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ODOUR AND BIOAEROSOL IMPACT ASSESSMENT OF THE LITTLETON RECYCLING FACILITY TO BE LOCATED IN LITTLETON, CO TIPPERARY.

PERFORMED BY ODOUR MONITORING IRELAND ON BEHALF OF ACORN RECYCLING LTD.

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EXECUTIVE SUMMARY

Odour Monitoring Ireland was commissioned by Acorn Recycling Ltd to carry out a baseline bioaerosol survey in the vicinity of the proposed recycling facility to be located in Littleton, Co. Tipperary. In addition, a desktop predictive odour and bioaerosol impact assessment was performed using library odour and bioaerosol emission data and dispersion modelling techniques. The purpose of this assessment was to ascertain the baseline levels of bioaerosols in the vicinity of the proposed recycling facility and to predicted levels of odours and bioaerosols in the vicinity for the proposed site as a result of proposed operations. The output data from the dispersion modelling assessment can also be used to establish limit values from scheduled emission points for odour and bioaerosol emissions for the proposed site during operations.

AERMOD Prime (07026) was used to construct the basis of the odour and bioaerosol impact assessment in accordance with the standard methodology. Seven consecutive years of meteorological data (Dublin airport 2000 to 2006 inclusive) was used within the dispersion model. Fifty metre Cartesian spaced grid was used within the dispersion model examination.

Each aspect of the odour control equipment and management procedures were examined and used to construct the basis of an odour management plan for the site. Specific key stress points in the overall odour control system were identified and included into the overall process verification procedure to ensure the installation of effective containment and end of pipe control technologies. The overall structure of an odour management plan was developed for the facility operations to allow for efficient management and control of the odour management system.

The overall design of the odour control and management system for the Recycling Facility considered containment, minimisation and treatment of odours generated within the facility. All composting operations including treatment will be carried out indoors. The recycling building will be sealed with an internal impermeable layer to provide near 100% odour containment within the facility building. Traditional cladding techniques including joint taping and double clad will allow approximately 10 to 30 m^3 of odourous air leakage per hour per square metre of clad surface. This will be eliminated with the installation of this inner impermeable layer upon the facility building. Rapid roller doors will be fitted to the access doors of the Recycling building. Double containment and zoned ventilation was incorporated into the overall design. All first and second stage high load odours are self-contained within closed composting tunnels. Extraction air from these composting tunnels will be directed to the odour treatment system for deodorisation. The biofiltration system will provide an empty bed retention time of 53 seconds at full air volume capacity.

The overall design of the recycling facility odour control system incorporates proven design elements on other reference facilities. The design considered contingency for media changeout through the operation of four individual beds and preventative maintenance so as to ensure optimal performance. The inlet air distribution plenum floor will be designed to provide homogenous airflow throughout the full biofilter bed medium (i.e. take into account headloss through the plenum floor).

In terms of treatment capacity, it was assumed that the odour control system would achieve an odour threshold concentration of less than 1000 Ou_E/m^3 on the exhaust airstream at full volume capacity. This is well within the capacity of such treatment technologies. In terms of bioaerosol emission rate, library based published emission data from biofilters treating composting emissions was utilised. The maximum airstream concentrations of Aspergillus *f*, Total fungi and total Mesophillic bacteria was assumed to be 1,200 CFU/m^3, 5000 CFU/m^3 and 10,000 CFU/m^3, respectively.

Following completion of the odour and bioaerosol predictive impact assessment, it was concluded and demonstrated that the overall Recycling Facility design should not cause any odour or bioaerosol impact assuming emission limits are achieved. The following key elements were achieved within the assessment:

1. This document provides the structure and methodologies for the development of an overall odour management, minimisation and mitigation procedure for the relevant operating entities at the Recycling Facility.

2. The overall proposed odour mitigation techniques are based on sound engineering principles and proven design. All such technologies are in operation for the management of odours at many facilities in Ireland. The overall incorporation of robust preventative maintenance procedures, containment measures, focused extraction, zoned ventilation, and treatment will ensure that odours will not cause impact on the surrounding area and that the odour control system will operate at optimal capacity.

3. The Recycling Facility design will ensure compliance with the odour impact criterion contained in *Section 3.9*. All ground level concentration of odours will be less than the $\leq 1.5\ Ou_E/m^3$ at the 98^{th} percentile of hourly averages and $\leq 3.0\ Ou_E/m^3$ for the 99.5^{th} percentile of hourly averages for seven years of meteorological data. The implementation of odour management, minimisation and mitigation techniques and technologies will achieve the odour impact criterion when operating at optimal capacity.

4. The proposed Recycling facility will not cause any bioaerosol impact (Aspergillus *fumigatus*, Total fungi and Total Mesophillic bacteria) as determined using worst-case bioaerosols emission rates and dispersion assessment. All ground level concentration of bioaerosols will be well below the impact criterion proposed by the Environment Agency, UK.

5. This overall document provides a strategy and engineering design for the implementation of odour minimisation, mitigation and control of odour emissions from the Recycling Facility and provides the backbone development of an odour management and preventative maintenance plan for the processes. The guaranteed emission rates of odours will provide compliance with the odour impact criterion contained in *Section 5.1.1*.

1. Introduction and scope

This section will describe in brief the overall assessment and the scope of the works.

1.1 Introduction

Acorn Recycling commissioned Odour Monitoring Ireland to perform a baseline bioaerosol assessment and predictive odour and bioaerosol dispersion modelling impact assessment of the proposed Recycling Facility design to be located in Littleton, Co. Tipperary. An odour and bioaerosol impact assessment for the Recycling facility design was performed in order to determine the potential risks of odour and bioaerosols on air quality. Since the propose Recycling Facility will be fully enclosed with a sealed inner impermeable layer, only scheduled emission(s) from odour control system exhaust points will occur. Specific library based odour and bioaerosols emission limit guarantees were developed from library-based data and used to construct the basis of the dispersion modelling assessment.

This odour emission data including source characteristics was utilised in conjunction with dispersion-modelling techniques (i.e. AERMOD Prime 07026) to assess any odour and bioaerosol impact on the surrounding area in accordance with established odour and bioaerosol impact criterion. All odour and bioaerosol dispersion modelling was performed in accordance with the recommendations contained within the Irish and UK EPA guidance documents “Odour impacts and odour emission control measures for intensive agriculture, EPA, 2001 and H Horizontal Guidance notes Parts 1 and 2, UK Environment Agency for the site. AERMOD Prime was used to perform dispersion modelling assessment due to the significant probability of on site building wake effects (i.e. large buildings and low emission points). AERMOD Prime will provide more conservative dispersion estimates and thereby provide a more conservative predicted ground level concentrations of odour and bioaerosols above background thereby providing greater protection for the general population. In addition, AERMOD Prime is the model mechanism preferred by the Environmental Agency and USEPA. Seven years of consecutive meteorological data (Dublin Airport 2000 to Dublin Airport 2006 inclusive) was used within the dispersion modelling assessment to provide statistically significant prediction over 7 years.

Following the development of odour and bioaerosol emission rates/fluxes, two data sets for odour and bioaerosol emission rates were calculated to determine the potential impact of the proposed Recycling facility specimen design during its proposed operation.

These included:

Ref Scenario 1: Predicted overall odour emission rate from proposed Recycling facility specimen design with the incorporation of odour mitigation protocols (*see Table 5.1*).

Ref Scenario 2: Predicted overall bioaerosol emission rate from proposed Recycling facility with the incorporation of odour management systems (*see Table 5.2*).

The output data was analysed to calculate the following:

<u>Ref Scenario 1:</u>

- Predicted odour emission contribution of overall proposed Recycling facility operation to surrounding population (*see Table 5.1*), to odour plume dispersal at the 98^{th} percentile for a ground level concentration of less than or equal to 1.50 Ou_E m^{-3} (*see Figure 9.2*).
- Predicted odour emission contribution of overall proposed Recycling facility operation to surrounding population (*see Table 5.1*), to odour plume dispersal at the 99.5^{th} percentile for a ground level concentration of less than or equal to 3.0 Ou_E m^{-3} (*see Figure 9.3*).

Ref: Scenario 2:

- Predicted Aspergillus *f* emission contribution of overall proposed Recycling facility operation to surrounding population (*see Table 5.2*), to bioaerosol plume dispersal at the 1 hour maximum ground level concentration of less than or equal to 1.50 CFU m^{-3} (*see Figure 9.4*).
- Predicted Total fungi emission contribution of overall proposed Recycling facility operation to surrounding population (*see Table 5.2*), to bioaerosol plume dispersal at the 1 hour maximum ground level concentration of less than or equal to 1.50 CFU m^{-3} (*see Figure 9.5*).
- Predicted Total Mesophillic bacteria emission contribution of overall proposed Recycling facility operation to surrounding population (*see Table 5.2*), to bioaerosol plume dispersal at the 1 hour maximum ground level concentration of less than or equal to 1.50 CFU m^{-3} (*see Figure 9.6*).
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These odour and bioaerosol impact criterions were chosen for the proposed Recycling facility in order to ascertain the level of proposed impact to the surrounding population.

These computations give the odour and bioaerosol concentration at each Cartesian grid receptor location that is predicted to be exceeded for 0% (0 hours), 0.5% (44 hours) and 2% (175 hours) of seven years of hourly sequential meteorological data.

It was concluded that:

1. The overall proposed odour mitigation techniques are based on sound engineering principles and proven design. All such technologies are in operation for the management of odours at many facilities in Ireland. The overall incorporation of robust preventative maintenance procedures, containment measures, focused extraction, zoned ventilation, and treatment will ensure that odours will not cause impact on the surrounding area and that the odour control system will operate at optimal capacity.

2. The Recycling Facility design will ensure compliance with the odour impact criterion contained in *Section 3.9*. All ground level concentration of odours will be less than the $\leq$ 1.5 Ou_E/m^3 at the 98^{th} percentile of hourly averages and $\leq$3.0 Ou_E/m^3 for the 99.5^{th} percentile of hourly averages for seven years of meteorological data. The implementation of odour management, minimisation and mitigation techniques and technologies will achieve the odour impact criterion when operating at optimal capacity.

3. The proposed Recycling facility will not cause any bioaerosol impact (Aspergillus *fumigatus*, Total fungi and Total Mesophillic bacteria) as determined using worst-case bioaerosols emission rates and dispersion assessment. All ground level concentration of bioaerosols will be well below the impact criterion proposed by the Environment Agency, UK.

4. This overall document provides a strategy and engineering design for the implementation of odour minimisation, mitigation and control of odour emissions from the Recycling Facility and provides the backbone development of an odour management and preventative maintenance plan for the processes. The guaranteed emission rates of odours will provide compliance with the odour impact criterion contained in *Section 3.9*.

The following recommendations were developed during the study:

1. Odour management, minimisation and mitigation procedures as discussed within this document in general will be implemented at the proposed Recycling facility in order to prevent any odour impact in the surrounding vicinity.

2. The maximum allowable odour emission rate from the overall proposed Recycling facility and biofiltration system should not be greater than 38,250Ou_E s^{-1} (*see Table 5.1*) inclusive of the odour emission contribution from the abatement systems installed.
3. Maintain good housekeeping practices (i.e. keep yard area clean, etc.), closed-door management strategy (i.e. to eliminate puff odour emissions), maintain first and second stage composting within separate highly ventilated zone, install rapid roller doors, install impermeable layer on inner side of building clad and to implement an odour management plan for the operators of the Recycling facility. All odourous processes will be carried out indoors.
4. The odour and bioaerosol management plan should include a process description, management strategies for the prevention of emissions and a strict maintenance and management program for ensuring all odour and bioaerosol mitigation techniques remain operation at optimal capacity throughout all operational scenarios.
5. Operate the proposed Recycling facility within specifications to eliminate overloading and under loading, which may increase emissions from the processes.
6. When operational, it is recommended that the operator should process prove the operation of the facilities containment and mitigation systems through the use of pumped smoke integrity testing and performance measurements of the odour control systems (i.e. static pressure testing, flow testing, odour removal testing, equal air distribution testing, etc). This initial data should be recorded in the odour and bioaerosol management plan and be used as the basis for identifying any issues during future operations.

1.2 Scope of the works

The main aims of this assessment include:

- Perform a baseline bioaerosol assessment in accordance with recognised standard techniques in the vicinity of the proposed Recycling facility.
- Develop maximum allowable odour and bioaerosol emission data for the proposed Recycling facility.
- Perform predictive odour impact assessment in accordance with recognised assessment methodology in order to determine the potential of odour impact in the vicinity of the facility.
- Perform predictive bioaerosol impact assessment in accordance with recognised assessment methodology in order to determine the potential of bioaerosol impact in the vicinity of the facility.
- Provide a list of key criteria for odour minimisation and management at the facility. Odour Monitoring Ireland was provided the general proposed outline for odour mitigation at the facility.

1.3 Key decision-making processes in designing the odour management system

The following key design elements will be implemented into the odour control and management system for the proposed Recycling Facility. These included:

1. The prevention of generation and release of odours from the process is key to ensure no odour impact in the vicinity of the facility. These include the implementation of odour management procedures, which will take account of daily operations to reduce the overall generation of odours from the facility. These include:
    - Responsible operation and handling of material.
    - Closed-door management strategy.
    - Facility management and cleaning procedures for all surfaces in contact with material.
    - Material acceptance procedures to include enforcement of acceptance of enclosed material loads, type of material accepted into the facility and the procedures in handling materials within the facility.
    - Other elements include the implementation of an odour management plan and operation and maintenance management plans for the odour control system.
2. Containment of odours within the Recycling Facility building is essential to effective capture and treatment. Proposed containment measures to be use within this Odour Management system design include:
    - The installation of an impermeable inner layer on the entire Recycling building. This will eliminate the leakage of odours from the building skin. Traditional double and single clad will have a leakage of between 10 to 30 m^3 per hour per m^2 of clad surface area. The absence of such an inner layer, even with relative negative pressure maintenance, the wind pressure effects on the building (both positive pressure on the side of the building facing the wind and negative vacuum pressure effects on the back side of the building) would result in odour leakage. The inclusion of the inner impermeable layer in this design will prevent this occurrence.
    - Within this design, high risk and high load odour processes are separately contained which is in keeping with best practice and BAT. By separately containing the high risk high odour load processes, the release and build up of such odours in the headspace of the larger building area is prevented.
    - The Facility access doors will be fitted with rapid roller doors to prevent the release of odours through the access doors of the facility.
    - The facility will be fitted with self-closing louvers, which will open and close depending on door opening. This ensures fresh air entry into the building is controlled so that when doors are closed the fresh air will enter the building

through the louvers and when doors open the fresh air will enter through the open doors.

- The makeup air for composting will be drawn from within the building to ensure no positive pressure effects as a result on outside air been ventilated through the composting piles.
- The Recycling Facility building will be divided into dedicated independent zones of extraction to include the waste reception hall, primary and secondary in vessel composting tunnels.
- Treatment of odours using end of pipe technologies is essential to ensure compliance with the proposed specified ground level concentrations. For this design a biofiltration system will be used for end of pipe treatment. The biofiltration system will be operated at a maximum of 53 seconds empty bed retention time and incorporate equal air distribution on the inlet air plenum and essential nutrient dosing if required.

3. The proposed design incorporates a self-supporting air distribution plenum, which is proven in the area of large biofiltration systems such as the one proposed in this design. The design ensures that the pressure distribution of air under the floor will facilitate homogenous flow throughout the biofilter bed.
4. All instrumentation will be SCADA monitored, trended, alarmed (for trigger levels) and data logged. Each element of the monitoring system will be cross-checked by facility personnel through the odour management plan and maintenance schedule.

2. General overview of formation and odour emissions at Composting facilities

Unlike a mechanical process, the breakdown of organic materials is very difficult to stop. When the necessary components for a particular biological process are not present in adequate amounts, the microbial population will develop to favour micro organisms capable of capitalizing on the existing conditions. For example, when adequate oxygen is available, aerobic micro organisms will dominate the population. However a lack of oxygen will cause organisms that do not require oxygen (anaerobic micro organisms) to take over as the dominant group. These different micro organism types use alternative processes to degrade organic material. This diversity of options is very healthy for our planet as it ensures that most nutrients will be recycled through some biological pathway.

From a facility operation point of view, some of the microbial degradation processes are definitely preferable to others particularly because of the associated odours generated. Microbes utilizing odour-producing processes commonly take over when conditions are:

Anaerobic: processes occurring without adequate oxygen often release strong-smelling gases that many people find objectionable. Many of these odourous compounds are pervasive and likely to be noticed off-site.

Low carbon/nitrogen ratio (C:N): a composting mixture that has a low C:N ratio will often release ammonia as part of the degradation process. Ammonia is not a pervasive odour and disperses easily, and so is more likely to be noticed on-site than by neighbours. It is, however, a signal that nitrogen is being lost from your mixture, which will lower the nutritive value of the final composted product.

There are two main stages at which material in a Recycling Facility may to exposed to these odour-producing conditions: before entering the facility, and/or when in the active composting phase.

2.1 Characterisation of odour.

The sense of smell plays an important role in human comfort. The sensation of smell is unique to each human, varies with the physical condition of the person, the odour emission conditions and the individual's odourous education or memory. The smell reaction is the result of a stimulus created by the olfactory bulb located in the upper nasal passage. When the nasal passage comes in contact with odourous molecules, signals are sent via the nerve fibres in the olfactory bulb in the brain where the odour impressions are created and compared subjectively with stored memories which help form a individual's perceptions and social values. Since the smell is subjective some people will be hypersensitive and some will be less sensitive (anosmia). Therefore, the sense of smell is the most useful detection technique available as it specialises in synthesising complex gas mixtures sensation to the human nose rather than analysing the individual chemical compound (Sheridan, 2000).

2.2 Odour qualities

An odour sensation, which may lead to a complaint, consists of a number of inter-linked factors. These include:

- Odour threshold/concentration.
- Odour intensity.
- Hedonic tone.
- Quality/Characteristics.
- Component characteristics.

The odour threshold concentration dictates the concentration of the odour in Ou_E m^{-3}. The odour intensity dictates the strength of the odour. The Hedonic quality refer to the determination of pleasantness/unpleasantness. Odour quality/characteristics indicated similarity to of the odour to a known smell (such as turnip, like dead fish, flowers, etc.). Individual chemical component identity determines the individual chemical components that constitute the odour (i.e. hydrogen sulphide, methyl mercaptan, carbon disulphide, etc.). Once odour qualities are determined, the overall odour impact can be assessed. Odour impact assessment can then be used to determine if an odour minimisation strategy is to be required and if so, the most suitable technology. Furthermore, by suitably characterising the odour through complaint logs, the most likely source of the odour can be determined, enabling the implementation of immediate odour mitigation techniques to prevent such emission in the future.

2.3 Perception of emitted odours.

Complaints are the primary indicators that odours are a problem in the vicinity of any facility. Perceptions of odours vary from person to person, with several conditions governing a person's perception of odour:

Control: A person is better able to cope with an odour if they feel it can be controlled.

Understanding: A person can better tolerate an odour impact if they understand its source.

Context: A person reacts to the context of an odour much as they do to the odour itself (i.e. waste odour source).

Exposure: When a person is constantly exposed to an odour: They may lose their ability to detect that odour. For example, a plant operator who works in the facility may grow immune to the odour *or* their tolerance to the odour reduces and they complain more frequently.

Based on these criteria, we can predict that odour complaints are more likely to occur when:

- A new facility is located areas where people are unfamiliar with facility's purposes;

- The establishment of a new process within a facility (i.e. composting plant, etc.);
- Or when an urban population encroaches on an existing facility.

The ability to characterise odours emitted from a facility will help to develop a better understanding of the impact of the odour on the surrounding vicinity. It will also help to implement and develop better techniques to minimise/abate odours using available technologies and engineering design. The correct recording of odour complaints data is very important to resolving any odour impact.

2.4 Characteristics of composting odours

Odours from composting arise mainly from the following sources:

- The uncontrolled anaerobic biodegradation of proteins and carbohydrates to produce unstable intermediates in the waste inlet stream,
- Directly from the accepted materials and bad material handling/management practices,
- Incorrect processing of waste and composting material,
- Positive wind pressure on buildings, open doors and temperature increases will increase positive pressure within waste transfer stations and biological treatment facilities and may cause the fugitive release of odour from such facilities. Incorporating efficient air extraction systems maintaining negative ventilation and appropriate treatment of extracted air within an odour control system will reduce/eliminate odour impact.

Odours are generated by a number of different components, the most significant being the sulphur containing compounds (thiols, Mercaptans, hydrogen sulphide), volatile fatty acids (butyric acid, valeric acid), amines (methylamine, Dimethylamine), phenols (4-methylphenol), chlorinated hydrocarbons (trichloroethylene, etc), etc. (Dawson et al. 1997). Most of these compounds have very low odour threshold concentrations as illustrated in *Table 2.1*.

Most of these compounds have hedonically offensive characters as illustrated in *Table 2.1*. Different concentrations and mixtures of these compounds can intensify or reduce odour threshold concentration, determined as synergism and antagonism respectively. Hobbs et al., (2002) performed studies on various odours commonly found in pig odour. This study concluded that 4-methyl phenol had a negative effective (reduced the overall odour threshold concentration) on perceived odour concentration when mixed with other odourants.

Table 2.1. Commonly encountered odour precursors in air stream from

Chemical component	Odour character
Ammonia	Pungent, sharp, irritating
Methylamine	Fishy, Putrid Fishy
Trimethylamine	Fishy, Pungent fishy
Dimethylamine	Putrid fishy
Ethylamine	Ammonia like
Triethylamine	Fishy
Pyridine	Sour, putrid fishy
Indole	Faecal, nauseating
Skatole	Faecal, nauseating
Hydrogen Sulphide	Rotten eggs
Methyl mercaptan	Rotten cabbage
Ethyl mercaptan	Decaying cabbage/flesh
Propyl mercaptan	Intense rotten vegetables, Unpleasant
Allyl mercaptan	Garlic, coffee
Benzyl mercaptan	Skunk, unpleasant
Thiocresol	Skunk
Dimethyl disulphide	Rotten vegetables
Carbon disulphide	Rubber, intense sulphide
Acetic acid	Vinegar
Butyric acid	Rancid
Valeric acid	Sweaty, rancid
Propionic acid	Rancid, pungent
Hexanoic acid	sharp, sour, rancid odour, goat-like odour
Formaldehyde	Pungent, medicinal
Acetone	Pungent, fruity, sweet
Butanone	Sweet, solventy
Acetophenone	Sweet pungent odour of orange blossom or jasmine
Limonene	Intense orange/lemons
Alpha Pinene	Intense pine, fresh
THN Tetrahydronaphthalene	Meat

O'Neill & Phillips et al. (1992) and Suffet at al., 2004.

2.5 Odourous compound formation in composting plants

Material coming onto a site may already have developed a strong odour due to the nature of the material itself or to the way it has been stored. For example:

Material stored under anaerobic conditions: fresh organic material stored in plastic bags or insufficiently ventilated containers. The potential for odour increases if the organic material has high moisture content, has been kept in an anaerobic state for a number of days, and/or has been subjected to high temperature and direct sunlight. (e.g. grass clippings, fresh plant material, wet leaves, food waste, etc).

Material that has a low C:N ratio: this can be a particular problem if the material also has a high moisture content. (e.g. sewage sludge or other high nitrogen sludge's, fish processing or slaughterhouse residuals, food waste, etc).

MANAGEMENT STRATEGIES

Such feedstock is often invaluable because of the nitrogen and moisture they provide to the composting recipe. Proactive management strategies can help you to capitalize on the benefits moist low C:N ratio material offer while minimising the potential for offensive odour release, the following strategy should be considered at minimum:

- Knowledge of delivery schedule or pattern: Knowing when a potentially odorous load is likely to arrive facilitates readiness to deal with the material immediately, minimising the likelihood for potential odours to escape off-site.
- An implementable plan in place for dealing with materials likely to be offensive. Such a plan should include the following:
    - Incorporate the material quickly. Have a stock of porous, high-carbon material on hand, which can be mixed immediately with the incoming material. Examples, currently being used with success include wood chips, wood shavings, or sawdust, dry leaves and straw. This helps to balance the C:N ratio, absorb the moisture in wet materials and add porosity so that the mixture can remain aerobic.
    - Handle loads of potentially offensive feedstock inside an enclosed work area ventilated by an odour control system.
    - If the material must be stored before blending/handling, add a blanket of saw dust or overs to cover the material to minimise potential odourous emissions.
    - Ensure the facility can process the organic material as soon as or within a short time frame (24 hrs) it enters the facility.

OPTIMISING THE PROCESS

The following basic elements:

1. Check your carbon to nitrogen ratio (C:N) when preparing the composting mix: recipes with a C:N ratio of less than 25 are likely to lose nitrogen in the form of ammonia. A ratio of 25-40 is better, with 30 being considered ideal for most materials.
2. Check the moisture content of the composting recipe: while too little moisture will slow the composting process, too much moisture will cause anaerobic conditions—as all of the small spaces in the material will be filled with water and not enough space is available for the air required by aerobic micro organisms. Moisture content between 40 and 60% is considered a good air/moisture balance to support aerobic processes.
3. Above neutral pH recipe. Basic mixtures above pH 8.5 will release nitrogen as ammonia.
4. Porosity is important in formulating the composting mix: a mixture consisting of nothing but fine textured materials will likely become compacted as the composting process develops, preventing air from penetrating the pile. To maintain porosity when composting include some coarser material (such as wood shavings or chips) so that air can continue to move freely through the material as it breaks down. This is particularly important in systems where the material will not be turned during active composting.
5. Ensure that material is aerated to maintain aerobic conditions. The continuous monitoring of interstitial Oxygen within the composting mix will help ensure maintenance of appropriate Oxygen levels within the material.
6. Appropriate pile size, which is not too deep: air will not be able to infiltrate the compost pile homogenously. If the pile is too deep, this results in various maturation rates for the composting process.

3. Materials and methods

This section describes the materials and methods use for the baseline bioaerosol and desktop odour and bioaerosol dispersion modelling assessment. This section will also include the backbone odour management methodology to be used at Littleton Recycling facility to ensure no odour and bioaerosol impact.

3.1 Baseline sampling and locations

Figure 8.1 and *Table 3.1* illustrates the sample locations in the vicinity of the proposed site for bioaerosols, sniff odour and Hydrogen sulphide.

Table 3.1. Monitoring locations and parameters monitored.

Monitoring locations	X cord (m)	Y cord (m)	Monitoring description
A1	219043	152275	H2S, Sniff odour
A2	219209	152125	H2S, Sniff odour
A3	219242	152025	H2S, Sniff odour
A4	219122	151814	H2S, Sniff odour
A5	219073	151894	H2S, Sniff odour
A6	219001	151889	H2S, sniff odour and Bioaerosols
A7	218895	151848	H2S, Sniff odour and Bioaerosols
A8	218879	151975	H2S, Sniff odour
A9	218901	152083	H2S, Sniff odour, and Bioaerosols
A10	219000	152086	H2S, Sniff odour and Bioaerosols
A11	219028	152177	H2S, Sniff odour

3.2 Meteorological data

Table 3.2 illustrates the average wind direction during the one-day monitoring period. Average wind speed was low breeze to breezy during the sampling. Cloud cover was high with an octave rating of 5 to 7 (i.e. on a 8 point scale). Barometric pressure was approximately 1005 mbar. Relative humidity was high with a range of readings from 70 to 90% while temperature was low from 10 to 15 degrees Celsius. This would be typical for this time period of the year in Southern Ireland.

Table 3.2 Meteorological conditions during the one-day monitoring period

Parameter	Day 1- 19/03/2008
Wind direction (From)	180 to 270
Wind speed (m s^{-1})	4 to 7
Cloud cover (Octaves)	5 to 7
Barometric pressure	1003 to 1008
Temperature (^{0}C)	10 to 15
Relative humidity (%)	70 to 90

3.3 Bioaerosols monitoring

Monitoring of bioaerosols was performed in strict accordance with available information and advice including the sources:

1. Standardised Protocol for the Sampling and Enumeration of Airborne Micro-organisms at Composting Facilities. (1999). The UK Composting Association.

2. Macher, J. (1999). Bioaerosol assessment and control. American Conference of Government Industrial Hygienists, Kemper Woods Centre, 1330 Kemper Meadow Drive, Cincinnati, OH.
3. Direct Laboratories, (formerly ADAS), Woodthorne, Wergs Road, Wolverhampton, WV6 8QT.
4. SKC Inc, 863 Valley View Road, Eighty-four, PA, 15330.

Impactor plate sampling was carried out in accordance with the document "Sampling Protocol for the Sampling and Enumeration of Airborne Micro-organisms at Composting facilities, The Composting Association, UK.

One sampling technique was employed namely:

- Biostage single stage 400 hole impactor (SKC Inc, PA)- This is directly equivalent to the Andersen N6 single stage impactor and meets the requirements of NIOSH 0800 and NIOSH 0801 biological sampling standards (i.e. this impactor is a direct copy of the Andersen N6 impactor with added benefits including the Surelok system which prevents any air leakages. This was an inherent problem of the Andersen N6 single stage impactor).

Generally, sampling times of 10 to 15 minutes were used to assess ambient background levels using the impactor plates as longer sampling times can lead to desiccation of the plate and impacted microbes. Sampling times of 10 minutes were used for the duration of this study.

The Biostage (i.e. Andersen N 6 equivalent impactor) was calibrated using a Bios Primary flow calibrator to a volumetric flow rate of 28.3 *litres* min^{-1} and Hi Flow 30 battery operated automatically timed pumps were used for suction airflow.

The Biostage impactors were fixed to tripods ensuring an adjustable sampling height of between 0.40 to 1.9 metres. The sampling height was fixed at 1.5 to 1.8 metres. Two Biostage impactors were used throughout the study period. The use of correctly designed sampling equipment ensured correct operation at all times throughout the study period.

The Irish Equine Centre and Oldcastle laboratories (ISO 17025 accredited) tested two medias including Malt Extract Agar media (MEA) for Aspergillus *fumigatus*, Total fungi and standard plate count agar (TVC) for total Mesophillic bacteria. MEA media facilitates the sporulation of Aspergillus *fumigatus*, which is used to identify the species. Sterile fresh 90mm plates were supplied by Cruinn Diagnostics accredited laboratory services and placed in sealed coolers. Fresh plates were used to eliminate the formation of a skin upon the plate upper surface (i.e. develops with age). It was thought that this may cause problems while using an impaction method (i.e. particle bounce off).

Bioaerosol samples were taken at monitoring locations A6, A7, A9 and A10 (two upwind and two downwind) in the vicinity of the proposed facility. The bioaerosol monitoring results are presented in *Table 6.1*.

3.4. Transport of bioaerosol samples

All sampling plates during monitoring were allowed to equilibrate to ambient temperature before sampling. This allowed for the development of less harsh conditions upon impacted bioaerosols. It was also noticed that cooled plates (approximately 5^0C) formed an outer "skin" which could facilitate particle bounce. Following equilibration, it was apparent from observation, better "knitting" of impactor plates occurred. Before each sampling event, the Biostage impactors were sterilised using cotton wool and 70% iso-proponal. The impactors were autoclaved for complete sterilisation before sampling. Once sampled, all agar plates were inverted, sealed with parafilm, placed within a flexible plastic container, and neatly stacked within a mobile cooler for delivery to Irish Equine Centre and Oldcastle laboratories. Once received, they were incubated at the appropriate temperatures of 30^0C for Total viable counts (i.e. Mesophillic bacteria) and 37^0C for Aspergillus *fumigatus* and Total fungi by the laboratory technician. Results were received within 10 days following sampling.

3.5. H_2S measurement

H_2S is commonly associated with waste handling and composting operations. It is used as an indicator gas for the assessment of significant odour nuisance in the vicinity of wastewater treatment plants and composting facilities. Hydrogen sulfide has a strong unpleasant odour. The threshold for detection of this odor is low, but shows wide variation among individuals. H_2S has established ambient air concentrations limits to prevent odour nuisance. The World Health Organization (WHO) recommends that in order to avoid substantial complaints about odour annoyance among the exposed population, hydrogen sulphide concentrations should not be allowed to exceed 0.005 ppm (5 ppb; 7 µg m^{-3}), with a 30-minute averaging time. The OEHHA (2000) adopted a level of 8 ppb (10 µg m^{-3}) as the chronic Reference Exposure Level (cREL) for use in evaluating long-term emissions from hot spots facilities. A level of 7 µg m^{-3}, based on a 30 minute averaging time, was estimated by a Task Force of the International Programme on Chemical Safety (IPCS) (1981) to not produce odour nuisance in most situations. On the other hand, the current California Ambient Air Quality standard for hydrogen sulfide, based on a 1-hour averaging time, is 42 µg m^{-3} (30 ppb). On this basis, the proposed REL of 10 µg m-3 (8 ppb) is likely to be detectable by many people under ideal laboratory conditions, but it is unlikely to be recognized or found annoying by more than a few. It is therefore expected to provide reasonable protection from odor annoyance in practice. Based on a review of 26 studies, the average odor detection threshold ranged from 0.00007 to 1.4 ppm (Amoore, 1985). Hydrogen sulfide is noted for its strong and offensive odour. Laboratory experiments performed by Sheridan (2003) in California measured H_2S detection threshold at 2 µg m^{-3} while the recognition odour threshold was 22 µg m^{-3}. At the current California Ambient Air Quality Standard (CAAQS) of 0.03 ppm, the level would be detectable by 83% of the population and would be discomforting to 40% of the population. These estimates have been substantiated by odour complaints and reports of nausea and headache (Reynolds and Kauper 1985) at 0.030 ppm H_2S exposures from geyser emissions.

The only instrument capable of providing comparison with such reference levels is a Jerome meter. This is a real time data-logging H_2S gold leaf analyser for the measurement of ambient hydrogen sulphide levels (Sheridan, 2003). An ambient baseline H_2S profile monitoring exercise was carried out in the vicinity of the proposed site using a pre-calibrated Jerome 631 X H_2S gold leaf continuous analyser with data logging capabilities. Samples were taken approximately 1.20 meter above ground level. The Jerome meter is a real time analyser with a range of detection from 3 ppb to 50 ppm. The Jerome meter was allowed to sample continuously at each monitoring locations A1 to A11 on the 19th March 2008. Every 1-minute, the average H_2S ambient air concentration was recorded. Average H_2S concentrations were computed from replicate samples at each location to allow for establishment of ambient H_2S baseline levels in the vicinity of the proposed facility. The H_2S monitoring results are presented in *Table 6.2*.

3.6 Odour by sniff assessment

Due to the fact that point source sampling and analysis via a laboratory based olfactometer is not a realistic, sensitive or accurate in methodology for the assessment of ambient baseline odours, sniff assessment in accordance with international recognised methodologies was use (adapted VDI-Guideline 3940-Determination of Odour in Ambient Air by field Inspectors and published Environment Agency Guidance document for the waste sector). Background olfactometry was not performed for the following technical reasons:

While point sampling, the dilutional affects of the atmosphere cannot be accounted for in the acquired sample. Odours in ambient air like any air contaminate fluctuate significantly due to vertical and horizontal deviations in the predominant wind field. While sampling, some odourous air will be captured within the sample bag along with ambient fresh air. The ratio of fresh air to odourous air cannot be calculated so hence the "real" concentration downwind/upwind cannot be measured.

Odour sampling equipment and the lab based olfactometer while odourless will have a very small background odour. This can interfere when measuring at such low odour concentrations and result in false positive results.

Lab based olfactometry at best has a ±20% accuracy not taking account of variations in the panel. The fact that olfactometry is based on geometric steps in dilution and also the fact that the realistic lower limits of detection of conventional olfactometry is from 32 to 100 Ou_E/m^3, the measurement of downwind/upwind odour concentrations is severely compromised.

These conclusions were drawn through discussion with world experts in this area in April 2004 at the specialty conference on odours in Seattle (Sheridan, 2004, McGinley, 2004, Jiang, 2004). Such worldwide experts agreed that lab-based olfactometry was not designed for ambient monitoring of odours. Other experts such as Van Lavenghove in the University of Ghent, Belgium have reverted to sniff assessment for the validation of dispersion models (VDI Guidelines 3940). Keeping this in mind, direct source sampling combined with dispersion modeling must be performed in order to assess downwind odour impact for an operating facility. This predictive assessment has been performed and is presented in this application.

One trained sniffer allocated odour extent, intensity levels and odour characters/quality to any odour plumes detected. This is a proven method for many facilities and countries in Europe and it is highly publicised (Sheridan, 2002).

This is a very useful fast test, which can provide a subjective "snap-shot" assessment of the presence, strength and character of an odour either within an installation boundary, at the boundary or in the area/community surrounding the site.

General considerations: When undertaking an assessment, the following guideline procedures need to be considered.

- Consideration needs to be given to evaluating the sensitivity of the person(s) carrying out this form of assessment. If necessary this can be confirmed by means of olfactometry. Obviously anyone with a poor sense of smell should be excluded. It is important to remember that regular exposure to a particular odour can produce olfactory fatigue.
- The person(s) undertaking the assessment should avoid strong food or drinks, including coffee, for at least half an hour before undertaking the assessment. Strongly scented toiletries should be avoided as well as the use of deodorisers in the vehicle used during the assessment.
- Colds, sinusitis or sore throat can affect the sense of smell. Planned assessments should be re-scheduled if possible or undertaken by someone else, otherwise the fact should be clearly noted on the report.
- The health and safety of the individual undertaking the assessment should not be compromised.

Testing location:

- Where possible move from areas of weaker strength to stronger odours.
- To evaluate a proposed development you should start upwind of the area,
- When investigating offsite installation odour start well down wind and move towards the installation. It should be remembered that an odour may change in character over a distance as a result of dilution and/or conversion.

Testing method:

1. Sense of smell verified in normal range (by means of Olfactometry on (19/03/08),
2. Survey started upwind of proposed development,
3. Survey carried out at selected points around the boundary of the proposed development,

4. A survey timeline of up to 10 minutes was utilised at each location. During this time the intensity and extent of any detected odour was evaluated.
5. All relevant weather information was recorded,
6. Data collated & recorded:
    - **DETECTABILITY / INTENSITY:** 1 No detectable odour, 2 Faint odour (barely detectable, need to stand still and inhale facing into the wind), 3 Moderate odour (odour easily detected while walking & breathing normally), 4 Strong odour, 5 Very strong odour (possibly causing nausea).
    - **EXTENT & PERSISTENCE:** (assuming odour detectable, if not then 0) 1 Local & transient (only detected on installation or at installation boundary during brief periods when wind drops or blows), 2 Transient as above, but detected away from installation boundary, 3 Persistent, but fairly localized, 4 Persistent and pervasive up to 50m from plant or installation boundary, 5 Persistent and widespread (odour detected >50 m from installation boundary)
    - **SENSITIVITY OF LOCATION WHERE ODOUR DETECTED:** (assuming detectable, if not then 0) 1 Remote (no housing, commercial/industrial premises or public area within 500m), 2 Low sensitivity (no housing, etc. within 100m of area affected by odour), 3 Moderate sensitivity (housing, etc. within 100m of area affected by odour), 4 High sensitivity (housing, etc. within area affected by odour), 5 Extra sensitive (complaints arising from residents within area affected by odour).
    - **OFFENSIVENESS** (taking into account strength, persistence and typical frequency of exposure): 1 Potentially offensive, 2 Moderately offensive, 3 Very offensive.

Since the function of sniff assessment is to ascertain level of impact and plume location no emissions were calculated. This qualitative and semi-quantitative survey tentatively determines the odour character and the likely hood of impact for the perceived odour concentration. During the survey on the 19th March 2008, no background odours were detected at the site of the proposed facility. The n-butanol detection threshed of the sniffer was 28 ppb, which is within the 20 to 80 ppb range specified within the EN13725:2003. A more detailed overview of results is presented in *Table 6.2*.

3.7 Odour and bioaerosol emission rate calculation

The measurement of the strength of a sample of odourous / bioaerosol air is, however, only part of the problem of quantifying odour / bioaerosol. Just as pollution from a stack is best quantified by a mass emission rate, the rate of production of an odour / bioaerosol is best quantified by the odour / bioaerosol emission rate. For a chimney or ventilation stack, this is equal to the odour threshold concentration (Ou_E m^{-3}) and Colony forming unit concentration (CFU/m^3) of the discharge air multiplied by its flow-rate (m^3 s^{-1}). It is equal to the volume of air contaminated every second (Ou_E s^{-1} / CFU/s). The odour / bioaerosol emission rate can be used in conjunction with dispersion modelling in order to estimate the approximate radius of impact or complaint (Hobson et al, 1995).

3.8 Dispersion modelling

3.8.1 Atmospheric dispersion modelling of odours: What is dispersion modelling?

Any material discharged into the atmosphere is carried along by the wind and diluted by wind turbulence, which is always present in the atmosphere. This process has the effect of producing a plume of air that is roughly cone shaped with the apex towards the source and can be mathematically described by the Gaussian equation. Atmospheric dispersion modelling has been applied to the assessment and control of odours for many years, originally using Gaussian form ISCST 3 and more recently utilising advanced boundary-layer physics models such as ADMS and AERMOD (Keddie et al. 1992). Once the odour emission rate from the source is known, ($Ou_E\ s^{-1}$), the impact on the vicinity can be estimated. These models can effectively be used in three different ways: firstly, to assess the dispersion of odours and to correlate with complaints; secondly, in a “reverse” mode, to estimate the maximum odour emissions which can be permitted from a site in order to prevent odour complaints occurring; and thirdly, to determine which process is contributing greatest to the odour impact and estimate the amount of required abatement to reduce this impact within acceptable levels (McIntyre et al. 2000). In this latter mode, models have been employed for imposing emission limits on industrial processes, odour control systems and intensive agricultural processes (Sheridan et al., 2002).

3.8.2 AERMOD Prime

The AERMOD model was developed through a formal collaboration between the American Meteorological Society (AMS) and U.S. Environmental Protection Agency (U.S. EPA). AERMOD is a Gaussian plume model and replaced the ISC3 model in demonstrating compliance with the National Ambient Air Quality Standards (Porter et al., 2003) AERMIC (USEPA and AMS working group) is emphasizing development of a platform that includes air turbulence structure, scaling, and concepts; treatment of both surface and elevated sources; and simple and complex terrain. The modelling platform system has three main components: AERMOD, which is the air dispersion model; AERMET, a meteorological data pre-processor; and AERMAP, a terrain data pre-processor (Cora and Hung, 2003).

AERMOD is a Gaussian steady-state model which was developed with the main intention of superseding ISCST3 (NZME, 2002). The AERMOD modeling system is a significant departure from ISCST3 in that it is based on a theoretical understanding of the atmosphere rather than depend on empirical derived values. The dispersion environment is characterized by turbulence theory that defines convective (daytime) and stable (nocturnal) boundary layers instead of the stability categories in ISCST3. Dispersion coefficients derived from turbulence theories are not based on sampling data or a specific averaging period. AERMOD was especially designed to support the U.S. EPA’s regulatory modeling programs (Porter at al., 2003)

Special features of AERMOD include its ability to treat the vertical in-homogeneity of the planetary boundary layer, special treatment of surface releases, irregularly-shaped area sources, a three plume model for the convective boundary layer, limitation of vertical mixing in the stable boundary layer, and fixing the reflecting surface at the stack base (Curran et al., 2006). A treatment of dispersion in the presence of intermediate and complex terrain is used that improves on that currently in use in ISCST3 and other models, yet without the complexity of the Complex Terrain Dispersion Model-Plus (CTDMPLUS) (Diosey et al., 2002).

3.9 Establishment of odour impact criterion for composting facility odours

Odours from Composting operations arise mainly from the volatilisation of odourous gases from:

- The uncontrolled anaerobic biodegradation of proteins and carbohydrates to produce unstable intermediates in the waste inlet stream,
- Directly from the accepted materials and bad material handling/management practices, Incorrect processing of waste and composting material,
- Positive wind pressure on buildings, open doors and temperature increases will increase positive pressure within waste transfer stations and biological treatment facilities and may cause the fugitive release of odour from such facilities. Incorporating efficient air extraction systems maintaining negative ventilation and appropriate treatment of extracted air within an odour control system will reduce/eliminate odour impact.
- Inefficient odour control/abatement equipment operation and design including loose fitting covers, inefficient extraction and odour control unit failure.

Some of the compounds emitted are characterised by their high odour intensity and low odour detection threshold (*see Section 2.4*). A sample of a report carried out in the Netherlands, United Kingdom and USA ranking generic and environmental odours according to the like or dislike by a group of people professionally involved in odour management is illustrated in *Table 3.3* (EPA, 2001, Environment Agency, 2002). Although not scientifically based, it is interesting to observe the results of such studies.

Table 3.3. Ranking of environmental odours according to like and dislike (i.e. similar odour hedonic tone).

Generic odours	*Hedonic score*[1] **Dravnieks, 1994**	**Ranking**[2]	**Ranking**[2]	**Ranking**[2]	**Environmental odours**	**Ranking**[2]	**Ranking**[2]	**Ranking**[2]
Descriptor	**USA**	**UK median**	**UK mean**	**NL mean**	**Descriptor**	**NL mean**	**UK mean**	**UK Median**
Roses	3.08	4	4.4	3.4	**Bread Factory**	**1.7**	**2.5**	**1**
Coffee	2.33	3	4.5	4.6	Coffee Roaster	4.6	3.9	2
Cinnamon	2.54	4	4.9	6	Chocolate Factory	5.1	4.6	3
Mowed lawn	2.14	4	4.9	6.4	Beer Brewery	8.1	7.7	6
Orange	2.86	4	5.2	5.8	Fragrance & Flavour Factory	9.8	8.5	8
Hay	1.31	7	6.9	7.5	Charcoal Production	9.4	9.2	8
Soap	0.96	8	7.8	7.3	**Green Fraction composting**	**14**	**10.3**	**9**
Brandy		9	8.8	7.8	Fish smoking	9.8	10.5	9
Raisins	1.56	8	8.8	7.9	Frozen Chips production	9.6	11	10
Beer	0.14	9	9.5	9.3	Sugar Factory	9.8	11.3	11
Cork	0.19	10	10	10.5	Car Paint Shop	9.8	11.7	12
Peanut Butter	1.99	10	10.4	11.1	**Livestock odours**	**12.8**	**12.6**	**12**
Vinegar	-1.26	14	13.3	14.8	Asphalt	11.2	12.7	13
Wet Wool	-2.28	14	14	14.1	**Livestock Feed Factory**	**13.2**	**14.2**	**15**
Paint	-0.75	15	14	14.4	**Oil Refinery**	**13.2**	**14.3**	**14**
Sauerkraut	**-0.6**	**15**	**14.6**	**12.8**	Car Park Bldg	8.3	14.4	15
Cleaning Agent	**-1.69**	**15**	**14.7**	**12.1**	**Wastewater Treatment**	**12.9**	**16.1**	**17**
Sweat	-2.53	18	16.6	17.2	Fat & Grease Processing	15.7	17.3	18
Sour Milk	-2.91	19	18	17.5	Creamery/milk products		17.7	10
Cat's Pee	-3.64	19	18.8	19.4	Pet Food Manufacture		17.7	19
Sewer odour	**-3.68**	-	-	-	Brickworks (burning rubber)		17.8	18
-	-	-	-	-	**Slaughter House**	**17**	**18.3**	**19**
-	-	-	-	-	**Landfill**	**14.1**	**18.5**	**20**

Notes: *Source: Draft Odour H4-Part 1, Integrated Pollution Prevention and Control (IPPC). (2004). Environment Agency, Bristol, UK.*
[1] denotes The higher the positive "value", the more pleasant the odour descriptor and similarly below, the greater the negative value, the more unpleasant the odour descriptor
[2] denotes ranking in order of dislike ability.

As can be observed from *Table 3.3*, and using the Dutch based ranking system, Green waste composting have a mean raking of 14.0 in terms of dislike. Other odours with similar mean dislike ranking include Landfill, Oil Refinery, Livestock Feed Factory, Livestock odour (i.e. intensive pig/poultry production). Green fraction composting and landfill odours are similar in their dislike ability and therefore it is rational to suggest that a similar odour impact criterion may be used based on these facts. Selection of odour impact criterion can be illustrated through the mean ranking system (i.e. 1.50 Ou_E m^{-3} for Abattoir/slaughterhouse odours with a mean ranking of 17 (very dislikeable) to 1.50 to 3.0 Ou_E m^{-3} for green fraction composting and landfill odour with a mean ranking of 14 (more likeable).

3.10 Commonly used odour annoyance criteria utilised in dispersion models

An odour impact criterion defines the odour threshold concentration limit value above baseline in ambient air, which will result in an odour stimulus capable of causing an odour complaint. There are a number of interlinked factor, which causes a nearby receptor (i.e. resident) to complain. These include:

- Odour threshold concentration, odour intensity and hedonic tone-defined measurable parameters at odour source,
- Frequency of odour-how frequently the odour is present at the receptor location,
- Duration of odour-how long the odour persists at the receptor location,
- Physiological-previous experiences encountered by receptor, etc.

By assessing these combined interlinked factors, the ability for a facility to cause odour complaint can be determined. As odour is not measurable in ambient air due to issues in sampling techniques, limit of detections for olfactometers and the inability to monitor continuously, therefore dispersion models become useful tools in odour impact assessments and odour risk analysis. Dispersion modelling also allows for the assessment of proposed changes in processes within the composting facility without actually having to wait for the processes to be changed (i.e. predictive analysis).

When utilising dispersion models for impact assessment, specific impact criterion (odour concentrations) need to be established at receptors. For odour assessment in general terms, this is called an odour impact criterion, which defines the maximum allowable ground level concentration (GLC) of odour at a receptor location for a particular exposure period (i.e. $\leq$ 1.50 Ou_E m^{-3} at the 98^{th} percentile of hourly averages). Commonly used odour annoyance criteria in Ireland, UK, Netherlands and other world wide countries are illustrated in *Table 3.4*. The odour concentration, % odour exposure at this odour concentration, the dislike ability, the dispersion model and industry it applies are presented (*see Table 3.4*).

Table 3.4. Odour annoyance criterion used for environmental odours.

Country	Odour conc. limit ($Ou_E\ m^3$)	Percentile value (%)	Average time (minutes)	Industry type	Dispersion model	Type area it applies	Dislike ability (*see Table 1.2*)	Application of criterion
Ireland	≤6.0[1]	98th	60	Intensive pig production	Complex 1	Limit value for existing pig production units	12.80	For all pig production units in Ireland
Ireland	≤3.0[1]	98th	60	Intensive pig production	Complex 1	Limit value for existing pig production units	12.80	For all pig production units in Ireland
Ireland	≤1.50[2]	98th	60	Slaughter house	Complex 1/ISC ST3	Limit value for new slaughter house facilities	17.0	Limit value for new slaughter house facilities
Ireland	≤1.50[3]	98th	60	Balbriggan WWTP	ISC Prime/ISC ST3	Limit value at sensitive receptor locations	12.90	Limit value for existing facility at sensitive receptor locations.
UK	≤1.50[4]	98th	60	WWTP	ADMS/ AERMOD	Indicative odour exposure criterion for licensing	12.90	IPPC H4 Guidance Notes Part 1-Regulation and Permitting, Environment Agency
Ireland	≤3.0[3]	98th	60	Enniscorthy WWTP	ISC Prime/ISC ST3	Limit value at sensitive receptor locations	12.90	Limit value for existing facility at sensitive receptor locations.
UK	≤5.0[4]	98th	60	WWTP-Newbiggin by the Sea Planning	ADMS	Used as a limit value prevent odour impact associated with WWTP	12.90	Planning application-Newbiggin by the Sea
UK	≤1.50[4]	98th	60	Livestock feed factory	ADMS/ AERMOD	Indicative odour exposure criterion for licensing	13.20	IPPC H4 Guidance Notes Part 1-Regulation and Permitting, Environment Agency
UK	≤1.50[4]	98th	60	Oil refinery	ADMS/ AERMOD	Indicative odour exposure criterion for licensing	13.20	IPPC H4 Guidance Notes Part 1-Regulation and Permitting, Environment Agency
UK	≤3.0[5]	98th	60	Landfill activities	Complex 1	Odour exposure criterion developed through laboratory based odour intensity studies and complaint correlation	14.10	Longhurst et al 1998 for Landfill planning application
NL	≤3.50[6]	98th	60	WWTP	Complex 1	Limit value to prevent odour nuisance existing plant	12.90	Industry sector specific air quality criterion for odours in Netherlands
NL	≤1.50[6]	98th	60	WWTP	Complex 1	Limit value to prevent odour nuisance new plant	12.90	Industry sector specific air quality criterion for odours in Netherlands

Notes: [1] denotes reference BAT Note development for intensive agriculture sector & EPA, 2001. Odour Impacts and Odour emissions control for Intensive Agriculture. R&D Report Series no. 14. EPA, Johnston Castle, Wexford.

[2] denotes EPA, (2004). BAT Notes for the Slaughterhouse sector, EPA, Johnston Castle, Wexford.

[3] denotes Odour limit values used during EIA application for WWTP's.

[4] denotes Environment Agency, (2002). Technical Guidance Notes IPPC H4-IPPC, Horizontal Guidance for Odour, Part 1-Regulation and Permitting. Environment Agency, Bristol, UK.

[5] denotes Magette, W., Curran, T., Provolo, G., Dodd, V., Grace, P., and Sheridan, B., (2002). BAT Note for the Pig and Poultry Sector. EPA, Johnston Castle, Wexford.

[6] denotes EPA, 2001. Odour Impacts and Odour emissions control for Intensive Agriculture. R&D Report Series no. 14. EPA, Johnston Castle, Wexford

Table 3.4. illustrates the range of odour impact criterion used in Ireland, UK, Netherlands, and other worldwide communities. The impact criterion accepted in Ireland and UK are based on research performed in Netherlands over the mid 80's and early 90's. In the late 90's the UK Environment Agency performed some research on validating those standards developed in Netherlands through studies performed in the UK. The main aims of these studies were for the developing of guidance notes on odour for licensing procedures under the EPA Act 1992. Over the last decade, these impact criterions have been providing protection to the community at large in the vicinity of such facilities. There is a general trend in odour impact criterion and dislike ability presented in *Table 3.3*. As can be observed in *Table 3.3 and 3.4*, the more offensive the odour is perceived, the lower the acceptable ambient odour concentration above baseline. Odours such as bakery odours are considered less offensive than pig production facilities and this is observed through the relative dislike ability and also the odour impact criterion established to limit nuisance. Green fraction composting odours have similar dislike ability to Waste water treatment and Landfill odour and therefore it would be rational to suggest a similar odour impact criterion. Other factors that require consideration include, the location of the facility, the surrounding sensitive receptors, and amount of odour mitigation to be implemented into the overall design. For example in Ireland, pig production facilities are generally located in rural environments, whereby sensitive receptors in the vicinity of the facility are working in similar livestock operations and therefore do not consider the perceived odour as offensive as say a person not familiar with the odour. This composting facility on the other hand is located close to the sensitive receptors. This results in the installation of odour management and mitigation technologies to control and abate the odour emission. By abating the sources of offensive odours within the Composting facility, the facility has a markedly lower potential risk of causing complaint. Taking into account these factors for the existing and proposed Composting facility, it is proposed that:

- All sensitive locations should be located outside the 1.50 Ou_E m^{-3} at the 98th percentile of hourly averages over a meteorological year.
- All sensitive locations should be located outside the 3.0 Ou_E m^{-3} at the 99.5th percentile of hourly averages over a meteorological year.

These proposed odour impact criterion is sufficiently conservative to provide protection to the community at large taking into account latest suggested odour impact criterion by environmental agencies in Ireland, UK and Netherlands. In the case of Waterford Composting facility, all odour sources capable of generating offensive odours will be enclosed inside the main building, sealed and negatively ventilated to an odour control system. Only the storage of finished compost and shredding of green waste material will be carried on outdoors. All other odour sources will be enclosed, sealed and abated with an odour treatment unit. The 99.5th percentile of hourly averages is used to complement the 98th percentile of hourly averages to take account of predicted downwind odour concentrations during short time worst-case meteorological conditions thereby providing added protection to the public at large.

3.11 Proposed Bioaerosols specifications

Suggested Occupational exposure limits, Threshold limit values, Residential limit values and a recommended WHO guideline value for bioaerosol exposure is presented in *Table 3.5*. Ranges of exposure concentrations range from 1000 to 5000 CFU/m^3 for Total bacteria and from 500 to 10^7 CFU m^3 for Total fungi concentration. In order to assume a worst-case scenario, values of 1000, 1000 and 500 CFU/m^3 for Total Fungi, Mesophillic bacteria and Aspergillus *fumigatus* will be used as upper threshold levels within the dispersion model to assess bioaerosol impact area. The distance downwind to achieve background levels of Aspergillus *fumigatus*, Total fungi and Total Mesophillic bacteria from the main bioaerosol source within the facility will also be assessed. A 1-hour maximum concentration calculation will be used to generate the output plots for presentation as contour isopleths. These contours can then be observed visually to assess the bioaerosol impact on the surrounding area. This can then be compared to the proposed bioaerosol exposure levels. The bioaerosol impact can also be assessed for factors such as changing facility operation and facility design.

Table 3.5. illustrates proposed occupational exposure levels (OEL's), threshold limit values (TLV's) and residential limit values (RLV) for bioaerosols encountered in different environments. Independently of these reference values, in an assessment of indoor exposure, the general assumption should be that in certain circumstances the microbial pathogen may be a cause of health problems, even at concentrations below the reference limit.

Occupational Exposure Limits (OELs) for airborne substances are set at a level at which, based on current scientific knowledge, there is no indication of risk to the health of workers who breathe it in day after day. At present, no country has OELs for airborne micro organisms or their associated toxins.

Thorne et al., 2000, stated that in order to produce reliable exposure data rigorous exposure chamber design, aerosol generation systems, exposure quantification and experimental protocols must be utilized. Inhalation models serve as important adjuncts to epidemiology studies. Fung et al., 2003 reported health effects caused by fungal bioaerosol exposure include allergy, infection, irritation, and toxicity. While the first three categories have well established mechanisms, there is a lack of dose-response data, and a highly variable degree of individual susceptibility.

It can be concluded that workers on composting facilities are potentially exposed to considerably higher concentrations of bacteria, including Gram-negative bacteria, actinomycetes, fungi and their associated toxins that are likely to be present in background air away from bioaerosol sources, nonetheless there is a lack of reported health related effects among compost workers in the literature. Since they are exposed to higher concentrations on a continuous basis, the effects of bioaerosols on health are not clearly understood. The precise risk of bioaerosols is impossible to quantify due to this lack of defined dose-response relationships (Wheeler et al., 2001).

Table 3.5. Proposed Occupational exposure levels (OEL's), Threshold limit values (TLV's) and Residential limit values (RLV's).

Suggested Value	Total Bacteria (CFU m^{-3})	Gram negative bacteria (CFU m^{-3})	Fungi (CFU m^{-3})	TOTAL MICRO ORGANISMS (CFU m^{-3})	Reference
Residential dwelling (RLV)	5 X 10^3	-	5 X 10^3	-	-
Industrial setting contaminated by dust (OEL) For respirable fraction the limit proposed should be twice as low.	Total Mesophillic bacteria 100 X 10^3	20 X 10^3	50 X 10^3	-	Gorny and Dutkiewicz (2002)
Suggested OELS in Scandinavia	-	1,000	10^5		Rylander et al 1994
OEL	-	2 x 10^4	-	1 x 10^4	Makros 1992
OEL	-	-	-	-	Dutkiewitz & Jablonski 1989
Suggested OEL (biotechnology)	-	300		-	Palchak 1990
WHO Guideline	-	-	500	-	McNeel et al., 1999
Suggested OEL in Scandinavia	10^4	Toxic pneumonitis 10^5 Respiratory inflam. 10^2 10^3	Toxic pneumonitis 10^7 Respiratory inflam. 10^5	-	Rylander 1994 Lavoie and Guertin (2001)
Suggested OEL 8 hr average	5-10,000	1,000	-	-	Sigsgaard 1990
Health based OEL*	-	2 x10^4	5 x 10^4	1 x 10^5	Dutkiewitz 1997

* Health based OEL refers to when continuous exposure to micro organisms concentrations above 10^5 CFU m^{-3} occurs, work-related respiratory disorders in workers are very common.

Table 3.5 continued. Proposed Occupational exposure levels (OEL's), Threshold limit values (TLV's) and Residential limit values (RLV's).

Suggested Value	Total Bacteria (CFU m^{-3})	Gram negative bacteria (CFU m^{-3})	Fungi (CFU m^{-3})	TOTAL MICRO ORGANISMS (CFU m^{-3})	Reference
Threshold values	1,000	1,000	-		Rylander et al 1980, 1983
Threshold values	-	1,000	5,000	5,000-10,000	Peterson & Vikstrom1984
Threshold values	-	1,000	-		Lacey et al 1992
Recommended maximum for residences, schools and offices	<4500	-	-	<500 in winter <2500 in summer	Finnish Ministry of Social Affaires and Health 1997
Provisional Dutch guideline for indoor air in the work environment	10,000	-	-		Dutch Occupational Health Association NWA 1989.
Number of spores necessary for development of acute symptoms	-	-	-	10^8	Miller 1992
Health based - number which can cause sensitisation	-	-	-	> 10^8	Malmberg 1991
Increased risk of EAA and ODTS	-	-	-	10^6	Lacey et al 1990
Proposed risk assessment concentrations UK EA (2002)	1000 Mesophillic bacteria	-	500 total fungi	1000	Wheeler (2002)

3.12 Bioaerosol dispersion modelling

The bioaerosol dispersion modelling incorporates the following assumptions:

- The bioaerosol is treated as an ideal gas and therefore no removal due to deposition (wet or dry) is accounted for in modelling scenarios,
- Bioaerosols are known to clump and fall close to the emission point due to deposition. No clumping is accounted for in the dispersion modelling assessment and therefore worst case plume spread can be assumed on this basis,
- Five years of meteorological data was used in the dispersion modelling assessment,
- A worst-case maximum 1-hour concentration value is assessed.
- Worst case published bioaerosol emission rates are used for the development of the data set.

The ground level output concentrations from the dispersion model allowed for the assessment of the following bioaerosol impact criterion. All predicted ground level concentrations of bioaerosols were below the assessment threshold presented in *Section 3.11*. These included:

- All sensitive locations and areas of amenity should be located outside the less than 500 CFU m^{-3} at the 1-hour maximum predicted ground level concentration for Aspergillus *f*.
- All sensitive locations and areas of amenity should be located outside the less than 1000 CFU m^{-3} at the 1-hour maximum predicted ground level concentration for Total fungi.
- All sensitive locations and areas of amenity should be located outside the less than 1000 CFU m^{-3} at the 1-hour maximum predicted ground level concentration for Total Mesophillic bacteria.

3.13 Meteorological data.

Dublin Airport meteorological station Year 2000 to 2006 inclusive was used for the operation of Aermod Prime. This allowed for the determination of the worst-case meteorological year for the determination of overall odour and bioaerosol impact from the proposed Littleton Recycling facility on the surrounding population. Dublin Airport was chosen as Cork Airport and Shannon Airport meteorological stations are located close to coast and estuarine based features while 90% acceptable cloud cover data for calculation of boundary layer dispersion estimates are not available from either Birr or Kilkenny meteorological stations.

The wind rose plot and statistical aspects of the meteorological file are contained in *Section 11*.

3.14 Terrain data.

Topography affects in the vicinity of the site were not accounted for in the model as the topography in this area was considered simple and not complex (i.e. no valley/hills). All building wake effects are accounted for in the modelling scenarios (i.e. building effects on point sources) as this can have a major effect on the odour plume dispersion at short distances (which is important in this instance).

4. Odour and bioaerosol management plan and systems

The Odour Management Plan (OMP) is a core document detailing operational and control measures appropriate to management and control of odour and bioaerosols at a site. The format of the OMP / BMP provides sufficient detail to allow operators and maintenance staff to clearly understand the odour and bioaerosol management operational procedures for both normal and abnormal conditions. The control of dust can in some circumstances act as a control mechanism for bioaerosols so if dust is controlled it is more likely that bioaerosols will also be control at the site. It is outside the scope of this document to discuss the control of dust at the facility, but details on dust mitigation measures are contained in *Section X* of the application. For here on only the Odour management plan will be discussed.

The OMP is designed to include sufficient feedback data to enable site management (and local authority inspectors) to audit site operations on odour management. An example of some of the issues to be considered are summarised as follows.

- A summary of the site, odour and bioaerosol sources and the location of receptors,
- Details of site management responsibilities and procedures for reporting faults, identifying maintenance needs, replenishing consumables and complaints procedure,
- Odour and bioaerosol management equipment operation procedures (e.g. correct use of equipment, process, materials, checks on equipment performance, maintenance and inspection (*see Section 4.4*),
- Operative training,
- Housekeeping,
- Maintenance and inspection of plant (both routine and emergency response),
- Spillage/contaminated surface management procedures,
- Record keeping – format, responsibility for completion and location,
- Emergency breakdown and incident response planning including responsibilities and mechanisms for liaison with the local authority.
- Public relations.

The Odour and Bioaerosol Management Plan will be regularly reviewed and upgraded. It should form the basis of a document Environmental and Odour / Bioaerosol Management system for the operating site. The Odour and Bioaerosol Management System documentation defines the roles of the Plant Operator and staff and sets out templates in relation to the operating of the facility and reporting procedures to be employed. Requirements for the Odour and Bioaerosol management plan should be implemented thought-out the site with a branched management system implemented in order to share responsibility around the site. The site manager will ensure all works are performed in accordance with the MP. The MP will be integrated in the overall Environmental Management/Performance System for the site.

Acorn Recycling will develop in agreement with the regulatory authority and implement a detailed odour and bioaerosol management plan for the actual as built plant before commencement of treatment of material at Littleton Recycling Facility.

4.1 General rules for reduction of odour emissions during the operation of Littleton Recycling Facility.

The following minimum design features for the control of odours will be provided. These include:

- The Recycling Facility will be fitted on all inner surfaces with an impermeable inner layer to ensure near 100% building skin integrity. Traditional cladding techniques (either double skin or single skin with joints taped and flexi sealed) will have an approximate leakage volume of 10 to 30 m^3 air per m^2 of clad surface area.
- The access doors of the Recycling Facility will be fitted with rigid rapid roller doors.
- The Recycling Facility odour management system will allow for gas extraction from individual zones within the composting process. Independent negative air extraction will be provided to the first and second stage composting processes, waste reception hall and screening hall. The overall ventilation and odour treatment system will have 3 individual fanset feeding air into the odour treatment system. This will provide 100% duty and 75% standby.
- The significant odourous processes within the Recycling Facility will be self contained and negatively ventilated to the odour control system. The first and second stage composting tunnels will be enclosed within their own enclosed structures within the sealed building. This will prevent the release of high strength odours to the headspace of the building. Furthermore, this significantly reduces the risk of odour escape from the building and provides significant comfort in terms of odour minimisation and management.
- The odour control system will consist of a biofiltration system operating at a empty bed retention time of 53 seconds at maximum treatment volume.
- The proposed air introduction plenum for the biofiltration system is based on proven air introduction techniques. The air introduction plenum will be divided into 4 separate cells to allow for the zoned treatment of odours.
- The recirculation system for the biofiltration system will allow for the focused addition of essential nutrients and minerals to ensure high microbial activity within the biofiltration bed medium.
- The biofiltration media will be of uniform size before filling into the biofilter cells to ensure homogenous airflow rate.
- The odour control system will be fitted with sensors and monitoring analysers to allow for preventative maintenance and alarm tagging through the SCADA system. In addition, hours of operation will be recorded and preventative maintenance will be scheduled on a runtime basis as recommended by the equipment manufacturers.
- All rough debris and organic matter will be cleaned from the surface of the waste reception hall floor at the end of each day’s operation. This will be recorded into a check sheet and incorporated into the overall odour management plan.
- All surfaces contaminated with odourous material will be washed down as required as part of the clean up schedule for the waste reception hall and finished compost screenings hall. This will be recorded into a check sheet and incorporated into the overall odour management plan.
- No waste will be stored outdoors at any time. All operations will be carried out indoors as required within the tender specification.
- Training and pre planned maintenance works will be organised using a check sheet approach. All staff will be trained in the execution of the Odour management plan. An annual check sheet will be used to ensure preventative maintenance is performed upon the odour management system for the Recycling Facility.

4.2 General rules for reduction of bioaerosol emissions during the operation of Littleton Recycling Facility.

The following minimum design features for the control of bioaerosols will be provided. These include:

Good housekeeping techniques should be incorporated including:

- Keeping the dry material damp;
- Keeping hard surfaces and roads damp with regular cleaning to prevent any dust emissions;
- Ensure all offloading is performed indoors and away from open external doors;
- Enclose tipping area within tipping bay

Extraction system and filtration: A suitable extraction system incorporating essential zoned extraction to reduce and bioaerosol emission within the building. The building should be maintained under negative ventilation and all air should be extracted through the biofiltration system. Door areas should be kept to a minimum in order to reduce air exchange rate and building fabric should be maintained in good condition to prevent any fugitive emissions.

Preventive maintenance: Ensure that all air extraction equipment (fans and ductwork, etc.) have indicator instrumentation (i.e. pressure sensors, etc) and are visually checked weekly to maintain maintenance log records for predictive maintenance schedules. Ductwork will require access ports in order to allow investigation of any dust build-up.

Training: Ensure all personnel are educated in bioaerosol reductive measures.

4.3 Complaints management and recording

It is generally accepted that all waste management facilities must deal with odour complaints. A systematic response to odour complaints will minimise the amount of effort spent dealing with complaints and minimise the potential for litigation and other potential negative outcomes. Odour Monitoring Ireland has significant experience in dealing with odour complaints. As part of an Environmental Management System (EMS), a dedicated recording system will be put in place to allow for the management of odour complaints. This EMS, quickly accessible records will be available and enable efficient and effective handling of complaints in a comprehensive manner. The odour complaint investigation begins as soon as the complaint is received. Gathering information from the complainant is a crucial step in determining the source of the offending odour. Staff who can understand and will act on the information received will immediately handle the investigation, typically this will be a lead operator or manager. Any staff handling a complaint will show a professional and compassionate demeanour. It is important not to take offence to the complaint and expect the complainant will be upset, odours can elicit strong emotional responses. Professionalism by the staff members handling the complaint can go a long way to ensure an acceptable outcome for nuisance odours.

In order to analyse complaints, accurate complaints recording will be performed. The most important factors associated with odour complaint recording include:

- Easily contactable phone number or web page for complainant to discuss their complaint. A free phone number is preferable. During normal working hours, an experienced person who is familiar with the processes should answer the phone. Only during out of hours should an answer phone be used. The answer phone should clearly state the information required of the complainant. The complainant should always be contacted back if a message is recorded. The least desirable means of receiving a complaint is via an elected official or governing body. If someone has used this method to complain, it probably means one of the methods noted above was not available or easy to use. No matter what method is used to receive odour complaints, it is important that the system provide prompt feedback.

- Clearly established questions and format of recording in order to isolate the most relevant information. This includes:
- Date and time of complaint (very important)
- Name of complainant
- Location of complainant
- Duration of odour
- Where and when odour was detected
- How strong the odour was/is (Intensity on a scale of 0 to 5 where 0 is not perceptible, 1 is very weak, 2 is weak, 3 is distinct, 4 is strong and 5 is very strong)?
- What did the odour smell like - A number of random descriptors should be proposed by the facility representative or offered by the resident (saying that the odour smells bad is not sufficient) (*see Tables 4.2, 4.3 and Figure 4.1*).
- Details of the responses made to the complainant.

- Continuous monitoring of meteorological data onsite using a met station recording data in accordance with World Meteorological Organization (WMO). Wind speed, wind direction, solar irradiance, barometric pressure, temperature and relative humidity. Minutely data should be recorded including, average, minimum, maximum, standard deviation, and max 3-second gust. The meteorological data for 30 minutes before and after the recorded odour duration should trended and added to the complaint register. Notes regarding precipitation and cloud cover can be used to help with the understanding of atmospheric stability and odour dispersion. This information will be useful later in the investigation if atmospheric dispersion modelling is used to diagnose odour transport and impact.

- The person responsible for complaint recording if not exposed to the odour should visit the complainant location immediately and perform subjective analysis of the immediate area. The most important of these tools are the investigators own nose, eyes and ears. If appropriate (i.e. characteristic rotten eggs odour detected), continuous monitors should be put in place at the location. The complainant location should also be geo referenced and relative direction to north from the facility should be calculated and added to the complaint register. Monitoring odours in the field can be a difficult task. The odours detected by the complainant may have significantly or completely abated by the time the investigator arrives on the scene. Brief interaction with the complainant should be performed. Additionally, the personnel responsible for field inspections should be familiar with all major site odour sources and characteristics.

- Complaints should be assessed taking into account the following factors:
- The context of the complaint (hypersensitive individuals, vexatious complaints, organised campaigns, whether there are other complainants, etc)
- The number of complaints against the alleged nuisance;
- The frequency of complaints, e.g. is it a one-off event or a regular occurrence?
- The person responsible for complaint recording should contact processes operators/maintenance personnel and record any process anomalies, upsets or maintenance activities that may have lead to the release of odours from your system. All data pertaining to abatement equipment operation should be assessed in order to

isolate any operational issues with abatement equipment (this will be addressed in more detail in *Section 4.4*).

- All complainant handling procedures and responses will be maintained on file and available for inspection by the relevant regulatory body.

Table 4.1 illustrates a typical odour complaint recording form for use within an EMS. This will be used in conjunction with the Odour abatement equipment management procedures/system. *Tables 4.2, 4.3 and Figure 3.1* illustrate basic odour descriptors, hedonic scores and an odour wheel which will facilitate the easy characterisation of any odours downwind or within the facility boundaries.

Table 4.1. Odour complaint recording form.

Record No.:____________	Odour complaint recording form		
Complainant details			
Complainant name		Date of complaint	
Complainant location (grid reference - N & E)		Time of complaint (24hr clock)	
Duration of complaint (minutes)		Type of complaint (i.e. odour, noise,)	
Name of person logging complaint		How was complaint received (phone, etc)	
How long till complainant contacted back (minutes)		Complainant address:	
Notes:			

Odour characteristics			
Odour intensity (0 to 5)	Please tick one	Odour hedonic tone (0 to 4)	Please tick one
No odour (0)		Neutral odour (0)	
Very weak odour (1)		Mildly unpleasant (-1)	
Weak odour (2)		Moderately Unpleasant odour(-2)	
Distinct (they can clearly recognise the odour) (3)		Unpleasant odour (-3)	
Strong odour (4)		Very unpleasant odour (-4)	
Very strong odour (5)			
What did the odour smell like-Descriptor? Please refer to *Section 4.2*			
Is/was the odour fluctuating or constant?			
Is/wasthe complainant a resident (R) of commercial receptor (C)?			
Notes:			

Weather condition *Please append historical records from met station to this record*			
Wind speed (m/s)		Temperature (^{0}C)	
Wind direction (from plant to complainant)		Relative humidity (%)	
Solar irradiance (W/m^2)		Cloud cover (0 to 8)	
Precipitation & Rainfall (mm/m^2)		Cloud height (low, medium, high)	
Notes:			

Complaint logging personnel only			
Name of personnel:		Did you detect an odour?	
Have you received training (Y/N)		What did it smell like - Descriptor?	
How fast was your response time (minutes)		Distance of odour detection to facility as crow flies (m)	
Odour Intensity (0 to 5)		Odour hedonic tone (0 to – 4)	
Is the odour fluctuating?		Are there any other odour sources in the immediate location	
Odour plume extent - graphically map odour area using mapping	*Please append to this record*		

Plant operation synopsis *Please append odour abatement plant overview*			
Waste flow into facility (tonnes per day)		Abnormal conditions	
Quantity of waste in facility on day		Are/were there any deviations (Y/N)	
Describe deviations			
Are all odour abatement equipment operating correctly	Please refer to *Section 4.4* for verification procedure.		
Notes:			

Odour descriptors

Descriptors can help to establish the source of an odour and therefore it is useful, when recording information from a complainant, to seek their description of the odour.

Table 4.2. Odour descriptors for commonly encountered compounds.

Substance	Odour	Substance	Odour
Acetaldehyde	Apple, stimulant	Dimethyl sulphide	Rotten vegetable
Acetic acid	sour vinegar	Diphenylamine	Floral
Acetone	chemical/sweetish/so lvent	Diphenyl sulphide	Burnt rubber
Acetonitrile	Ethereal	Ethanol	Pleasant, sweet
Acrylaldehyde	Burning fat	Ethyl acetate	Fragrant
Acrolein	Burnt sweet, pungent	Ethyl acrylate	Hot plastic, earthy
Acrylonitrile	Onion, garlic, pungent	Ethylbenzene	Aromatic
Aldehydes C9	Floral, waxy	Ethyl mercaptan	Garlic/onion, sewer, decayed cabbage, earthy
Aldehydes C10	Orange peel	Formaldehyde	Disinfectant, hay/straw-like, pungent
Allyl alcohol	Pungent, mustard like	Furfuryl alcohol	Ethereal
Allyl chloride	Garlic onion pungent	n-Hexane	Solvent
Amines	Fishy, pungent	Hydrogen sulphide	Rotten eggs
Ammonia	Sharp, pungent odour	Indole	Excreta
Aniline	Pungent	Iodoform	Antiseptic
Benzene	Solvent	Methanol	Medicinal, sweet
Benzaldehyde	Bitter almonds	Methyl ethyl ketone	Sweet
Benzyl acetate	Floral (jasmine), fruity	Methyl isobutyl ketone	Sweet
Benzyl chloride	Solvent	Methyl mercaptan	Skunk, sewer, rotten cabbage
Bromine	Bleach, pungent	Methyl methacrylate	Pungent, sulphide like
Sec-Butyl acetate	Fruity	Methyl sulphide	Decayed vegetables
Butyric acid	Sweat, body odour	Naphthalene	Moth balls
Camphor	Medicinal	Nitrobenzene	Bitter almonds
Caprylic acid	Animal like	Phenol	Sweet, tarry odour, carbolic acid
Carbon disulphide	Rotten vegetable	Pinenes	Resinous, woody, pine-like
Chlorine	Irritating, bleach, pungent	Propyl mercaptan	Skunk
Chlorobenzene	Moth balls	Putrescine	Decaying flesh
2-Chloroethanol	Faint, ethereal	Pyridine	Nauseating, burnt
Chloroform	Sweet	Skatole	Excreta, faecal odour
Chlorophenol	Medicinal	Styrene	Penetrating, rubbery, plastic
p-Cresol	Tar-like, pungent	Sulphur dioxide	Pungent, irritating odour
Cyclohexane	Sweetish when pure, pungent when contaminated	Thiocresol	Rancid, skunklike odour
Cyclohexanol	Camphor, methanol	Toluene	Floral, pungent, moth balls
Cyclohexanone	Acetone-like	Trichloroethylene	Solventy
Diamines	Rotten flesh	Triethylamine	Fishy, pungent
1,1-Dichloroethane	Ether-like	Valeric acid	Sweat, body odour, cheese
1,2-Dichloroethylene	Chloroform-like	Vinyl chloride	Faintly sweet
Diethyl ether	Pungent	Xylene	Aromatic, sweet
Dimethylacetamide	Amine, burnt, oily		

Hedonic Scores

These scores are also referred to as "Dravnieks" and are derived from laboratory-based experiments. They give an indication of the relative pleasantness or unpleasantness of one odour compared to another. When considering odours from industrial activities, the descriptors given in *Table 4.2* can be used.

Use of Hedonic scores

The higher the positive "score", the more "pleasant" the odour descriptor, and the greater the negative figure the more "unpleasant" the odour descriptor. The terms pleasant and unpleasant are used to indicate relative response rather than a sign of a positive or negative level of satisfaction. Zero cannot be considered to be neutral.

Table 4.3. Hedonic scores

Description	Hedonic Score	Description	Hedonic Score	Description	Hedonic Score
Cadaverous (dead animal)	-3.75	Fishy	-1.98	Wet paper	-0.94
Putrid, foul, decayed	-3.74	Musty, earthy, mouldy	-1.94	Medicinal	-0.89
Sewer odour	-3.68	Sooty	-1.69	Chalky	-0.85
Cat urine	-3.64	Cleaning fluid	-1.69	Varnish	-0.85
Faecal (like manure)	-3.36	Kerosene	-1.67	Nail polish remover	-0.81
Sickening (vomit)	-3.34	Blood, raw meat	-1.64	Paint	-0.75
Urine	-3.34	Chemical	-1.64	Turpentine (pine oil)	-0.73
Rancid	-3.15	Tar	-1. 63	Kippery-smoked fish	-0.69
Burnt rubber	-3.01	Disinfectant, carbolic	-1.60	Fresh tobacco smoke	-0.66
Sour milk	-2.91	Ether, anaesthetic	-1.54	Sauerkraut	-0.60
Stale tobacco smoke	-2.83	Burn, smoky	-1.53	Camphor	-0.55
Fermented (rotten) fruit)	-2.76	Burnt paper	-1.47	Cardboard	-0.54
Dirty linen	-2.55	Oily, fatty	-1.41	Alcoholic	-0.47
Sweaty	-2.53	Bitter	-1.38	Crushed weeds	-0.21
Ammonia	-2.47	Creosote	-1.35	Garlic, onion	0.17
Sulphurous	-2.45	Sour, vinegar	-1.26	Rope	-0.16
Sharp, pungent, acid	-2.34	Mothballs	-1.25	Beery	-0.14
Household gas	-2.30	Gasoline, solvent	-1.16	Burnt candle	-0.08
Wet wool, wet dog	-2.28	Animal	-1.13	Yeasty	-0.07
Mouse-like	-2.20	Seminal, sperm-like	-1.04	Dry, powdery	-0.07
Burnt milk	-2.19	New rubber	-0.96		
Stale	-2.04	- Metallic	0.94		

Table 4.3 continued. Hedonic scores.

Description	Hedonic Score	Description	Hedonic Score	Description	Hedonic Score
Cork	0.19	Crushed grass	1.34	Maple syrup	2.26
Black pepper	0.19	Celery	1.36	Pear	2.26
Musky	0.21	Green pepper	1.39	Caramel	2.32
Raw potato	0.26	Tea leaves	1.40	Coffee	2.33
Eggy (fresh eggs)	0.45	Aromatic	1.41	Meaty (cooked, good)	2.34
Mushroom	0.52	Raisins	1.56	Melon	2.41
Beany	0.54	Cooked vegetables	1.58	Popcorn	2.47
Geranium leaves	0.57	Clove	1.67 Minty, peppermint	2.50	
Grainy (as grain)	0.63	Nutty	1.92	Lemon	2.50
Dill	0.87	Coconut	1.93	Fragrant	2.52
Woody, resinous	0.94	Grapefruit	1.95	Fried chicken	2.53
Soapy	0.96	Perfumery	1.96	Cinnamon	2.54
Laurel leaves	0.97	Peanut butter	1.99	Cherry	2.55
Eucalyptus	0.99	Spicy	1.99	Vanilla	2.57
Molasses	1.00	Banana	2.00	Pineapple	2.59
Incense	1.01	Almond	2.01	Apple	2.61
Malty	1.05	Sweet	2.03	Peach	2.67
Caraway	1.06	Buttery, fresh butter	2.04	Violets	2.68
Soupy	1.13	Grape juice	2.07	Fruity, citrus	2.72
Bark, birch bark	1.18	Honey	2.08	Chocolate	2.78
Anise (liquorice)	1.21	Cedarwood	2.11	Floral	2.79
Oak wood, cognac	1.23	Herbal, green, cut grass	2.14	Orange	2.86
Seasoning (for meat)	1.27	Cologne	2.16	Strawberry	2.93
Leather	1.30	Fresh green vegetables	2.19	Rose	3.08
Raw cucumber	1.30	Fruity, other than citrus	2.23	Bakery (fresh bread)	3.53
Hay	1.31	Lavender	2.25		

Odour wheel

The odour wheel is useful in characterizing the odour in the field and facilitating interaction with the complainant. It is also useful in identifying compounds that may be responsible for the odour.

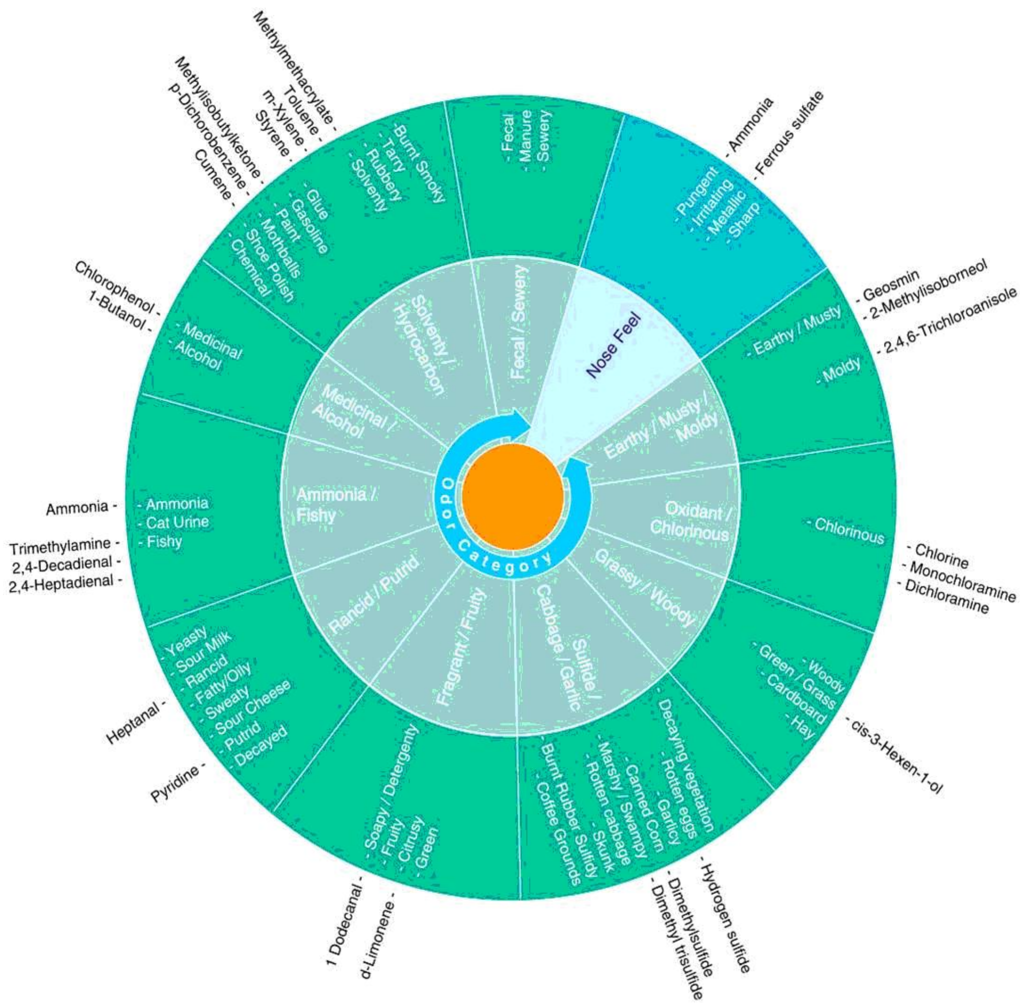

Figure 4.1. Odour wheel for odour descriptors. Suffet, M (1999).

Notes

1. Dravnieks A, Masurat T, Lamm R A, "Hedonics of Odours and Odour Descriptors": in *Journal of the Air Pollution Control Association,* July 1984, Vol. 34 No. 7, pp 752-755

2. Guidance for the Regulation of Odour at Waste Management Facilities under the Waste Management Licensing Regulations, July 2001, Version 2.

3. IPPC H4 guidance, Horizontal guidance for odour, Part 1-Regulation and Permitting (2002).

4.4 Odour abatement management system/procedures

Odour abatement/minimisation systems are installed with the aim of mitigating odours from the particular process(s). In some circumstances odour abatement system can become significant sources of odour especially if inappropriately maintained. This may results in insufficient treatment, poisoning of media, exhaustion of media, insufficient gas removal volume, broken doors, building fabric, etc. There is a tendency in many facility environments that once installed the odour control system requires very little system checking, especially if SCADA controlled. A simple management system incorporated into site operations can significantly reduce the risk of odour control equipment failure and also provide a valuable picture for operations and maintenances schedules.

The overall odour control equipment management system will vary for various technologies. For the proposed Littleton Recycling Facility, the following odour control/minimisation equipment is/will be installed to control odours emanating from specific processes within the equipment.

For each aspect of the odour control technologies, an operational verification procedure should be performed physically visiting each piece of equipment. For sensitive mechanical odour control equipment such as biofilters, a daily check will be performed. Small changes in operational parameters could lead to significant impact on equipment performance.

For odour control/minimisation equipment such as rapid doors, odour control ductwork, etc., which are less susceptible to breakdown, a daily observation and weekly mechanical check will be performed. All system checks will be documented and available for viewing by odour complaints verification personnel, chief maintenance personnel and equipment manager. Response/Action plans will be established for system repair where by a repair team trained in the operation and maintenances (O&M) of this specific equipment are available to perform dedicated repair work. O&M manuals will always be available and a spares inventory will be maintained.

Table 4.4 illustrates a typical odour control equipment daily/weekly checking procedure for odour abatement equipment such as chemical scrubber, carbon filtration system and flares. Certain parameters such as subjective and objective assessment checks (airflow rate, static/differential pressures etc) will be performed daily while other parameters such as odour threshold concentration will be performed quarterly which is in compliance with EPA recommendations for similar facilities. *Table 4.5 & 4.6* illustrates a typical odour minimisation equipment system checking procedure for doors, odour control ductwork, air curtains, etc.

All static pressure sensor readings will be verified using a handheld pressure sensor on a weekly basis while all sensors requiring calibration will be performed in accordance with manufacturers requirements. Frequent span checks will also be incorporated into the schedule.

Table 4.4. Odour Control Unit (OCU) checking procedure and recording example.

Odour Abatement equipment process data sheet			
OCU name		**Location (NE coordinate)**	
OCU P&ID ref. No.		**Time of check (24 hr)**	
Date of check:		**Commissioning date:**	
QA/QC by:		**Next service date:**	
Supplier and contact details:			
Emergency contact No.			
OCU description			
Notes:			
Process description **SENSOR CALIBRATION DATES**			
Biofilter	**Differential/static pressure**		
Biofilter	**Temperature**		
Inlet/Outlet of biofilter	**Airflow rate/ Dust sensor**		
Outlet biofilter	**Mercaptans**		
Outlet biofilter	**Ammonia**		
Outlet biofilter	**Amines**		
Outlet biofilter	**Hydrogen sulphide**		
Outlet biofilter	**Odour units**		
Notes:			
Subjective process verification			
Is the fan running and sounding OK (Y/N comments)?			
Is liquid recirculating within the recirculating line of the biofilter (Y/N comments)? Please record value			
Is dump liquor flowing freely from overflow sump (Y/N comments)?			
Is liquid distributed equally over packing media and is there evidence of settlement in biofilter/scrubbing media (Y/N comments)?			
Is recirculating liquor clear or cloudy (Y/N comments)			
Are all liquid distribution nozzles/gate clear (Y/N comments)			
Notes:			

Table 4.4 continued. Odour Control Unit (OCU) checking procedure and recording example.

Objective process verification					
Parameter	**Average**	**Min**	**Max**	**Design value as per P&ID**	**Action**
Air flow rate (m3/hr)					
Temperature (^{0}C)					
Inlet ductwork Static pressure (mm WG)					
Differential pressure across system components (mm WG)					
Inlet dust load (mgN/m3)					
Odour character: (Descriptor)					
Notes:					
Treated airflow	**Average**	**Min**	**Max**	**Design value as per P&ID**	**Action**
Airflow rate (Nm^3/hr)					
Temperature (^{0}C)					
Outlet static pressure (mm WG)					
Outlet odour conc. (Ou_E/m^3)					
CEMS outlet conc. (mg/m3)					
Outlet odour emission rate (Ou_E/s)					
Outlet odour character: Descriptor					
Irrigation recirculation	**Average**	**Min**	**Max**	**Design value as per P&ID**	**Action**
Recirculation flow (m^3/hr)					
Temperature (^{0}C)					
Conductivity (μs)					
PH (0 to 14)					
Redox if appropriate (mv)					
Stability on Redox/pH historically					
Irrigation drainage	**Average**	**Min**	**Max**	**Design value as per P&ID**	**Action**
Dump volume (m^3/hr)					
Conductivity (μs)					
Batch dumping frequency (weeks)					

Table 4.5 illustrates a typical odour minimisation equipment system weekly checking procedure for odour control ductwork, etc.

Odour Abatement Plant process data sheet			
Equipment name		**Location (NE coordinate)**	
Equipment P&ID ref. No.		**Time of check (24 hr)**	
Date of check:		**Commissioning date:**	
QA/QC by:		**Next service date:**	
Supplier and contact details:			
Emergency contact No.			
Equipment description			
Notes:			

Process description		
Item description	**Parameter**	**Compliant/Actions**
Ductwork	**Static pressure P&ID location No 1**	
	Static pressure P&ID No location 2	
	Static pressure P&ID No location 3	
	Static pressure P&ID No location 4	
Volume control dampers (VCD)	**P&ID No. 1 Damper setting/head loss**	
	P&ID No. 2 Damper setting/ head loss	
	P&ID No. 3 Damper setting/ head loss	
	P&ID No. 4 Damper setting/ head loss	
Are all condensate drip points free flowing and unblocked?		
Notes:		

Table 4.6 illustrates a typical odour minimisation equipment system weekly checking procedure for building louvers, doors, etc.

Odour Abatement Plant process data sheet			
Equipment name		**Location (NE coordinate)**	
Equipment P&ID ref. No.		**Time of check (24 hr)**	
Date of check:		**Commissioning date:**	
QA/QC by:		**Next service date:**	
Supplier and contact details:			
Emergency contact No.			
Equipment description			
Notes:			

Process description		
Item description	**Parameter**	**Compliant/Actions**
Static pressure in tunnel and volume flow on fresh air intake vents	**Static pressure/volume flows P&ID location No 1**	
	Static pressure/volume flows P&ID location No 2	
	Static pressure/volume flows P&ID location No 3	
	Static pressure/volume flows P&ID location No 4	
Rapid roller doors-Building static pressure to ensure building skin integrity	**P&ID No. 1 Door 1 opened/closed**	
	P&ID No. 2 Door 2 opened/closed	
	P&ID No. 3 Door 3 opened/closed	
	P&ID No. 4 Door 4 opened/closed	
Are all flexible sealants in position on tunnel doors?		
Notes:		

The implementation of such quality checking procedures will provide both system confidence and preventative maintenance thereby mitigating any risk associated with odour control/minimisation equipment.

The frequency and planning of sampling depend on the type of process. When the parameters are expected to develop gradual trends like carbon filtration systems rather than sudden changes like chemical scrubbers, the frequency of checking can be low (monthly, biweekly). If the system is more susceptible to cyclic loads, weekly or even daily monitoring may be required, depending on the history and the consequences that may arise from not realising an issue. More importantly seasonal changes in odour loads on equipment can affect the overall performance of the system and combined with the behaviour of people on the receptor side during changing weather conditions (i.e. warm summer days could result in higher odour loads due to higher metabolic activity of bacteria coupled with people enjoying outdoor activities, etc.) For some processes, continuous monitoring may be useful, especially when the consequences of failure are significant. Risk assessment of plant failure is important to define key operational and maintenance parameters for the odour control unit (OCU). On the basis of this risk assessment measures will be defined to reduce the probability of high consequence events or to mitigate their impact.

The public will remember unscheduled emission episodes with great tenacity. It is therefore important to not fully rely on the environmental performance of odour mitigation under normal operational conditions but also consider them under unscheduled emission events. It is therefore crucial to consider and manage risks of odour emissions during:

- Odour Control Unit (OCU) commissioning
- Start-up and shutdown of odour abatement units with consideration for duty standby on particularly odour processes (which has been implemented into the proposed design)
- Management of highly odorous materials
- OCU servicing, and unscheduled shutdown.

In assessing these risks, it must be taken into account that response to odours is almost immediate. In order to manage these odour detection and complaint risks, a number of actions may be considered:

- Plan high-risk activities in periods where receptor sensitivity to annoyance is low like during wet weather when people are indoors, or during colder winter months, or during early morning/late evenings during periods of low atmospheric turbulence, etc.
- Consider providing standby capacity, etc.

If all else fails, inform potentially affected residents of the probability of temporarily increased odours and explain the reasons for these possible increases (i.e. maintenance of OCU, etc.)

4.5 Minimum maintenance schedule for Recycling Facility odour minimisation and control systems.

Table 4.7 illustrates the typical preventative maintenance schedule checking that is required to ensure the continuous efficient operation of the proposed odour control systems to be located within the proposed Recycling Facility.

As can be observed, daily, weekly, monthly, six monthly and yearly checking and maintenance should be performed on the key mechanical elements of each odour control system. The operation and maintenance manual for each odour control system should be consulted before performing any physical works, which requires the removal, changing or alteration of any key component within the odour minimisation and control system.

This schedule allows for the identification of key failure mechanisms for each odour control system and also allows for the implementation of a preventative maintenance schedule. Spare parts for each critical component should be stored to ensure speedy replacement if fault occurs. In addition to this mechanical preventative maintenance schedule, the results generated from the preventative checking performed as part of the Odour Management Plan (*see Section 4*) for the odour control systems will also be consulted and considered.

Table 4.7. Maintenance schedule for Littleton Recycling Facility odour control system.

Equipment	Daily	Weekly	Monthly	Six Monthly	Annually	Estimated life span	Risk of failure
Centrifugal fans	Check for excessive noise/vibration	Check and verify total airflow rate using pitot in stack. Cross verify with VSD recorded values and fan curve.	Check lubrication of bearings	Inspect impellor for signs of excessive vibration, corrosion or solids build up.	Replace bearings if necessary and rebalance in accordance with manufacturers specifications	10 yrs	Low
pH Monitor	-	Clean any scale of surface of pH electrode using detergent.	Calibrate using pH buffer solution 4 and 7.	Replace Electrode	-	1/2 to 1 yr	Medium
Ductwork Extract Grilles	-	-	Clean and check for blockage/damage	-	Check and rebalance VCD on each extract grills as necessary.	10 to 15 yrs	Low
Building membrane integrity	Check building fabric for damage	Check static pressure sensor on building fabric with handheld sensor and verify readings	-	-	Perform annual building integrity test using smoke generation machine	-	Low/Medium
Irrigation Pumps	Check for leaks	Check for excessive noise/vibration	-	-	Replace seals if required	5 yrs	Medium
Nutrient Pump	Check for leaks	Check for excessive noise/vibration	Check pump connections for damage/ weeping	Clean and check operation of non return valve in head of pump	Replace diaphragm and pump head if required	1 to 3 yrs	High
Spray Nozzles	-	Check for Blockages clean and replace if necessary	-	-	Replace spray nozzles if necessary.	1 to 2 yrs	High
Static pressure sensors	Check piping connection for blockages and for condensing moisture, clean as necessary	Verify SCADA reading with onsite handheld sensor and calibrate as necessary	-	-	Replace static pressure sensors if necessary	1 to 2 yrs	High

Table 4.7 continued. Maintenance schedule for Littleton Recycling Facility odour control system.

Equipment	Daily	Weekly	Monthly	Six Monthly	Annually	Estimated life span	Risk of failure
Variable speed drives	-	Perform self diagnostic	-	Change fresh air inlet panel enclosure filters.	-	10 yrs	Low
Biofiltration multistage gauze filter	-	Check pressure sensor connection. Isolate sprinkling system and clean gauze filters with detergent.	-	-	-	3 to 7 yrs	High
Inlet and Outlet drain from Biofiltration system	Check for blockage and clean as necessary	-	-	-	-	10 yrs	High
Biofiltration inlet plenum	-	Check biofiltration side walls for excessive airflow through visual inspection	Check bed medium for settlement. Excessive settlement may be a result of plenum failure	-	-	15 to 20 yrs	Low
Biofiltration medium	Review SCADA differential pressure and CEMS readings to ensure within specification	Check bed medium for abrasion and dry spots, check sprinkling system for failure.	Check bed medium for settlement, top up filter bed if necessary, check base level of filter bed for excessive biomass growth, pH adjustment to be used if excessive biomass growth observed.	Perform quarterly olfactometry testing of exhaust air stream from biofilter to ensure within specification	Review SCADA collated data and independent testing result to establish any trends	10 to 15 yrs	Low
Anti vibration mounts	-	Check visually for failure and corrosion	-	-	-	2 to 5 yrs	Low
Biofilter water recirculation storage tank	Check tank for leaks and integrity.	-	Check tank internals for excess sedimentation and desludge as necessary	-	-	20 yrs	Low
Rapid roller doors	Clean LED and radar safety sensors with clean cloth. Check control panel for error codes	Check gaskets, door rail, saw tooth belts and springs for wear and tear.	-	-	Perform service under contract with supplier and replace consumable parts (dependent on use)	10 to 15 yrs	Medium

4.6 General process verification techniques to be used during build and operate stages for Littleton Recycling facility operations.

The following assessment and monitoring procedures will be utilised for process verification during the build, commissioning and operation stages of the Littleton Recycling Facility in order to ensure effective odour minimisation, containment and treatment of odours occur at the facility.

4.6.1 Containment assessment techniques

The following techniques will be used during the build stage of the project to ensure that containment systems are sufficiently designed to contain odours at the Facility. All subcontractors will be requested to perform the following works in conjunction with an independent assessment team before sign off on installed works. These include:

- Building integrity testing of the facility to include individual zones of the building utilising pressurisation and smoke generation testing. A small fan will pressurise the various building zones skin while a smoke generation machine will generate a 0.2 μm particle size smoke to a 1-metre visibility distance. Sufficient building integrity will be assessed through the absence of the escape of large volumes of smoke from the building. During the build stage of the building, the inner side of the complete building will be coated with an impermeable layer, which will prevent any leakage from this building.
- All rapid roller doors will be flashed sufficiently to prevent the release of odours. The door-mounting rail will be flashed directly to the inner wall of the building while the door mounting rails will be gasketed to prevent any release of odours during process upset. The integrity of this seal will be accessed during the building integrity test.
- Any zones of identified leakage from the recycling building will result in the performing of additional works to ensure integrity.

The assessment of all containment techniques will be implemented into the overall contract to ensure works are carried out properly and operate without difficulties.

4.6.2 Ventilation and extraction system assessment techniques

The following techniques will be used to ensure the installed equipment is sufficient and compliant with requirements. All subcontractors will be requested to perform the following works in conjunction with an independent assessment team before sign off on installed works. These include:

- The odour ventilation system will be assessed for all parameters including materials of construction, design, duct airflow velocities, system pressures, etc.
- The ventilation system will be designed to ensure sufficient extraction throughout the system with head loss in mind.
- The ventilation system ductwork will be designed to ensure condensate does not cause blockage in any section of the extraction system. Access ports will also be installed to allow maintenance staff to access volume control dampers and for ease of cleaning. Self-drains will be directly ducted to an enclosed sump within the composting process.
- The ventilation extraction grills on all process ductwork within the Facility will be designed with low face velocities in mind to minimise the entrainment of dust within the ductwork. In addition, the ductwork will be located away from dust generating operations.
- Static pressure sensors will be installed at strategic points in the system to allow for predictive maintenance. All static sensors will be SCADA linked with tag alarm levels included. All alarm levels will be established during the commissioning aspects of the project. Continuous volumetric airflow monitoring is not an attractive option in composting extraction systems due to the build up of residues upon pitot/sensor heads resulting in erroneous results.
- Entry points into processes will be designed in such a manner to minimise the collection of dust and prevent blocking on duct extraction points. Access ports will be

installed in order to allow for easy of cleaning in such an event. Low face velocities across extraction grills will minimise dust entrainment.

- Ductwork will be flanged in sections to allow for easy of maintenance and to allow for sectional removal/replacement as necessary.
- All extraction system design will be confirmed and assessed in accordance with presented design, pressure monitoring and airflow rate monitoring.

Such assessment and control techniques are used through out Ireland on odour control installations. The client is welcome to visit such installation

4.6.3 Odour control system assessment techniques

The following techniques will be used to ensure the installed odour control equipment is sufficient and within contract specifications. All subcontractors will be requested to perform the following works in conjunction with an independent assessment team before sign off on installed works. These include:

- Assessment of odour emission rate from odour control unit in accordance with EN13725:2003.
- Assessment of volumetric treatment capacity in accordance with ISO10780:1994.
- Assessment of Hydrogen sulphide, Mercaptans, Ammonia treatment capacity.
- Assessment of static pressures throughout the system for SCADA alarm tagging,
- Assessment of tiered SCADA control system for odour control systems to be located upon the Facility.

Emission limit values as specified in *Section 5* will ensure compliance. In addition, the overall site Odour Management Plan will form part of the preventative maintenance schedule for the facility.

5. Results of odour and bioaerosol emission rates and dispersion modelling.

5.1 Odour and bioaerosol emission data

Two data sets for odour and bioaerosol emission rates were calculated to determine the potential odour and bioaerosol impact of the proposed Littleton Recycling Facility operation and design utilising library individual source odour and bioaerosol emission data. These scenarios included:

Ref Scenario 1: Predicted overall odour emission rate from proposed Recycling facility specimen design with the incorporation of odour mitigation protocols (*see Table 5.1*).

Ref Scenario 2: Predicted overall bioaerosol emission rate from proposed Recycling facility with the incorporation of odour management systems (*see Table 5.2*).

5.1.1 Odour emission rates from proposed Littleton Recycling facility operations for atmospheric dispersion modelling Scenarios

Table 5.1 illustrate the overall odour emission rate from the proposed Littleton Recycling facility (i.e. indicative design with installed odour mitigation strategies implemented).

As can be observed in *Table 4.1,* the overall odour emission rate from the proposed Littleton Recycling facility indicative design with the implementation of odour minimisation, mitigation and management strategies. The overall source odour emission is predicted to be at or less than 38,250 Ou_E/s. This odour emission rate is based on a number of mitigation assumptions that will require to be implemented into the facility design. These are discussed throughout this document.

Table 5.1. Predicted overall odour emission rate from proposed Littleton Recycling Facility indicative design with the incorporation of odour mitigation protocols (ref Scenario 1).

Emission points	Efflux velocity (m/s)	Volumetric airflow rate (m^3/s)	Odour threshold conc (Ou_E/m^3)	Odour emission rate (Ou_E/s)
Biofilter 1	0.0379	9.5625	1,000	9563
Biofilter 2	0.0379	9.5625	1,000	9563
Biofilter 3	0.0379	9.5625	1,000	9563
Biofilter 4	0.0379	9.5625	1,000	9563
Total odour emission rate (Ou/s)[1, 2]	**-**	**38.25**	**-**	**38250**

<u>Notes:</u>

[1] denotes that all composting operations will be carried out indoors. This includes the delivery and tipping of waste material will be performed indoors, shredding, amendment and mixing of material, loading of material into primary first stage and second stage composting tunnels, screening of primary first stage digested material, loading of primary first stage digested material into second stage composting tunnels and final screening of material. The containment principle will apply here to ensure no emissions of odours escape to atmosphere. Odours collected from the headspace of the intake waste reception hall and secondary building will be directed to an odour control unit (i.e. biotrickling filter). All odourous air collected will be directed to the odour control units. The building will be fitted with rapid roller doors in order to minimised and prevent the release of odours during door opening. The building envelope will be fitted with absolute pressure control fresh air intake vents, which will automatically close and open depending on negative pressure applied to the building.

[2] denotes the overall odour treatment extraction rate is assumed and may need revision depending on process layout and final engineering design. The overall containment process of the building will be process proved independently using traditional smoke generation techniques so as to demonstrate containment of odours within the building.

5.1.2 Proposed specific bioaerosol emission rate from the proposed Recycling Facility

A specific bioaerosol risk assessment was performed in order to ascertain the ground level concentration impact in the vicinity of the site. *Table 5.2.* illustrates the predicted bioaerosol emission rate from the facility emission points. These values are considered worst case on this biofiltration system due to the type of media used within the system design. All activities associated with the composting process will be carried out indoors which will further reduce any associated impacts within the vicinity of proposed site location. The emission rates presented are calculated from library based peer reviewed publications on bioaerosol emissions from biofiltration systems. The results of the dispersion modelling assessment are presented in *Section 6.3* while the proposed Environment agency Environmental Assessment Level was used as the ground level limit value.

Table 5.2. Bioaerosol emission rate from Recycling Facility process odour control units.

Library based bioaerosol emission rates from typical biofilters			
Bioaerosol identity	**Predicted emission conc. (CFU/m^3)**	**Total volumetric airflow rate from composting odour control units (m^3/s)**	**Total Bioaerosol emission rate (CFU/s)[3]**
Aspergillus fumigatus[1,2]	1,200	38.25	45,900
Total Mesophillic bacteria[1,2]	5,000	38.25	191,250
Total fungi[1,2]	10,000	38.25	382,500

<u>**Notes:**</u> [1] denotes the library based emission concentration obtained from: Sanchez, MA., Steinford, E., (2003). Environ. Sci. Tech. 37, 4299-4303.
Ottengraf, S. P. P., Konings, J., H. G. (1991). Bioprocess Eng, 7 (1-2), 89 to 96.
Martens, W., Martinec, M., Zapirain, R., Stark, M., Hartung, E., Palmgre, U., (2001). Int, J. Hyg. Environ. Health, 203. 335 to 345.
[2] denotes Bioaerosol emission rates were calculated from library based bioaerosol concentrations levels from other biofilters used in the international community treating composting air streams multiplied by the calculated ventilation rate to maintain the ICF under negative ventilation. Biofiltration system surface area (m/hr) and superficial gas velocity (m min-1) were taken account of during the calculations in order to ensure similar biofiltration operation as library based systems.

5.1.3 Odour and bioaerosol dispersion modelling results.

AERMOD Prime (USEPA ver. 07026) was used to determine the overall contaminant impact (odour and bioaerosols) impact of the Littleton Recycling facility.

Impacts from emission points are assessed in accordance with the impact criterion contained in *Section 3.9 and 3.11*.

Two distinct scenarios were assessed:

The output data was analysed to calculate the following:

<u>**Ref Scenario 1:**</u>

- Predicted odour emission contribution of overall proposed Recycling facility operation to surrounding population (*see Table 5.1*), to odour plume dispersal at the 98th percentile for a ground level concentration of less than or equal to 1.50 Ou_E m^{-3} (*see Figure 8.2*).
- Predicted odour emission contribution of overall proposed Recycling facility operation to surrounding population (*see Table 5.1*), to odour plume dispersal at the 99.5th percentile for a ground level concentration of less than or equal to 3.0 Ou_E m^{-3} (*see Figure 8.3*).

Ref: Scenario 2:

- Predicted Aspergillus *f* emission contribution of overall proposed Recycling facility operation to surrounding population (*see Table 5.2*), to bioaerosol plume dispersal at the 1 hour maximum ground level concentration of less than or equal to 1.50 CFU m^{-3} (*see Figure 8.4*).
- Predicted Total fungi emission contribution of overall proposed Recycling facility operation to surrounding population (*see Table 5.2*), to bioaerosol plume dispersal at the 1 hour maximum ground level concentration of less than or equal to 1.50 CFU m^{-3} (*see Figure 8.5*).
- Predicted Total Mesophillic bacteria emission contribution of overall proposed Recycling facility operation to surrounding population (*see Table 5.2*), to bioaerosol plume dispersal at the 1 hour maximum ground level concentration of less than or equal to 1.50 CFU m^{-3} (*see Figure 8.6*).

These odour and bioaerosol impact criterions were chosen for the proposed Recycling facility in order to ascertain the level of proposed impact to the surrounding population. These computations give the odour and bioaerosol concentration at each Cartesian grid receptor location that is predicted to be exceeded for 0% (0 hours), 0.5% (44 hours) and 2% (175 hours) of seven years of hourly sequential meteorological data.

This will allow for the predictive analysis of any potential impact on the neighbouring sensitive locations while Recycling Facility is in operation. It will also allow the operators of the facility to assess the effectiveness of their suggested odour abatement/minimisation strategies. The intensity of the odour from the two or more sources of the facility operation within the Recycling facility will depend on the strength of the initial odour threshold concentration from the sources and the distance downwind at which the prediction and/or measurement is being made. Where the odour emission plumes from a number of sources combine downwind, then the predicted odour concentrations may be higher than that resulting from an individual emission source. It is important to note that various odour sources have different odour characters. This is important when assessing those odour sources to minimise and/or abate. Although an odour source may have a high odour emission rate, the corresponding odour intensity (strength) may be low and therefore is easily diluted.

6. Discussion of results from baseline and dispersion modelling study

This section provides discussion on the results obtained during the baseline and predictive impact assessment.

6.1 Baseline Bioaerosol concentration levels

Table 6.1 illustrates the results from bioaerosol air quality monitoring. Both Aspergillus *fumigatus* and Total Mesophillic bacteria were assessed on the day of sampling namely 19th March 2008.

Table 6.1. Bioaerosols concentration levels within and in the vicinity of the proposed recycling facility.

Location ID	Average Aspergillus fumigatus concentration (CFU m^{-3})[1]	Average Mesophillic bacteria concentration (CFU m^{-3})[1]
A6	<7	162
A7	<8	84
A9	<7	92
A10	<8	124

Note: [1] denotes a total of 6 blanks (3 plate and 3 impactor blanks for the monitored bioaerosol) were incorporated into the sampling exercise. All blanks were negative CFU m^{-3}.

Table 6.1 illustrates the ambient bioaerosol air quality within and in the vicinity of the proposed facility. As can be observed, Aspergillus *fumigatus* concentrations are low and at expected ambient concentration levels. Total mesophillic bacteria concentration levels were also low at all baseline monitoring locations. Monitoring in this area in Autumn could result in higher levels of bioaerosols as a result of rotten vegetation from tree planting in the area although it is expected that this would be generally low and localised.

Following a review of literature, it is reported that concentration levels of bioaerosols in ambient environment range from 0 to 400 CFU m^{-3} for Aspergillus *fumigatus*, 0 to 15,673 CFU m^{-3} for Total fungi and 79 to 3204 CFU m^{-3} for Total bacteria. The data set measured is within the lower end of this range. Background monitoring of bioaerosols is important due to the complexities in monitoring once a facility is in operation. The main reasons for background monitoring include:

- Microbes are ubiquitous in the environment and air or surface samples will always contain some bacteria or fungi.
- Microbes grow and are released at irregular intervals and depend on some sort of air turbulence to be transported from their original source.
- Bioaerosols vary greatly in size and therefore some remain in ambient air for longer periods of time in comparison to larger, heavier particles that fall quickly to the ground. This is explained with Stokes law.
- Meteorological factors such as relative humidity, temperature and wind speed greatly effect ambient air concentrations.
- Due to the variety of size and sensitivity, the sampling methodology will greatly affect the measured concentration.
- Seasonal effects can increase of decrease ambient bioaerosol concentrations.

In accordance with the assessment criteria reported in *Table 6.1*, bioaerosol concentrations within lower range for Aspergillus fumigatus and Total Mesophillic bacteria.

6.2. Baseline hydrogen sulphide odour sniff assessment

Table 6.2. illustrates the results obtained from the ambient air hydrogen sulphide and odour survey (sniff assessment).

Table 6.2. Hydrogen sulphide and odour sniff survey analysis monitoring results.

Location[1]	Hydrogen sulphide conc (ppb)	Odour intensity	Odour extent	Location sensitivity[2]	Odour descriptor
A1	<3	1	0	3	No detectable odour
A2	<3	1	0	3	No detectable odour
A3	<3	1	0	3	No detectable odour
A4	<3	1	0	3	No detectable odour
A5	<3	1	0	3	No detectable odour
A6	<3	1	0	3	No detectable odour
A7	<3	1	0	3	No detectable odour
A8	<3	1	0	3	No detectable odour
A9	<3	1	0	3	No detectable odour
A10	<3	1	0	3	No detectable odour
A11	<3	1	0	3	No detectable odour

Notes: [1] denotes refer to Environment Agency Guidance document – Internal guidance for regulation of odour at waste management facilities for description of identifiers.
[2] denotes Location sensitivity refers to the potential risk of housing located in close proximity to odour sources.

Table 6.2 illustrates the results obtained from the Hydrogen sulphide and odour sniff survey performed on the 19th March 2008. As can be observed, ambient air concentrations of hydrogen sulphide on the day of monitoring were less than 3 ppb. No detectable odour was present at any of the monitoring locations on the day of monitoring in the vicinity of the proposed location of the facility.

6.3 Predicted Littleton Recycling Facility odour impact assessment

The plotted odour concentrations of ≤ 1.50 Ou_E m^{-3} for the 98^{th} and ≤ 3 Ou_E m^{-3} for the 99.5^{th} percentile for the proposed Littleton Recycling facility operation is illustrated in *Figure 8.3 and Figure 8.4,* respectively. As can be observed, it is predicted that odour plume spread is small with a radial spread of approximately 120 metres. Greater odour plume spread will be experienced on the eastern boundary of the plant. In accordance with odour impact criterion in *Section 3.7.4*, and in keeping with currently recommended odour impact criterion in this country, no long-term or short-term odour impacts will be generated by receptors in the vicinity of the proposed Recycling facility indicative design. The main contributor of odour to the actual plume spread is the odour control system. All waste reception, mixing, primary and secondary and screening composting operations will be performed indoors within a sealed building with negative air extraction application.

6.4 Predicted Littleton Recycling Facility bioaerosol impact assessment

Figure 8.4. illustrates the predicted impact of Aspergillus *fumigatus* from the proposed Littleton Recycling Facility. As can be observed the overall plume spread of Aspergillus *fumigatus* is small and mainly concentrated around the Facility buildings. The maximum predicted ground level concentration of 12 CFU/m^3 is predicted in and around the facility. This is approximately 97% lower than the proposed Aspergillus *fumigatus* impact criterion of 500 CFU/m^3 proposed by the Environment Agency guidance document.

Figure 8.5. illustrates the predicted impact of Total fungi from the proposed Littleton Recycling Facility. As can be observed the overall plume spread of Total fungi is small and mainly concentrated around the Facility buildings. The maximum predicted ground level concentration of 99 CFU/m^3 is predicted within the facility boundary. This is approximately 91% lower than the proposed Total fungi impact criterion of 1000 CFU/m^3 proposed by various researchers in the international community.

Figure 8.6. illustrates the predicted impact of Total Mesophillic bacteria from the proposed Recycling Facility. As can be observed the overall plume spread of Total Mesophillic bacteria is small and mainly concentrated around the Facility buildings. The maximum predicted ground level concentration of 48 CFU/m^3 is predicted within the facility boundary. This is approximately 96% lower than the proposed Total Mesophillic bacteria impact criterion of 1000 CFU/m^3 proposed by the Environment Agency guidance document.

Therefore the proposed Recycling Facility design will not cause any significant bioaerosol impact in the vicinity of the facility.

7. General conclusions

The following general conclusions were drawn from the study:

1. The overall proposed odour mitigation techniques are based on sound engineering principles and proven design. All such technologies are in operation for the management of odours at many facilities in Ireland. The overall incorporation of robust preventative maintenance procedures, containment measures, focused extraction, zoned ventilation, and treatment will ensure that odours will not cause impact on the surrounding area and that the odour control system will operate at optimal capacity.

2. The Recycling Facility design will ensure compliance with the odour impact criterion contained in *Section 3.9*. All ground level concentration of odours will be less than the $\leq 1.5\ Ou_E/m^3$ at the 98^{th} percentile of hourly averages and $\leq 3.0\ Ou_E/m^3$ for the 99.5^{th} percentile of hourly averages for seven years of meteorological data. The implementation of odour management, minimisation and mitigation techniques and technologies will achieve the odour impact criterion when operating at optimal capacity.

3. The proposed Recycling facility will not cause any bioaerosol impact (Aspergillus *fumigatus*, Total fungi and Total Mesophillic bacteria) as determined using worst-case bioaerosols emission rates and dispersion assessment. All ground level concentration of bioaerosols will be well below the impact criterion proposed by the Environment Agency, UK.

4. This overall document provides a strategy and engineering design for the implementation of odour minimisation, mitigation and control of odour emissions from the Recycling Facility and provides the backbone development of an odour management and preventative maintenance plan for the processes. The guaranteed emission rates of odours will provide compliance with the odour impact criterion contained in *Section 3.9*.

8. General recommendations

The following recommendations were developed during the study:

1. Odour management, minimisation and mitigation procedures as discussed within this document in general will be implemented at the proposed Recycling facility in order to prevent any odour impact in the surrounding vicinity.
2. The maximum allowable odour emission rate from the overall proposed Recycling facility and biofiltration system should not be greater than $38{,}250 Ou_E\ s^{-1}$ (*see Table 5.1*) inclusive of the odour emission contribution from the abatement systems installed.
3. Maintain good housekeeping practices (i.e. keep yard area clean, etc.), closed-door management strategy (i.e. to eliminate puff odour emissions), maintain first and second stage composting within separate highly ventilated zone, install rapid roller doors, install impermeable layer on inner side of building clad and to implement an odour management plan for the operators of the Recycling facility. All odourous processes will be carried out indoors.
4. The odour and bioaerosol management plan should include a process description, management strategies for the prevention of emissions and a strict maintenance and management program for ensuring all odour and bioaerosol mitigation techniques remain operation at optimal capacity throughout all operational scenarios.
5. Operate the proposed Recycling facility within specifications to eliminate overloading and under loading, which may increase emissions from the processes.
6. When operational, it is recommended that the operator should process prove the operation of the facilities containment and mitigation systems through the use of pumped smoke integrity testing and performance measurements of the odour control

systems (i.e. static pressure testing, flow testing, odour removal testing, equal air distribution testing, etc). this initial data should be recorded in the odour and bioaerosol management plan and be used as the basis for identifying any issues during future operations.

9. *Appendix I* – Littleton Recycling Facility Odour and Bioaerosol contour plots from dispersion modelling assessment.

9.1 Location layout map

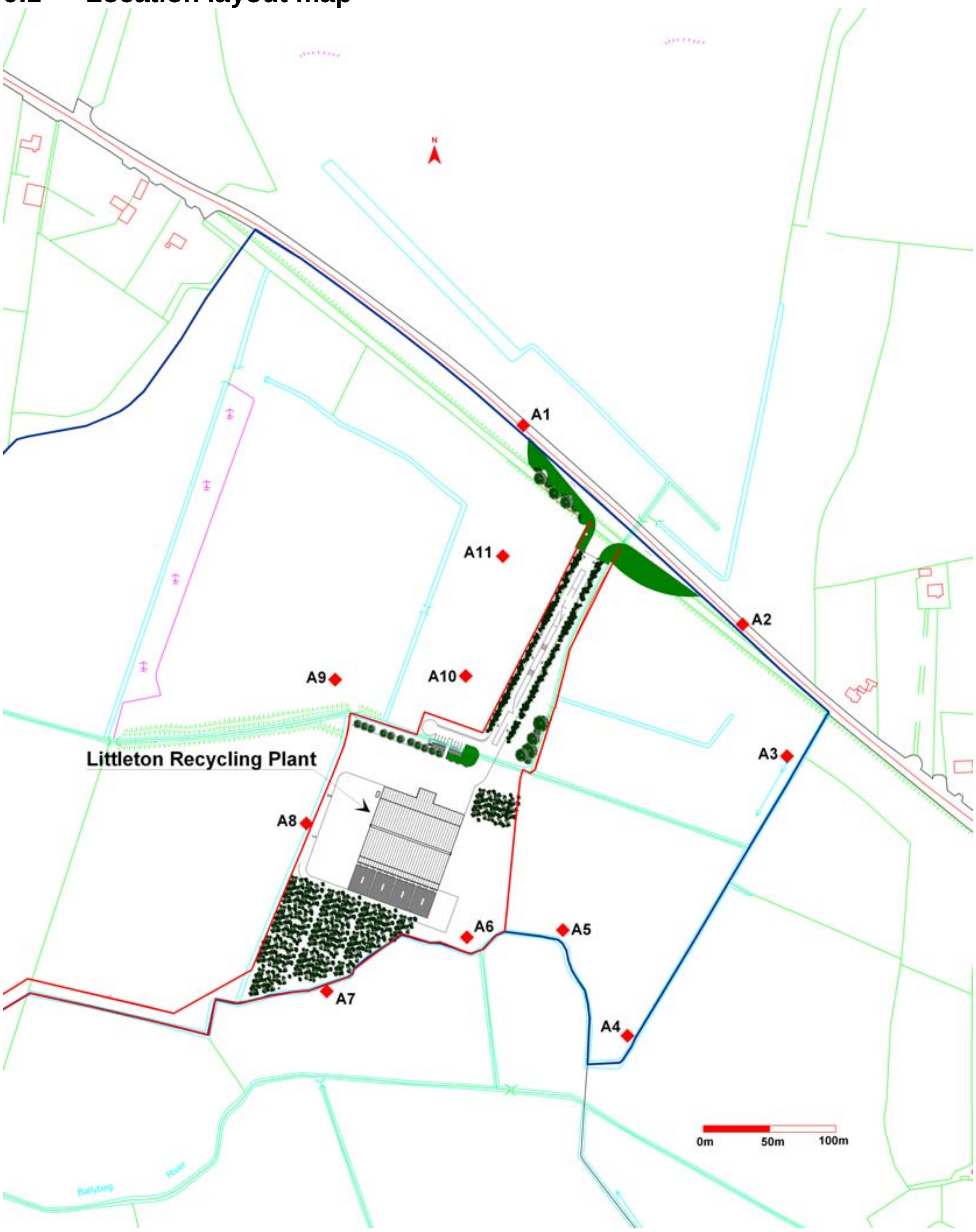

Figure 9.1. Aerial diagram of proposed Littleton Recycling Facility, proposed boundary (▬) and baseline monitoring locations (♦)

9.2 Predicted Littleton Recycling Facility odour dispersion modelling assessment contour plots

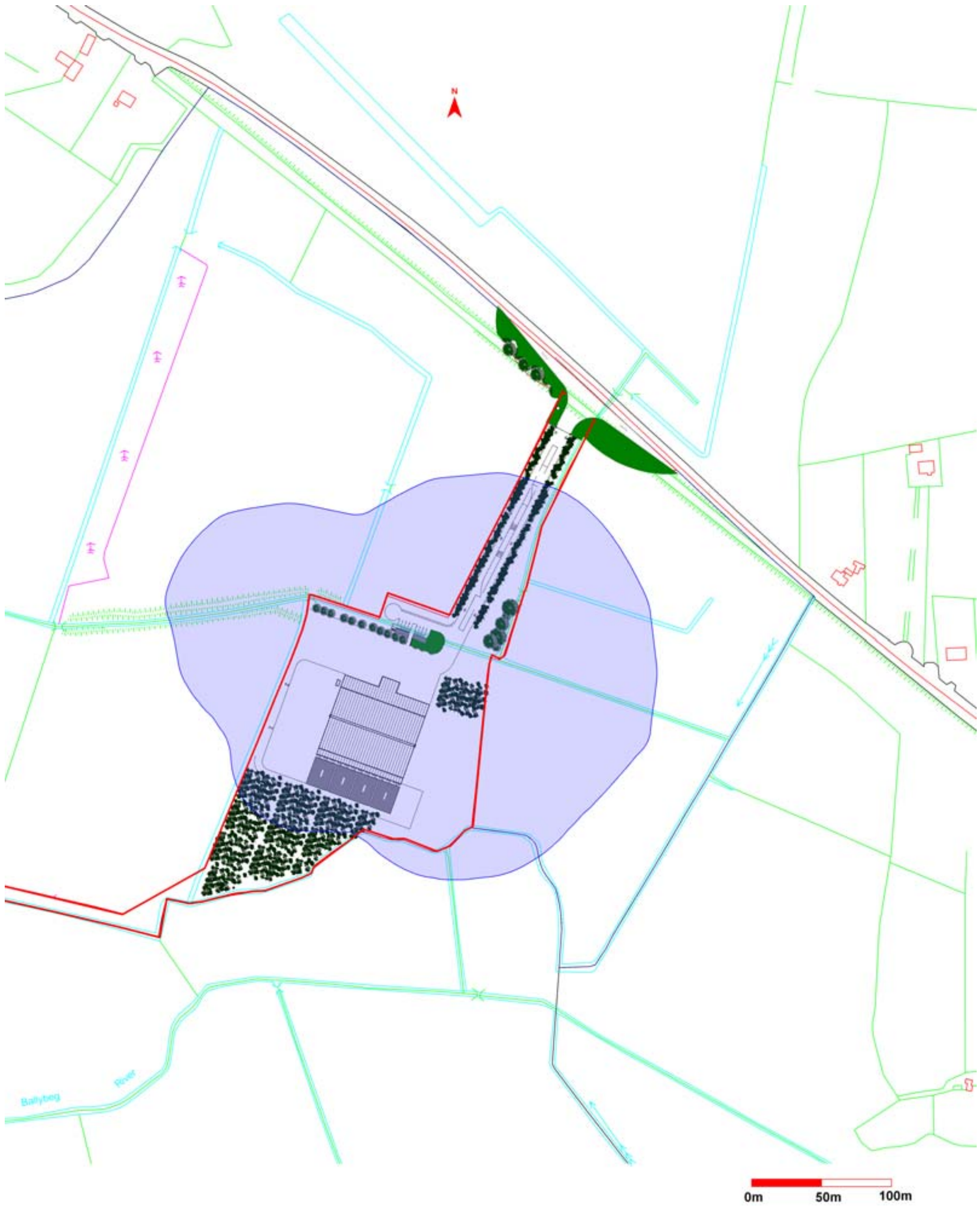

Figure 9.2. Predicted odour emission contribution of proposed overall Littleton Recycling Facility operation with odour abatement protocols implemented to odour plume dispersal for the 98th percentile for an odour concentration of ≤ 1.5 Ou_E m^{-3} (▬▬) for 7 years of hourly sequential meteorological data from Dublin airport (2000 to 2006 inclusive).

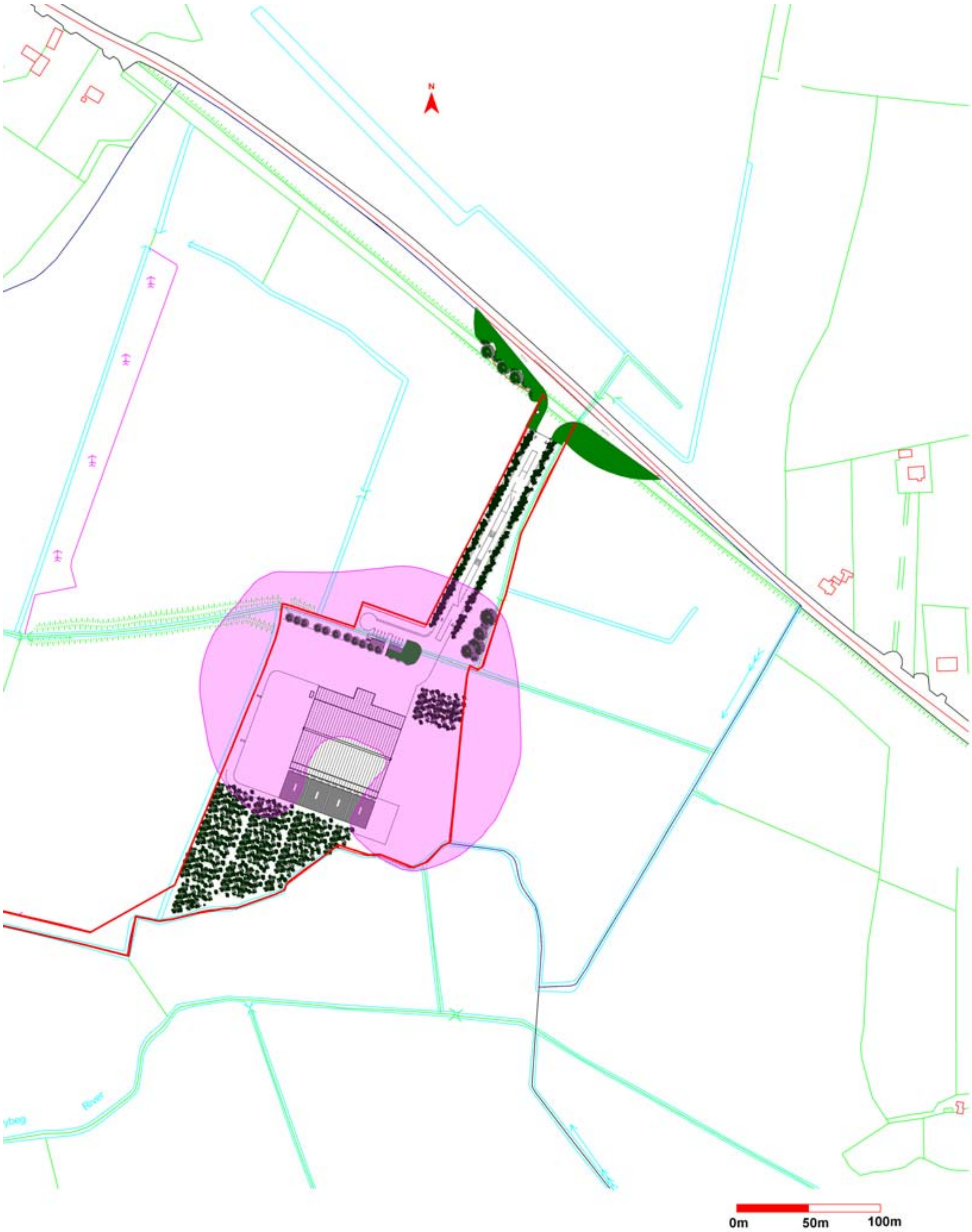

Figure 9.3. Predicted odour emission contribution of proposed overall Littleton Recycling Facility exhaust point operation with odour abatement protocols implemented to odour plume dispersal for the 99.5th percentile for an odour concentration of $\leq$ 3.0 Ou_E m^{-3} (▬) for 7 years of hourly sequential meteorological data from Dublin airport (2000 to 2006 inclusive).

9.3 Predicted Littleton Recycling Facility bioaerosol dispersion modelling assessment contour plots

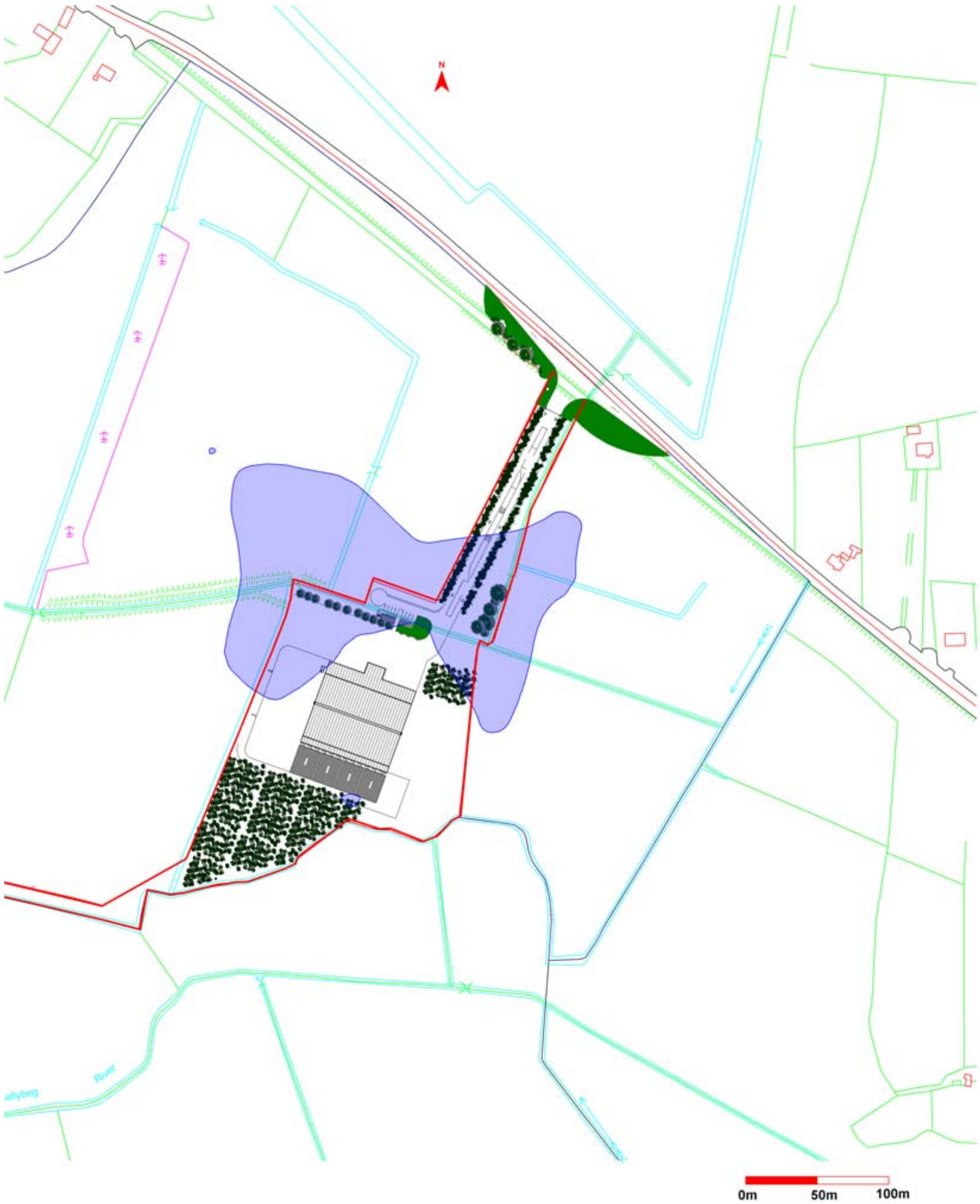

Figure 9.4. Predicted Aspergillus *fumigatus* emission contribution of proposed Littleton Recycling Facility operation to Aspergillus *fumigatus* plume dispersal for the 1 hour Aspergillus *fumigatus* plume spread for an Aspergillus *fumigatus* concentration of ≤ 9.0 CFU m^{-3} (▬▬) for 7 years of hourly sequential meteorological data from Dublin airport (2000 to 2006 inclusive).

Figure 9.5. Predicted Total fungi emission contribution of proposed Littleton Recycling Facility operation to Total fungi plume dispersal for the 1 hour Total fungi plume spread for an Total fungi concentration of ≤ 75 CFU m^{-3} (magenta line) for 7 years of hourly sequential meteorological data from Dublin airport (2000 to 2006 inclusive).

Figure 9.6. Predicted Total Mesophillic bacteria emission contribution of proposed Littleton Recycling Facility operation to Total Mesophillic bacteria plume dispersal for the 1 hour Total Mesophillic bacteria plume spread for an Total Mesophillic bacteria concentration of ≤ 38 CFU m^{-3} (▬) for 7 years of hourly sequential meteorological data from Dublin airport (2000 to 2006 inclusive).

10. *Appendix II* - Meteorological data examined and used in the dispersion modelling exercise

Table 10.1. Tabular illustration of Dublin Airport meteorological files for Years 2000 to 2006 inclusive (7 years).

7 year Meteorological file for Dublin Airport 2000 to 2006 inclusive							
Dir \ Speed	**<= 1.54 m/s**	**<= 3.09 m/s**	**<= 5.14 m/s**	**<= 8.23 m/s**	**<= 10.80 m/s**	**> 10.80 m/s**	**Total**
0.0	0.64	0.48	0.93	0.45	0.06	0.00	**2.56**
22.5	0.14	0.48	1.06	0.54	0.16	0.00	**2.38**
45.0	0.11	0.32	1.31	0.74	0.22	0.01	**2.71**
67.5	0.08	0.24	1.56	0.90	0.37	0.03	**3.17**
90.0	0.13	0.41	2.18	0.92	0.30	0.07	**3.99**
112.5	0.16	0.66	2.54	0.76	0.16	0.04	**4.30**
135.0	0.21	0.76	4.18	2.81	0.79	0.15	**8.90**
157.5	0.21	0.72	2.53	1.71	0.60	0.09	**5.86**
180.0	0.20	0.45	1.33	0.77	0.33	0.05	**3.12**
202.5	0.17	0.40	2.25	2.20	1.02	0.25	**6.30**
225.0	0.17	0.60	4.21	4.55	2.31	0.67	**12.51**
247.5	0.18	0.59	4.76	5.24	2.91	0.96	**14.63**
270.0	0.18	0.62	4.96	4.26	2.15	0.70	**12.86**
292.5	0.17	0.67	4.10	2.22	0.72	0.15	**8.03**
315.0	0.24	0.50	2.73	1.31	0.27	0.04	**5.10**
337.5	0.22	0.34	1.48	0.77	0.14	0.04	**2.98**
Total	**3.19**	**8.25**	**42.10**	**30.15**	**12.47**	**3.25**	**99.42**
Calms	-	-	-	-	-	-	**0.50**
Missing	-	-	-	-	-	-	**0.08**
Total	-	-	-	-	-	-	**100.00**

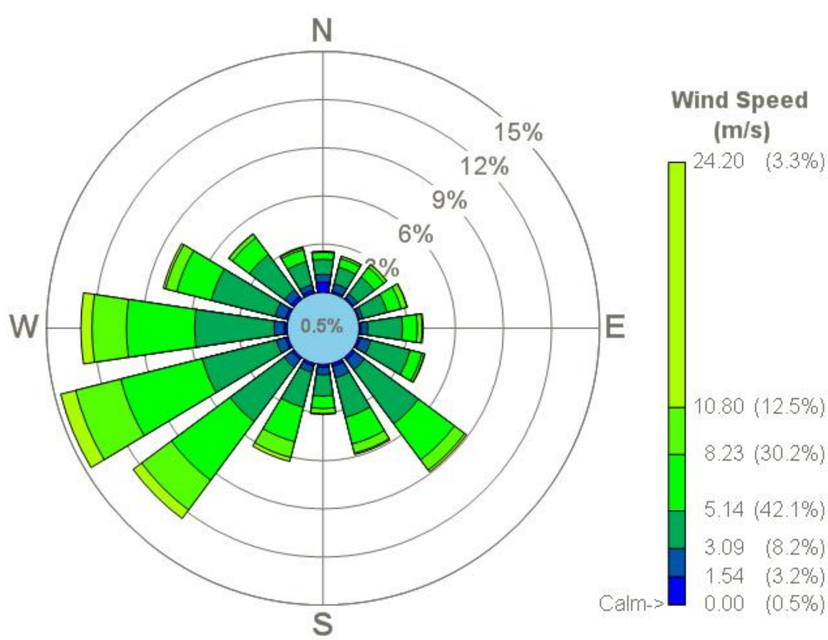

Figure 10.1. Windrose illustration of meteorological files Dublin Airport 2000 to 2006 inclusive.