 4

Scenario:
Bio-scrubber
3ACH
Half Site Extraction
20m Stack

98th%ile of 1-Hour Mean Odour Concentrations (OU/m³) (Year 2014)

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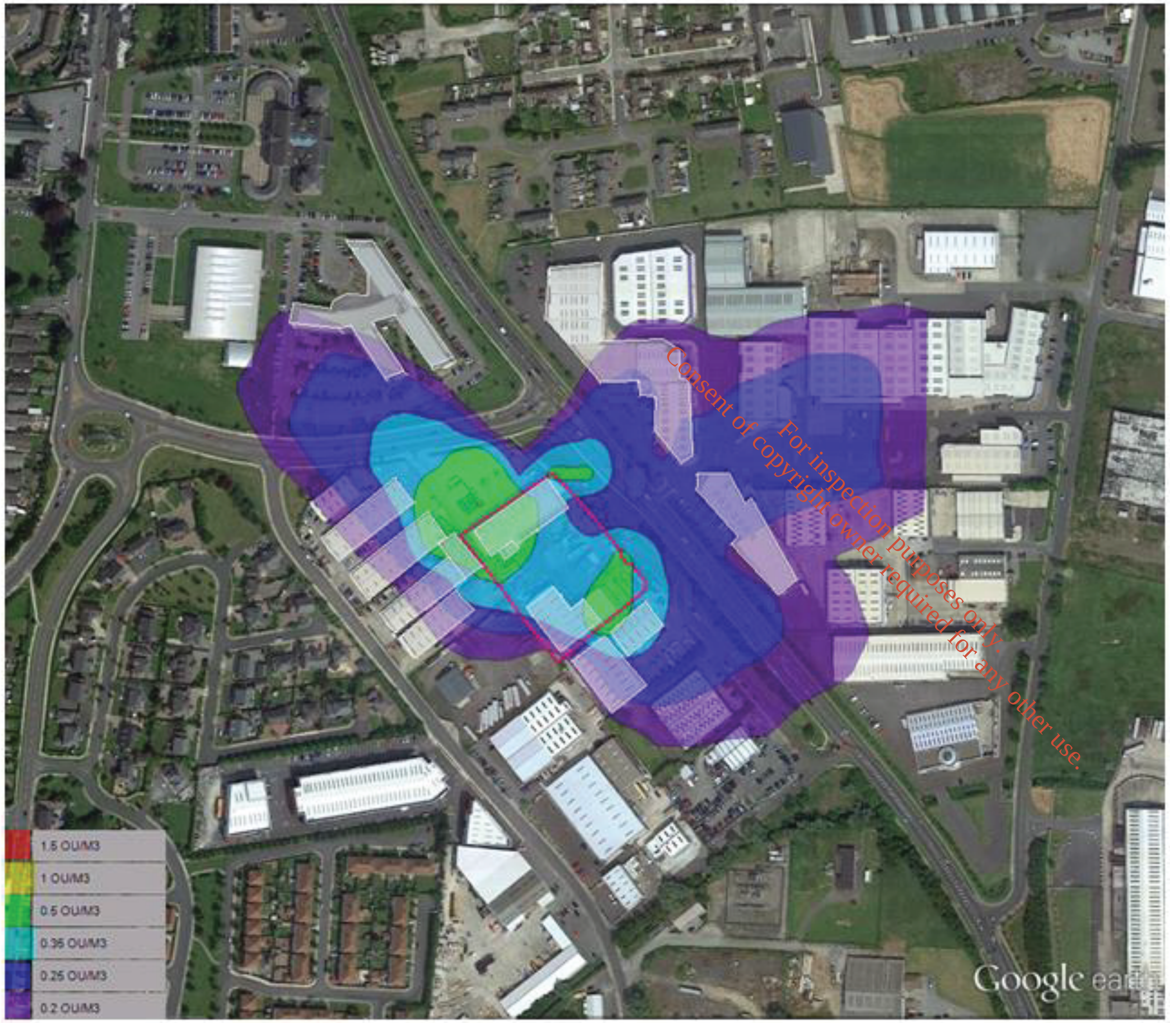

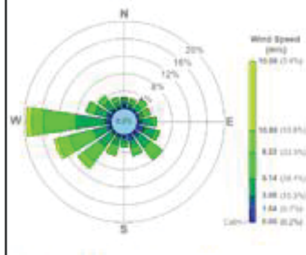

Background Mapping from Google Earth

98th%ile of 1-Hour Mean Odour Concentrations

Maximum Concentration at ASR = 0.13 OU/m^3

Maximum Concentration Outside Site Boundary = 1.02 OU/m^3

Boundary Of Facility

N

Project
Oxigen Coes Road – Odour Abatement Modelling Study

Reference
EP/13/6839AR02_2

Figure 5
Scenario:
Carbon-based Scrubber
4ACH
Half Site Extraction
12m Stack

98th%ile of 1-Hour Mean Odour Concentrations (OU/m^3) (Year 2012)

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3.3 Stack Height Assessment Results for Carbon-based Scrubber

A stack height of 20m (stack height for which planning permission has been granted) was applied for all bio-scrubber modelling scenarios. Various stack heights were modelled for the carbon-based scrubber scenario to determine the optimum stack height. Results for all stack height modelling scenarios are shown in Table 10 and Figure 6.

The dispersion modelling results presented in Table 10 and Figure 6 show that for the carbon-based scrubber, the predicted 98^{th}%iles of mean hourly odour concentrations range from 0.62 – 1.16 OU_E/m^3 (41 – 77% of the UK guideline limit value) at the worst-case boundary receptors based on a stack height ranging from 10 – 20m. The predicted 98^{th}%iles of mean hourly odour concentrations at the worst-case ASRs range from 0.08 – 0.14 OU_E/m^3 (5 - 9% of the UK guideline limit value) based on a stack height ranging from 10 – 20m.

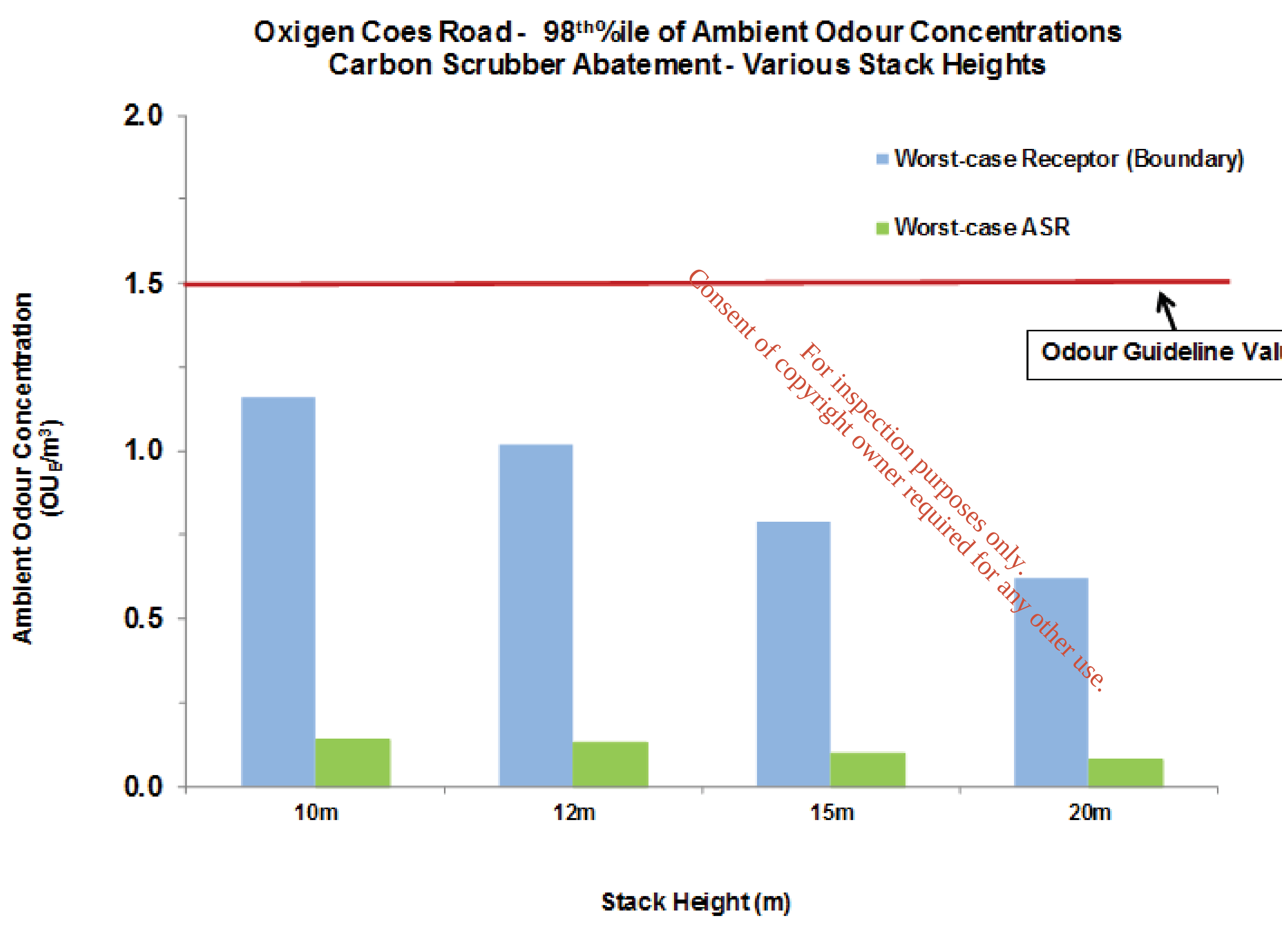
Results for the 99.5^{th}%ile of hourly mean odour concentrations from the carbon-based scrubber scenario exceeded the New Zealand guideline level at all worst-case boundary receptors for all stack heights from 10 - 20m. However, the predicted 99.5^{th}%ile of hourly odour concentrations at the ASRs are well below the site boundary concentrations. The 99.5^{th}%ile of mean hourly odour concentrations at the worst-case ASRs ranged from 0.18 – 0.34 OU_E/m^3 based on a stack height ranging from 10 – 20m, reaching at most 34% of the New Zealand guideline value.

The optimum stack height was selected by identifying the lowest stack height at which predicted impacts for the 98^{th}%ile of hourly mean concentrations at all receptors (boundary receptors and ASRs) were less than 75% of both guideline limit values. Thus, a stack height of 12m has been deemed the optimum stack height for carbon-based scrubber.

Table 10 Predicted Odour Concentration At Worst-case Offsite Receptors and ASRs for a Range of Stack Heights for the Carbon Scrubber Abatement Scenario – Oxigen Environmental Coes Road Waste Transfer & Recycling Facility (OU_E/m^3)

Model Scenario / Meteorological Year	**Stack Height**	**Predicted Odour Conc. (OU_E/m^3)**			
		Boundary Of Facility		**Nearest Residential Receptor**	
		99.5th%ile of 1-Hour Means	**98th%ile of 1-Hour Means**	**99.5th%ile of 1-Hour Means**	**98th%ile of 1-Hour Means**
Carbon Scrubber, 4 ACH / Year 2011 (99.9th%ile) & 2012 (98th%ile)	10m	1.61	1.16	0.34	0.14
	12m	1.34	1.02	0.30	0.13
	15m	1.18	0.79	0.25	0.1
	20m	1.18	0.62	0.18	0.08
Guideline Limit Values (OU_E/m^3)		*New Zealand Guidance*	*Ireland / UK Guidance*	*New Zealand Guidance*	*Ireland / UK Guidance*
		1.0	*1.5*	*1.0*	*1.5*

Red font indicates predicted concentration exceeds guideline limit value
Green font indicates optimum stack height



Project	Reference	Figure 6
Oxigen Coes Road – Odour Abatement Modelling Study	EP/13/6839AR02_2	Ambient Odour Concentrations (98th%ile of 1-Hr Means) at Worst-case Receptor (OU_E/m^3) based on Various Stack Heights for Carbon Scrubber

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4.0 CONCLUSION

AWN Consulting Ltd (AWN) was commissioned by Oxigen Environmental Coes Road Waste Transfer Station And Recycling Facility in Dundalk, County Louth to consider suitable odour abatement options in order to identify the most efficient means of ensuring that no odour nuisance will occur at nearby receptors (both residential and commercial premises).

The assessment took into account the proposed odour abatement system for which planning permission was provided by Louth County Council on 20/06/16. There are two proposed options for the abatement system; a bio-scrubber system and a carbon-based scrubber system. Both scenarios have been assessed to determine the optimum stack height and ensure no odour nuisance will occur beyond the site boundary.

The dispersion modelling results show that the 98^{th}%ile of mean hourly odour concentrations are in compliance with the UK guideline level at all off-site receptors modelled reaching 68% of the UK guideline limit value for the carbon-based scrubber scenario and 91% for the bio-scrubber scenario at the worst-case boundary receptors.

The predicted odour concentrations at the ASRs are well below the concentrations at the site boundary. The 98^{th}%ile of mean hourly odour concentrations complies with the UK guideline level for all abatement scenarios modelled. The worst-case odour concentration at an ASR for the bio-scrubber scenario was 17% of the UK guideline level. The worst-case odour concentration at an ASR for the carbon-scrubber scenario was 9% of the UK guideline level.

The dispersion modelling results were also compared with the more stringent New Zealand guideline level of 1.0 OU_E/m^3 for the 99.5^{th}%ile of hourly mean concentrations. The results show that the 99.5^{th}%ile of mean hourly odour concentrations exceeds the New Zealand guideline level at the worst-case boundary receptors for both abatement scenarios modelled. However, the predicted 99.5^{th}%ile of hourly odour concentrations at the ASRs are well below the site boundary concentrations. The 99.5^{th}%ile of mean hourly odour concentrations at the worst-case ASRs is 49% of the New Zealand guideline value for the bio-scrubber and 30% for the carbon-based scrubber scenario.

The modelling results demonstrate that the odour impact off-site decreases rapidly with distance from the proposed stack and that odour nuisance at the ASRs will likely be insignificant for both abatement options modelled. The bio-scrubber system requires a 20m stack to achieve adequate dispersion of odour while the carbon-based scrubber system requires a 12m stack.

In summary, both abatement system options will achieve compliance with the UK odour nuisance criterion (expressed as the 98^{th}%ile of hourly mean concentrations) for all off-site receptors. The more stringent New Zealand odour nuisance criterion (expressed as the 99.5^{th}%ile of hourly mean concentrations) was exceeded at the boundary receptors for both scenarios modelled but results for the closest ASRs (residential receptors) were well below the New Zealand guideline value.

References

(1) EPA (2010) Air Dispersion Modelling from Industrial Installations Guidance Note (AG4)
(2) USEPA (1998) AERMOD Description of Model Formulation
(3) USEPA (2005) Guidelines on Air Quality Models, Appendix W to Part 51, 40 CFR Ch.1
(4) USEPA (1995) User's Guide for the Industrial Source Complex (ISC3) Dispersion Model Vol I & II
(5) USEPA (2000) Seventh Conference on Air Quality Modelling (June 2000) Vol I & II
(6) USEPA (1998) Human Health Risk Assessment Protocol, Chapter 3: Air Dispersion and Deposition Modelling, Region 6 Centre for Combustion Science and Engineering
(7) USEPA (1999) Comparison of Regulatory Design Concentrations: AERMOD vs. ISCST3 vs. CTDM PLUS
(8) Schulman et al "Development and evaluation of the PRIME Plume Rise and Building Downwash Model" Air & Waste Management Association, 1998.
(9) Paine, R & Lew, F. "Consequence Analysis for Advancement of PRIME: an Advanced Building Downwash Model" Prepared for the EPRI, ENSR Document No. 2460-026-450 (1997).
(10) Paine, R & Lew, F. "Results of the Independent Evaluation of ISCST3 and ISC-PRIME" Prepared for the EPRI, ENSR Document No. 2460-026-3527-02 (1997).
(11) USEPA (2000) Estimating Exposure to Dioxin-Like Compounds Volume IV, Chapter 3 Evaluating Atmospheric Releases of Dioxin-Like Compounds from Combustion Sources (Draft)
(12) Water Environment Federation (1995) Odour Control in Wastewater Treatment Plants
(13) AEA Technology (1994) Odour Measurement and Control – An Update, M. Woodfield and D. Hall (Eds)
(14) Warren Spring Laboratory (1980) Odour Control – a concise guide, F.F.H. Valentine and A.A. North (Eds)
(15) C.R. Clarkson and T.H. Misselbrook (1991) "Odour emissions from Broiler Chickens" in "Odour Emissions from Livestock Farming", Elsevier Applied Science Publishers London
(16) J.E. McGovern & C.R. Clarkson (1994) in "The Development of Northumbrian Water Limited's Approach to Odour Abatement for Wastewater Facilities", Proceedings of Symposium on Odour Control and Prevention in the Water Industry
(17) CH2M Beca Ltd (2000) Analysis of Options For Odour Evaluation For Industrial & Trade Processes - Prepared for Auckland Regional Council
(18) Environment Agency (2002) IPPC Draft Horizontal Guidance for Odour Part 1- Regulation and Permitting.
(19) Environment Agency (2003) IPPC Draft Horizontal Guidance for Odour Part 2 – Assessment and Control.
(20) Ministry for the Environment New Zealand (2016) Good Practice Guide for Assessing and Managing Odour
(21) USEPA (1998) User's Guide to the AERMOD Meteorological Preprocessor (AERMET)
(22) Longhurst, P. (2002) "Emission Fluctuations & Site Controls At Waste Transfer Stations" Presented at the International Conference on Odour Management & Treatment, Cranfield University, UK
(23) Sironi et al (2006) "Odour Emission Factors for the Prediction of Odour Emissions from Plants for the Mechanical & Biological Treatment of MSW" Atmospheric Environment 40 (2006) 7632 – 7643
(24) Auer Jr, (1978) Correlation of Land Use and Cover with Meteorological Anomalies, Journal of Applied Meteorology 17(5):636-643.

APPENDIX I

Description of the AERMOD Model

The AERMOD dispersion model has been recently developed in part by the U.S. Environmental Protection Agency (USEPA)[2]. The model is a steady-state Gaussian model used to assess pollutant concentrations associated with industrial sources. The model is an enhancement on the Industrial Source Complex-Short Term 3 (ISCST3) model which has been widely used for emissions from industrial sources.

Improvements over the ISCST3 model include the treatment of the vertical distribution of concentration within the plume. ISCST3 assumes a Gaussian distribution in both the horizontal and vertical direction under all weather conditions. AERMOD with PRIME, however, treats the vertical distribution as non-Gaussian under convective (unstable) conditions while maintaining a Gaussian distribution in both the horizontal and vertical direction during stable conditions. This treatment reflects the fact that the plume is skewed upwards under convective conditions due to the greater intensity of turbulence above the plume than below. The result is a more accurate portrayal of actual conditions using the AERMOD model. AERMOD also enhances the turbulence of night-time urban boundary layers thus simulating the influence of the urban heat island.

In contrast to ISCST3, AERMOD is widely applicable in all types of terrain. Differentiation of the simple versus complex terrain is unnecessary with AERMOD. In complex terrain, AERMOD employs the dividing-streamline concept in a simplified simulation of the effects of plume-terrain interactions. In the dividing-streamline concept, flow below this height remains horizontal, and flow above this height tends to rise up and over terrain. Extensive validation studies have found that AERMOD (precursor to AERMOD with PRIME) performs better than ISCST3 for many applications and as well or better than CTDMPLUS for several complex terrain data sets[7-10].

Due to the proximity to surrounding buildings, the PRIME (Plume Rise Model Enhancements) building downwash algorithm has been incorporated into the model to determine the influence (wake effects) of these buildings on dispersion in each direction considered. The PRIME algorithm takes into account the position of the stack relative to the building in calculating building downwash. In the absence of the building, the plume from the stack will rise due to momentum and/or buoyancy forces. Wind streamlines act on the plume leads to the bending over of the plume as it disperses. However, due to the presence of the building, wind streamlines are disrupted leading to a lowering of the plume centreline.

When there are multiple buildings, the building tier leading to the largest cavity height is used to determine building downwash. The cavity height calculation is an empirical formula based on building height, the length scale (which is a factor of building height & width) and the cavity length (which is based on building width, length and height). As the direction of the wind will lead to the identification of differing dominant tiers, calculations are carried out in intervals of 10 degrees.

In PRIME, the nature of the wind streamline disruption as it passes over the dominant building tier is a function of the exact dimensions of the building and the angle at which the wind approaches the building. Once the streamline encounters the zone of influence of the building, two forces act on the plume. Firstly, the disruption caused by the building leads to increased turbulence and enhances horizontal and vertical dispersion. Secondly, the streamline descends in the lee of the building due to the reduced pressure and drags the plume (or part of) nearer to the ground, leading to higher ground level concentrations. The model calculates the descent of the plume as a function of the building shape and, using a numerical plume rise model, calculates the change in the plume centreline location with distance downwind.

The immediate zone in the lee of the building is termed the cavity or near wake and is characterised by high intensity turbulence and an area of uniform low pressure. Plume mass captured by the cavity region is re-emitted to the far wake as a ground-level volume source. The volume source is located at the base of the lee wall of the building, but is only evaluated near the end of the near wake and beyond. In this region, the disruption caused by the building downwash gradually fades with distance to ambient values downwind of the building.

AERMOD has made substantial improvements in the area of plume growth rates in comparison to ISCST3[(2)]. ISCST3 approximates turbulence using six Pasquill-Gifford-Turner Stability Classes and bases the resulting dispersion curves upon surface release experiments. This treatment, however, cannot explicitly account for turbulence in the formulation. AERMOD is based on the more realistic modern planetary boundary layer (PBL) theory which allows turbulence to vary with height. This use of turbulence-based plume growth with height leads to a substantial advancement over the ISCST3 treatment.

Improvements have also been made in relation to mixing height[(2)]. The treatment of mixing height by ISCST3 is based on a single morning upper air sounding each day. AERMOD, however, calculates mixing height on an hourly basis based on the morning upper air sounding and the surface energy balance, accounting for the solar radiation, cloud cover, reflectivity of the ground and the latent heat due to evaporation from the ground cover. This more advanced formulation provides a more realistic sequence of the diurnal mixing height changes.

AERMOD also contains improved algorithms for dealing with low wind speed (near calm) conditions. As a result, AERMOD can produce model estimates for conditions when the wind speed may be less than 1 m/s, but still greater than the instrument threshold.

APPENDIX II

Meteorological Data - AERMET PRO

AERMOD incorporates a meteorological pre-processor AERMET PRO(21). AERMET PRO allows AERMOD to account for changes in the plume behaviour with height. AERMET PRO calculates hourly boundary layer parameters for use by AERMOD, including friction velocity, Monin-Obukhov length, convective velocity scale, convective (CBL) and stable boundary layer (SBL) height and surface heat flux. AERMOD uses this information to calculate concentrations in a manner that accounts for changes in dispersion rate with height, allows for a non-Gaussian plume in convective conditions, and accounts for a dispersion rate that is a continuous function of meteorology.

The AERMET PRO 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. A morning sounding from a representative upper air station, latitude, longitude, time zone, and wind speed threshold are also required.

Two files are produced by AERMET PRO for input to the AERMOD dispersion model. The surface file contains observed and calculated surface variables, one record per hour. The profile file contains the observations made at each level of a meteorological tower, if available, or the one-level observations taken from other representative data, one record level per hour.

From the surface characteristics (i.e. surface roughness, albedo and amount of moisture available (Bowen Ratio)) AERMET PRO calculates several boundary layer parameters that are important in the evolution of the boundary layer, which, in turn, influences the dispersion of pollutants. These parameters include the surface friction velocity, which is a measure of the vertical transport of horizontal momentum; the sensible heat flux, which is the vertical transport of heat to/from the surface; the Monin-Obukhov length which is a stability parameter relating the surface friction velocity to the sensible heat flux; the daytime mixed layer height; the nocturnal surface layer height and the convective velocity scale which combines the daytime mixed layer height and the sensible heat flux. These parameters all depend on the underlying surface.

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 types was carried out in line with USEPA recommendations(2,24).