ODOUR & Environmental Engineering Consultants

Unit 32 De Granville Court, Dublin Rd, Trim, Co. Meath

Tel: +353 46 9437922
Mobile: +353 86 8550401
E-mail: info@odourireland.com
www.odourireland.com

ODOUR IMPACT ASSESSMENT AND APPRAISAL OF ODOUR CONTROL TECHNIQUES TO BE IMPLEMENTED ON THE DRY FERMENTATION AND REFUSE DERIVED FUEL FACILITY TO BE LOCATED IN PANDA WASTE LTD, BAUPARC BUSINESS PARK, NAVAN, CO. MEATH.

PERFORMED BY ODOUR MONITORING IRELAND ON BEHALF OF PANDA WASTE LTD.

PREPARED BY:	Dr. Brian Sheridan
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EXECUTIVE SUMMARY

Odour Monitoring Ireland was commissioned by Panda Waste Ltd to carry out an odour impact assessment and design of the odour control techniques to be implemented on the proposed Dry fermentation and Refuse derived fuel facility to be located in Bauparc Business Park, Navan, Co. Meath. The purpose of this assessment was to design odour minimisation, management and mitigation techniques for the proposed facilities and to ascertain compliance of such a design with internationally recognised odour impact criteria.

Emission point guarantees for odours were established within the appraisal in order to allow for assessment of compliance of the overall designs with such odour impact criterion in order to eliminate odour risks associated with the facilities.

AERMOD Prime (12060) was used to construct the basis of the odour impact assessment in accordance with national and international odour impact criterion. Five years of hourly sequential meteorological data (Dublin airport 2002 to 2006 inclusive) was screened in the dispersion model with worst case year Dublin 2004 utilised for presentation of results.

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.

Each odour control management system will be fitted with a SCADA system to ensure continuous monitoring of key parameters such as temperature, pH, liquid flow rate, % consumables remaining, static and differential pressure, operation hours, etc. This integrated SCADA system will facilitate the assessment and control of the overall odour management system to ensure effective operation. Alarm tagging of process specific values such as differential pressure, pH and flow rate, etc. will ensure the overall odour management system operates at optimal capacity to ensure no odour impact in the vicinity of the facility.

The overall design of the odour control and management system for the Dry fermentation and Refuse derived fuel facility considered containment, minimisation and treatment of odours generated within the facility. All facility operations including reception, handling, processing and treatment of material will be carried out indoors. The facility buildings will be fitted with a building fabric in order to provide near 100% odour containment within the facility buildings. The cladding techniques including joint taping and double skin clad will provide excellent odour containment techniques to ensure the efficient capture of odours within the enclosed facilities. Rapid roller doors where necessary will be fitted to the access doors of the facilities. Double containment and zoned ventilation will be incorporated where required into the overall design so as to ensure efficient capture and extraction of odours to the treatment system.

For the Dry fermentation facility, all high load odours are self-contained within enclosed composting tunnels. Extraction air from these composting tunnels will receive two stages of odour treatment. First stage treatment will consist of acid scrubbing for the removal of biofiltration system poisons Ammonia and Amines. This Ammonia and Amine free airstream will then be directed to a biotrickling filtration system providing approximately 50 seconds empty bed retention time. Following this acid scrubbing treatment this air stream will be mixed with general low odour load ventilation air from the waste reception hall, mixing and screenings hall and processing hall of the dry fermentation facility. All treated air will be directed to a single emission stack (A2-1) for dispersion with a finished height of 15 m above ground level. As part of the overall odour treatment system, an integrated CEMS and SCADA monitoring system will be incorporated into the design to allow for continuous monitoring of physical performance of the odour control equipment.

The overall design of the facility odour control system incorporates proven design elements on other reference facilities. The design considered contingency for media changeout and

preventative maintenance so as to ensure optimal performance. The inlet air distribution plenum floor chosen will provide homogenous airflow throughout the biofilter bed medium. The biotrickling bed medium chosen is inorganic based and of uniform particle size. The bed medium is lightweight, will not degrade, is free draining, has excellent structural integrity and low headloss. The design life of the bed medium is in excess of 10 years therefore reducing downtime associated with changeout. The medium can be sucked out and blown in to the biotrickling filter. The operation of the biotrickling filter with a continuous moving liquid film will ensure contaminant build up within the media will be minimised within the biotrickling bed and allow for the continuous control and addition of nutrients, minerals, pH and biofilm development. The exhaust stack of the biotrickling filter will achieve an odour threshold concentration less than 700 Ou_E/m^3 as a stack guarantee.

For the Refuse derived fuel facility, the exhaust air from the thermal drier will be directed to a cyclone for the removal of large particulate load. Following this treatment step, the air stream will be directed to the biomass boiler (A2-2). The biomass boiler combustion zone will be operated at a temperature of between 800 and 850 deg C. A total retention time of approximately 2 seconds will be achieved within the combustion zone to ensure complete odour removal. All treated air will be directed to a single emission stack for dispersion with a finished height of 16 m above ground level. The exhaust gas will be treated to an odour level of less than or equal to 1,000 Ou_E/m^3 as a stack guarantee. The Refuse derived fuel facility building will be maintained under negative pressure using a combined dust filtration and carbon filter (A2-6). A total extraction volume of up to 100,000 m^3/hr will be extracted from the building where odour material will be handled. The exhaust gas will be treated to an odour level of less than 500 Ou_E/m^3.

Following completion of the odour impact assessment, it was concluded and demonstrated that the overall Dry fermentation and Refuse derived fuel facility design will not cause odour impacts on the surrounding area. These key design elements and conclusions included:

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 Panda Waste Dry fermentation and Refuse derived fuel 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 throughout the world (references included with documentation). The overall incorporation of robust preventative maintenance procedures, containment measures, focused extraction, zoned ventilation, SCADA control, monitoring, trending and data-logging and multiple stages of treatment will ensure that odours will not cause impact on the surrounding area and that the odour control systems (biotrickling filter and biomass thermal oxidiser) will operate at optimal capacity.

3. The Dry fermentation and RDF facility design will ensure that all ground level concentration of odours at the nearest sensitive receptors will be less than 1.50 Ou_E/m^3 at the 98th percentile of hourly averages for five years of screened hourly sequential meteorological data in the vicinity of the facility. The implementation of odour management, minimisation and mitigation techniques and technologies outlined in the overall facilities operation will achieve the specified odour impact criterion to prevent nuisance odours at nearest residential and business neighbours (*see Figures 8.2*).

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

1. Introduction and scope

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

1.1 Introduction

Panda Waste Ltd commissioned Odour Monitoring Ireland to perform odour control system design and dispersion modelling assessment, odour minimisation, management and mitigation strategies for the proposed Dry fermentation (DF) and Refuse derived fuel (RDF) facility design to be located in Bauparc Business Park, Navan, Co. Meath. An independent odour impact assessment and overall appraisal was performed for facility odour control system designs in order to determine the potential risks of odour in the vicinity of the facility. Since the proposed facility will be fully enclosed, only scheduled emission(s) from odour control system exhaust point will occur. Realistic specific odour emission limit guarantees were developed from library-based data and through extensive experience in such technologies.

This odour emission data including source characteristics was utilised in conjunction with dispersion-modelling techniques (i.e. AERMOD Prime 12060) to assess any odour impact on the surrounding area in accordance with international and national odour impact criteria (*see Section 5*). Odour 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, AG4 - Air Dispersion Modelling from Industrial Installations Guidance Note (AG4) and H Horizontal Guidance notes Parts 1 and 2, UK Environment Agency. 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 stacks). AERMOD Prime will provide more conservative dispersion estimates and thereby provide even more conservative predicted ground level concentrations of odour thereby providing greater protection for the local area. In addition, AERMOD Prime is the model mechanism preferred by the Environmental Agency and USEPA. Five years of consecutive meteorological data (Dublin Airport 2002 to Dublin Airport 2006 inclusive) was screened within the dispersion modelling assessment to provide statistically significant prediction over 5 years.

Various scenarios as specified within *Section 5* of this document were examined. These overall odour emission rates and specified source characteristics were inputted into AERMOD Prime in order to determine any overall impact in the vicinity of the facility.

This document provides on overview of the odour management system to be implemented within the facility design and provides assurance for the regulator that the facility will not result in any odour impact in the vicinity of the facility.

1.2 Scope of the works

The main aims of this assessment include:

- Development and design of odour control management and mitigation techniques for the proposed Dry fermentation and RDF facility.
- Ascertain the average and maximum ground level concentration of odours at the 98th percentile of hourly averages based on 5 years of screened meteorological.
- Ascertain whether the proposed facility will be in compliance with the 1-hour 98th percentile limit values of 1.50 Ou_E/m^3 for 5 years of hourly sequential meteorological data at the nearest sensitive receptors in the vicinity of the facility.
- Ascertain whether the proposed odour management, minimisation and mitigation techniques for the facility are robust and sufficiently design to eliminate associated odours with these operations.
- Provide an overview of the overall odour management and mitigation strategies to be implemented at the facility.
- Provide assurance and guarantees to the regulator that such the assessment was performed in accordance with Irish and UK EPA guidance documents "Odour impacts and odour emission control measures for intensive agriculture, EPA, 2001, AG4 - Air Dispersion Modelling from Industrial Installations Guidance Note (AG4) and H Horizontal Guidance notes Parts 1 and 2, UK Environment Agency.

1.3 Key assessment criteria used in this report

The approach adopted in this assessment is considered a worst-case investigation in respect of emissions to the atmosphere from proposed emission points A2-1, 2-2 and A2-6. These predictions are therefore most likely to over estimate the GLC's that may actually occur for each modelled scenario. These assumptions are summarised and include:

- Emissions to the atmosphere from the emission points – A2-1 and A2-6 process operation were assumed to occur 24 hours each day / 7 days per week over a standard year at 100% output. A2-2 process operation was assumed to occur 24 hours each day / 6 days per week over a standard year at 100% output.
- Five years of hourly sequential meteorological data from Dublin Airport 2002 to 2006 inclusive was screened to assess worst case dispersion year which will provide statistical significant results in terms of the short and long term assessment. This is in keeping with current national and international recommendations. The worst case year Dublin 2004 for used for data presentation.
- All emissions were assumed to occur at maximum potential emission concentration and mass emission rates for each scenario.
- AERMOD Prime (12060) dispersion modelling was utilised throughout the assessment in order to provide the most conservative dispersion estimates.
- Five years of hourly sequential meteorological data from Dublin 2002 to 2006 inclusive was used in the modelling screen which will provide statistical significant results in terms of the short and long term assessment. The worst case year for Dublin met station was 2004 and was used for contour plot presentation. This is in keeping with current national and international recommendations (EPA Guidance AG4 and EA Guidance H4). In addition, AERMOD incorporates a meteorological pre-processor AERMET PRO. The AERMET PRO meteorological preprocessor requires the input of surface characteristics, including surface roughness (z0), Bowen Ratio and Albedo by sector and season, as well as hourly observations of wind speed, wind direction, cloud cover, and temperature. The values of Albedo, Bowen Ratio and surface roughness depend on land-use type (e.g., urban, cultivated land etc) and vary with seasons and wind direction. The assessment of appropriate land-use type was carried out to a distance of 10km from the meteorological station for Bowen Ratio and Albedo and to a distance of 1km for surface roughness in line with USEPA recommendations.

- All building wake effects on all applicable emission points were assessed within the dispersion model using the building prime algorithm (e.g. all buildings / structures / tanks were included).

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

The following key decision making process was used in the design of the odour control and management systems for the proposed facility designs. These included:

1.4.1 Dry fermentation and RDF facility

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 waste.
    - Closed-door management strategy and interlocks on door access.
    - Facility management and cleaning procedures for surfaces in contact with waste.
    - Waste acceptance procedures to include enforcement of acceptance of enclosed waste loads, type of waste accepted into the facility and the procedures in handling waste within the facility (100% organic only).
    - Other elements include the implementation of an odour management plan and operation and maintenance management plans for the odour control systems.
2. Containment of odours within the facility buildings is essential to effective capture and treatment. Proposed containment measures to be use within this Odour Management system design include:
    - The installation of a high integrity building fabric. This will eliminate the leakage of odours from the building skins. The absence of such a high integrity fabric could lead to positive leakage of odours from the facility even with high volume negative ventilation as a result of wind pressure. The inclusion of a high integrity fabric in this design will prevent this occurrence.
    - Within this design, high risk and high load odour processes are double contained which is in keeping with best practice and BAT (DF Facility only). By doubly containing the high risk high odour load processes, the release and build up of such odours in the headspace of the building is prevented. This will ensure that the specification of compliance to all relevant legislative requirements of odour management are achieved. These high risk high strength odours will then received two stages of treatment while building ventilation air (i.e. low risk low odour load) will receive one stage of treatment (DF Facility only). For the RDF facility, general building air will be used as make up air for the thermal dryer and a combined dust / carbon filter will be utilised to provide negative pressure within the operations building.
    - The Facility buildings access doors will be fitted with rapid roller doors where necessary to prevent the release of odours through the access doors of the facilities.
    - 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 (i.e. DF facility only).
    - The facility building will be divided into dedicated independent zones of extraction to include the waste reception hall, screening and processing areas, in vessel composting tunnels and the access corridor through the facility (i.e. DF facility only).

3. Treatment of odours using end of pipe technologies is essential to ensure no odour impact in the vicinity of the facility. For these two separate processes, three technologies will be used for end of pipe treatment. For the DF facility, acid scrubbing will be utilised to remove Ammonia and Amines from the high risk high strength odours from the in vessel tunnels and secondary cleaning using a biotrickling filter of low strength odours from the acid scrubber and building ventilation headspace. This will significantly reduce the risk of escape of untreated odours and also significantly reduce any associated risk of odour control failure through air stream preparation and the removal of ammonia. Ammonia will poison traditional biofilters and biofilter medium and lead to acidification through the production of nitric acid. Subsequent nitrate build up within the bed medium leads to Oxygen transfer difficulties within the biofilm of the biofilter. Acid scrubbers are in operation in many facilities to include:
    - One composting facilities, New Earth Solutions, UK.
    - Thornton’s Recycling Composting facility, Kilmainhamwood, Co. Meath
    - Ringsend Waste water treatment plant, Ringsend, Dublin 3.
    - Sutton Pumping Station, Sutton Cross, Dublin.
    - Carrickgrehan Waste water treatment plant, Cork.
    - Portlaw Composting facility, Waterford.

    For the RDF facility, all process air will be dedusted using high efficiency cyclones and deodorised using a biomass thermal oxidiser operated on biomass. The system will achieve approx 850 degC and approx. 2 seconds retention time within the combustion zone. In addition, further negative pressure will be applied to the facility building utilising a combined dust / carbon filter.
4. For the DF facility biotrickling filter, 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. In addition, the design of the inlet air distribution system will facilitate operation of individual zones within the biofiltration bed. This is a very important design parameter in order to ensure equal air distribution throughout the biofilter bed and also to ensure equal empty bed retention time for maximum biofiltration capacity gas treatment. Frequently, such design elements are overlooked and this can lead to significant heterogeneity within the biofilter bed medium and the release of untreated gases. In addition, the plenum can be driven upon which facilitates easy emptying of the bed if required. The biofilters are positioned at the edge of the first floor level of the dry fermentation tunnel, which during biofilter bed emptying will allow for the pushing of the biofilter bed medium over the edge of the first floor to the ground floor below.
5. For the DF facility biotrickling filter, the proposed design includes a proven inorganic bed medium for incorporation into the biofiltration system. We have chosen this medium for the following reasons:
    - Proven in the treatment of odours at many facilities (see reference list) to include use in biofilters in Ireland, UK, France and Norway.
    - Inorganic based and hence will not breakdown or rot like woodchip/root based medium.
    - Engineered uniform particle size, which is essential for homogenous flow through the bed. This will not be achieved using wood chip based medium.
    - Excellent pore porosity of up to 83%, which ensures sufficient surface area for microbial consortium habitation.
    - Excellent surface roughness for microbial surface attachment.
    - Excellent structural integrity, which will prevent the biofiltration bed medium from compacting and minimising pressure loss throughout the bed medium over its lifetime, and ensures homogenous airflow throughout the biofilter bed medium.
    - Long lifetime of up to 10 to 15 years. Wood chip based medium will only achieve 2 to 4 years lifetime before full changeout is required.
    - Light weight which allows the bed medium to be blown and sucked out of position.

- Excellent free draining characteristics, which will allow the biofiltration system to be operated in biotrickling mode. This will allow for the delivery of essential vitamins and nutrients to the microbial consortium to ensure high activity. It ensures that no dry zones will form within the biofilter bed medium. This can also be used to supplement food stock to the microbial consortium during periods of shut down so thereby eliminating any start-up lag period (i.e. glucose dosing). In addition, acid derivatives and salts will be easily washed from the bed in this mode ensuring excellent Oxygen transfer into the microbial consortium and the washing away of poisons from the bed, which would result in odour treatment failure. Automated pH adjustment and biomass control can be achieved easily in this mode.
- Inert and non hazardous.
- Easy to handle.

6. The selected Continuous emission monitoring (CEMS) and SCADA system for the monitoring of the odour control systems is based on key design elements and requirements which include:
    - Static differential pressure and temperature monitoring, trending, alarming and reporting.
    - Combustion fuel consumption rate
    - Liquid flow rate monitoring, trending, alarming and reporting
    - pH monitoring, trending, alarming and reporting,
    - Automated dosing for pH and nutrients,
    - VSD controlled pump sets and fanset to ensure sufficient volume extraction and liquid addition.

2. General overview of formation and odour emissions at Biological treatment and Refuse derived fuel 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. Within this facility all anaerobic gases will be contained within gas tight vessels and directed to the existing site for the production of electricity.

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 Facility may be exposed to these odour-producing conditions: before entering the facility, and/or when in the active composting phase.

For the RDF facility, the input waste material will be mechanically separated. The resulting waste plastic / paper will be separated further using various separation and shredding equipment where it will enter the thermal dryer for the evaporation of water vapour. The resulting finished product will be shredded further to the suitable fraction size before been bulk stored or baled for transport for use as a fuel. Through the installation of a high efficient building fabric (near 100%) and negative pressure in and around the organic separation section of the process the release of odours will be prevented. The stored finished product will be less than 10% moisture content and therefore will not be odourous in nature as experience demonstrates.

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 an 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 Waste and composting odours

Odours from dry fermentation and RDF facilities 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 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.

Although gases are only indicators of odour emission from various processes within a facility, knowing which compound precursors are responsible for odour is useful in designing control techniques to minimise and abate any potential odours. Technologies such as carbon filtration rely on the binding efficiency of the carbon (Van der Waals forces and molecular sieving) and knowing the gas constituents will help determine the best form of carbon to perform the task. For example, Hydrogen sulphide, because of its molecular size will not bind efficiently to activated carbon. By impregnating the carbon with potassium/sodium hydroxide, chemisorption can be used to efficiently bind and hold on to the Hydrogen sulphide. The technology chemical scrubbers are good for low concentration VOC steady stream processes while high VOC concentration non-steady stream processes, as encountered in composting will not be as affectively treated with chemical scrubbers although many stages of treatment can be provided to buffer out the cyclic loading (but at greater expense). In addition, non water-soluble compounds such as Aldehydes, Ketone and Terpenes which are always present in composting odour air streams are not effectively removed by oxidant based chemical scrubbers. Such chemical scrubbers will not attain the strict stack emission levels required in this facility. The roughing of the main gaseous components using an acid scrubber can lead to more efficient overall treatment of emissions in terms of Operational expenditure. Roughing out the main emission constituents, the more expensive polishing stage media can be protected to ensure long-term operation with minimal media changeout.

2.5 Odourous compound formation in Dry fermentation 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 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 (e.g. 24 hrs) it enters the facility.

OPTIMISING THE COMPOSTING 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 8.50 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 odour dispersion modelling assessment and appraisal of odour mitigation measures. This section will also include the backbone odour management methodology to be used at Panda Waste to ensure no odour impact occurs during operation in the vicinity of the facility buildings.

3.1 Odour management plan

The Odour Management Plan (OMP) is a core document detailing operational and control measures appropriate to management and control of odour at a site. The format of the OMP provides sufficient detail to allow operators and maintenance staff to clearly understand the odour management operational procedures for both normal and abnormal conditions.

The OMP includes 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 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 management equipment operation procedures (e.g. correct use of equipment, process, materials, checks on equipment performance, maintenance and inspection (*see Section 3.4*),
- 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 Management Plan will be regularly reviewed and upgraded. It should form the basis of a document Environmental and Odour Management system for the operating site. The Odour Management System (OMS) 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 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 OMP. The OMP will be integrated in the overall Environmental Management/Performance System for the site.

Panda Waste will develop in agreement with the authority / regulator and implement a detailed odour management plan for the actual as built plant before commencement of treatment of waste at either facility building.

3.2 General rules for reduction of odour emissions during the operation of the each facility.

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

3.2.1 Dry fermentation Facility

- The Dry Fermentation Facility will be fitted with a high integrity building skin to ensure near 100% building skin integrity.
- The access doors of the facility will be fitted with rigid rapid roller doors with an opening speed of approx. 2.60 m/s minimum. Each door will also be fitted with a high efficiency air curtain where deemed necessary. Computational fluid dynamic modelling performed on a similar facility has demonstrated greater than 90% containment efficiency on open doors. Coupled with the negative air extractions system, it is anticipated that no odours will escape through door openings.
- The proposed facility odour management system will allow for gas extraction from individual zones within the dry fermentation and composting process. Independent negative air extraction will be provided to the composting tunnels, waste reception hall and finished compost and screening and processing hall. The overall ventilation and odour treatment system will have 2 individual fanset feeding air into the odour treatment system. This will provide 100% duty and 50% standby.
- The significant odourous processes within the Facility will be doubly contained and negatively ventilated to two stages of odour control. The 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 and also ensure no odour impact at nearest sensitive receptors. 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 acid scrubbing of ammonia and amines and second stage polishing biofiltration of all odours. This will ensure preparation and sufficient treatment of this high strength and high-risk odourous air stream. The main aim of acid scrubbing will ensure that ammonia poisoning of the biofiltration bed medium will not occur. In addition the biofiltration bed medium will operate in biotrickling mode which will ensure all contaminants that could build up within a traditional fixed phase biofiltration system will be minimal as contaminants will be washed from the biofiltration bed media. This is only possible through the use of the high efficiency, free draining inorganic medium proposed in this design. In addition, the use of the inorganic medium will ensure no increases in headloss through settlement and the medium will maintain its structural integrity. Wood chip based medium will settle, rot over time (2 to 4 years) which will lead to heterogeneous (i.e. unequal) air flow through the bed and inefficient treatment (Sheridan, 2002).
- 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 within the second stage polishing biofiltration system.
- 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. As wood chip bed medium is not free draining, nutrient addition to this bed medium will result in build up at the upper application surface and therefore result in poor distribution within the biofilter bed. Therefore frequent bed medium turning is required to ensure homogenous nutrient addition for wood chip and root based biofilter beds.
- The bed medium proposed will ensure trouble free operation over 10 to 15 years. The bed medium is light weight and can be easily blown and sucked from the biofiltration beds. In addition, the use of the plenum floor will allow for small diggers/bobcats to enter the biofilter to remove the bed medium in emergency conditions. Since the biofilter bed is divided into 4 zones, each individual zone can be cleaned out

separately therefore allowing biofiltration bed operation during partial biofilter bed medium cleanout. Wood chip/root based bed medium will require cleanout every 2 to 4 years possibly (i.e. cleanout occurs when the bed medium settles to a point where heterogeneity in flow occurs and back pressure becomes excessive). The use of this proven medium will reduce the downtime associated with bed medium clean out from 2.5 to 5 times based on a conservative 10 year clean out cycle. The proposed plenum floor is designed with equal air distribution in mind to ensure homogenous flow through the biofilter bed.

- 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 putricable waste will be stored outdoors at any time. All operations will be carried out indoors.***
- 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 Facility.

3.2.2 Refuse derived fuel Facility

- The RDF Facility will be fitted with a high integrity building skin to ensure near 100% building skin integrity.
- The access doors of the facility will be fitted with rapid roller doors. Coupled with the negative air extractions system, it is anticipated that no odours will escape through door openings.
- All process air from the thermal dryer will be dedusted and deodorised using high efficiency cyclones and a biomass boiler. The exhaust odour threshold concentration will be less than 1,000 Ou_E/m^3.
- A negative air pressure system incorporating dust and carbon filtration will be installed. The system will be capable of treating 100,000 m^3/hr and achieve an odour threshold concentration of less than 500 Ou_E/m^3.
- The finished RDF material will contain less than or equal to 10% moisture content and therefore will not have any potential to cause odours inside or outside the facility building.
- All waste material will be stored indoor at all times.

4. Dispersion modelling of odours for the overall facilities design – DF and RDF facilities.

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}, g/s), 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
- Thirdly, to determine which process is contributing greatest to the odour impact and estimate the amount of required abatement to reduce this impact to 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 composting processes (Sheridan et al., 2002).

Any dispersion modelling approach will exhibit variability between the predicted values and the measured or observed values due to the natural randomness of the atmospheric environment. A model prediction can, at best, represent only the most likely outcome given the apparent environmental conditions at the time. Uncertainty depends on the completeness of the information used as input to the model as well as the knowledge of the atmospheric environment and the ability to represent that process mathematically. Good input information (emission rates, source parameters, meteorological data and land use characteristics) entered into a dispersion model that treats the atmospheric environment simplistically will produce equally uncertain results as poor information entered into a dispersion model that seeks to simulate the atmospheric environment in a robust manner. It is assumed that odour emission rates are representative of maximum odour events, source parameters accurately define the point of release and surrounding structures, meteorological conditions define the local atmospheric environment and land use characteristics describe the surrounding natural environment. These conditions are employed within the dispersion modelling assessment therefore providing good confidence in the generated predicted exposure concentration values.

4.1 AERMOD Prime

The AERMOD model (12060) 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, 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 modelling 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 designed to support the U.S. EPA's regulatory modelling 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, but without the complexity of the Complex Terrain Dispersion Model-Plus (CTDMPLUS) (Diosey et al., 2002).

4.2 Brief comparison between previously used ISCST3 and AERMOD predicted values from other research studies

Many comparisons have been made between dispersion models. A comparison of the ISCST3, AERMOD, and CALPUFF models has shown that maximum predicted impact from a typical process was similar for ISCST3 and CALPUFF run in the refined mode (Diosey, Hess, and Farrell, 2002). Predicted impacts for AERMOD were a factor of 24 lower than ISCST3 and a factor of 2 lower for CALPUFF run in the screening model. Sheridan et al., (2002) (2005) performed a comparison between ISC ST3 and AERMOD Prime for a typical emission process. It was concluded that AERMOD Prime predicted a higher 1-hour ground level concentration and impact area (approx. 2 times area) in comparison to ISCST3 but when percentile exceedence were applied to the 1 hour concentration value, the plume spread was similar with both dispersion models predicting similar impact areas. Porter et al., (2004) reported that predicted ground level concentrations from AERMOD (i.e. not Prime version) are lower than those of ISCST3 for point sources and higher than ISCST3 for area sources. Although the magnitude of the difference is not large, the result for an odour control perspective is that impacts from area sources will appear greater than those from process vents or stacks using AERMOD instead of ISCST3 (Porter et al., 2004). The advanced model AERMOD provides improvements in the way the pollutant dispersion is characterised. The benefits derived are partly due to dispersion algorithms and partly due to improved characterisation of the atmospheric environment. Keeping in mind that under proposed operations in the facility, all odour sources will be contained and only residual odours from the end of pipe technique will be emitted through an elevated stack with high efflux velocity. Therefore in order to conservatively assess the ground level impacts from the proposed processes, **AERMOD Prime** as opposed to AERMOD was used in order to accurately take account of building wake effects (updates in the BPIP algorithmic through the use of Prime Ver. 12060).

4.3 General design of extraction volumes for treatment at Panda Waste Dry fermentation and RDF facility.

4.3.1 Proposed Dry Fermentation and RDF Facility treatment volumes

Table 4.1 illustrates the proposed extraction volume for the proposed facility buildings and from specified processes. In terms of treatment, the proposed DF facility building will be divided into five distinct extraction zones. This methodology is used as it provides greatest control over the application of effective extraction within the facility building.

For the RDF building, process air will be collected and ducted directly to the biomass burner for treatment. In addition a combined dust / carbon filtration system will be directly ducted from the stage 1 section of the mechanical separation process.

For the Dry fermentation processes, the design has enclosed those processes considered most odourous and capable of causing significant odour emissions. This will ensure meeting the requirements of legislative limits of odourous compounds within the workspace. Double containment is provided on high-risk odour sources (i.e. in vessel composting tunnels). Lower risk odour sources (in terms of odour threshold concentration and emissions) such as the waste reception hall and finished compost screenings and storage hall will have individual localised extraction. The building can be assumed to be near 100% leak free as the design allows for the installation of a high integrity building fabric. This will also be the case for the RDF building fabric.

As can be observed for the DF facility, 2 AC/hr negative extraction will be provided within the main processing building and processes. The overall design has taken account of the risk of odour sources within the process through double containment and treatment design.

All odours from the in vessel composting process (where most the odour is generated) will receive two stages of treatment to ensure compliance with the strict odour emission rate and ground level concentration requirements. All odourous air from the in vessel composting tunnels will be first passed through an acid scrubber for the removal of basic ammonia and amines (see *Section 4.7.2* for design notes). Other alkaline-based odourants will also be removed. This ammonia and amine free odourous air stream will then be mixed with general ventilation air and passed through a biofiltration system whereby the majority of odourous compounds will be oxidised and removed. This biofiltration system will be operated at an empty bed retention time of approx. 50 seconds. The outlet air from the biofilter will then be directed to the exhaust stack. The total treatment volume will be approx. 104,000 m^3/hr with a total odour threshold concentration of less than 700 Ou_E/m^3. This specified odour threshold concentration is achievable due to the biofilter media proposed biofilter inlet plenum design allows for equal air distribution and the nutrient and contaminant control mechanism proposed (i.e. operated in biotrickling mode). Biotrickling mode of operation is only achievable, as a direct result of the biofilter medium proposed which is inorganic, does not break down (i.e. inert), free draining and has engineered equal particle size range distribution. Biotrickling filtration is not achievable in a wood chip based medium. In addition, the inorganic medium will minimise the development of anaerobic zones, and has low residual odour (unlike woodchip). The overall changeout frequency of this media is approximately every 10 to 15 yrs while a wood chip based medium will require changeout every 2 to 4 years. The use of innovative medium and the utilisation of spent activated carbon will ensure compliance with the limits.

Table 4.1. Treatment volume characteristics from proposed DF and RDF facility buildings and processes.

Extraction volume characteristics from proposed facility buildings / processes			
Collection zones	**Void Volume (m^3)**	**Required extraction rate (AC/hr)**	**Total treatment volume per zone (Am^3/hr)**
Dry fermentation building Stack 1			
Waste reception hall and mixing zone	12,320	2	24,640
Ranking, screening, mixing zone	27,032	2	54,064
In-vessel composting tunnels (half full)	4,257	3[1]	13,000
Pasteurisation tunnels (dump air + 1 AC/hr at half full)	1060	4000 m^3/hr dump + 1 AC/hr	5,060
Finished composting screening and storage hall (Intake directed from this building to the main building)	-	2	See Ranking, screening and mixing zone volume
Total extraction volume (m^3/hr)	**-**	**-**	**96,764**
Design treatment capacity	**-**	**-**	**104,000**
Spare capacity	**-**	**-**	**7,263**
RDF facility building stack			
Biomass TO system	**-**	**-**	**35,523**
Design treatment capacity	**-**	**-**	**40,824**
Spare capacity	**-**	**-**	**5,300**

Notes: [1] denotes that 3AC/hr air dump volume will be performed upon the in vessel composting tunnels. 3 AC/hr recirculation volume will be performed in each of the composting tunnels. Each tunnel will be approx. half filled with composting material. This provides the 3 AC/hr treatment volume thereby maintaining these high odour load processes under negative pressure.

4.4 Pollutant emission rate guarantees, stack characteristics and proposed location for the Dry Fermentation and Refuse Derived Fuel processes

The specific emission point characteristics to include location, stack height, stack tip efflux velocity, temperature, proposed ground level (AOD), and proposed finish level height (AOD) are presented in *Table 4.2* for observation. This data formed the basis for emission point characteristics and source characteristics used within the dispersion model.

Table 4.2. Emission exhaust point characteristics used within Aermod Prime (USEPA 07026) dispersion model for contaminant dispersion modelling.

Emission point characteristics	Proposed RDF emission point – Biomass boiler A2-2	Proposed RDF emission point – Carbon filter A2-6	Proposed Dry fermentation Emission point – BTF A2-1
X coordinate ING (m)	297519.963	297435.3	297551.50
Y coordinate ING (m)	269092.271	269109.9	269250.70
Proposed ground level AOD (m)	56	56	61.50
Proposed finish level AOD (m)	73	70	71.50
Stack height from ground level (m)	16	14	15
Stack tip diameter (m)	0.85	1.50	1.40
Efflux velocity in stack tip (m/s)	20.32	<15	18.76
Temperature (K)	523	293	293

In conjunction with the total volumetric extraction flow rates presented in *Table 4.1*, the overall odour emission rates were calculated in *Section 4.4.1*. Screening dispersion modelling was used to ascertain the maximum allowable odour threshold concentration for the emission point. *The overall odour emission rates presented are based on library data for such systems and therefore achievable in this context*.

4.4.1 Proposed Dry Fermentation and Refuse Derived Fuel facility odour emission rate

Table 4.3 illustrates the odour emission rate for the proposed Dry fermentation and RDF facility exhaust points. As can be observed the overall design treatment volume proposed for the DF facility is up to 28.88 m^3/s and 39.31 m^3/s for the RDF facility. The overall design exhaust odour threshold concentration will be 700 Ou_E/m^3 for the DF facility and 1,000 and 500 Ou/m^3 for the biomass boiler and dust/carbon filter to be located in the RDF facility, which will result in an overall odour emission rate from the three emission points of 45,635 Ou_E/s.

This emission data and source characteristics were used in conjunction with dispersion modelling to assess compliance with the odour impact criterion contained in *Section 5*. The results of the dispersion modelling assessment are presented in *Section 6.1.*

Table 4.3. Guaranteed odour emission data from emission points within the proposed Dry fermentation and Refuse derived fuel Facility processes

Guaranteed odour emission data from emission points within the proposed Dry fermentation and RDF Facility			
Odour source identity	**Volumetric airflow rate (Am^3/s)**	**Guaranteed Odour threshold conc. (Ou_E/m^3)**	**Total odour emission rate (Ou_E/s)**
Proposed Dry fermentation process OCU A2-1	28.88	700	20,216
Proposed Refuse Derived Fuel process OCU A2-2	11.53	1,000	11,530
Proposed negative air RDF system A2-6	27.78	500	13,889
Total odour emission rate (Ou_E/s)	**-**	**-**	**45,635**

4.4.2 Overview of input data

Data presented in *Section 4.4 and 4.4.1* was used to form the basis of the dispersion modelling scenarios in order to determine the ground level impact of the facility emission point. This allows for the transparent transfer of information in order to allow verification of overall design. Since all processes will be indoors with good building fabric (near 100% efficiency for the Facility buildings with a leakage rate of less than 3m^3/m^2clad surface/hr), rapid roller doors where necessary, certain processes doubly contained (i.e. high odour load processes such as the in vessel tunnels) and focused negative ventilation, no fugitive odour emission will occur. In addition, the design of the odour control systems will ensure treatment can continue during routine maintenance. The overall management and control system is designed with odour mitigation as one of the primary elements of the waste treatment and dry fermentation composting process (i.e. holistic approach for design through to CEMS and spot check monitoring during operation).

4.5 End of pipe treatment technologies for the proposed Dry fermentation and Refuse Derived Fuel Facility designs.

This section discusses and evaluates the main technologies that will be used to treat odourous air emanating from processes within the facility. There are many different technologies available for the treatment of odours within such processes, each with varying degrees of effectiveness. By selecting the appropriate combination of technologies and implementing them in the most suitable environment within the facility, the full effectiveness of the technology can be realised. Just as important is the life cycle operational costs for maintaining such odour control effectiveness. The cost of ownership of an odour control technology can be affected significantly through its implementation and where/how it is implemented (i.e. installing carbon filtration technology on high VOC concentration odourous airstreams will incur significant operation costs and also lead to increased frequency of shutdown for carbon replacement, the installation of chemical scrubbers utilising oxidising solutions such as Hypo chloride will lead to excessive waste water production that cannot be used in the composting process because of free chlorine). A thorough review of lifetime costs contributes considerably to making sound decisions on overall cost effectiveness of abatement options.

4.5.1 Hierarchy of odour controls

The preferred hierarchy of odour control measures comprises:

- Prevention
- Containment
- Collection and treatment (DEFRA, 2004).

Operational and financial restrictions mean this hierarchy cannot be applied rigidly to every application and a cost-benefit analysis will determine the most appropriate measures for any given situation. The following control options are proposed: The following strategy should be adapted where possible:

Good housekeeping: Inappropriate housekeeping practices can lead to significant emissions of odours from processes that should be relatively odour free. The maintenance of quality and documented management systems for preventative odour release will be implemented as good housekeeping. A closed doors policy will be implemented through out the Dry fermentation and RDF Facility. In addition, scheduled shutdown of plant and equipment will be controlled to minimise odour release. Organic matter debris will be prevented from building up on surfaces and equipment will be organised to allow for easy cleaning of organic matter build-up. Liquid ponding will be prevented while drains/galleys will be designed to prevent blockage and retention of liquid leading to odours. All yard space will be kept clean. Emergency spill cleanup procedure will be available and the cleaning of odourous equipment outdoors will be prevented. Meteorological conditions will be coordinated when any unscheduled odour emission procedure occurs to provide maximum potential odour dispersion before commencement of procedure.

Process control: Will sometimes be the next most cost effective control depending on process flows and process characteristics.

Process modification: Changing process procedures, waste handling procedures, retention time of waste on the floor, Compost handling procedures, etc.

Containment and negative extraction: Odours from waste handling, dry fermentation and RDF cannot often be controlled by total containment and it is more common use with negative extraction to odour control units. This will prevent the release of fugitive odours from the contained process. Enclosing highly odourous processes such as first stage and second stage composting ensures no significant contamination of building headspace and enables better control of odours. In addition, the negative extraction of odours from around the mechanical separation process will also aid in the efficient capture of odours in the RDF process. Generally, the odorous air will be extracted and treated using end-of-pipe odour abatement system. Also dispersion is usually incorporated into the end of pipe technology to improve dispersion and reduce the risk of odour detection.

4.6 End-of-pipe odour abatement systems to be utilised in the proposed Dry fermentation and Refuse Derived Fuel Facility design

This section describes in detail the overall operation of the proposed odour management, minimization and mitigation techniques to be implemented into the design upgrade of the proposed Dry fermentation and RDF Facility to ensure odours do not result in odour impairment beyond the facility boundary.

4.6.1 Dry fermentation Facility design

The following key infrastructure will be incorporated into the overall design of the facility design in terms of odour management and control. These include:

1. Installation of a high integrity building fabric providing near 100% leak free integrity. In this proposed design, no leakage will occur from the building skin as the building fabric will prevent any odour leakage and protect the building skin from corrosive gases.

2. Installation of high speed rigid rapid roller doors will provide added protection from odour release through the access doors of the facility.

3. Installation of fresh air intake louvers on each end of the building. These louvers will be designed to allow fresh air into the building on a head loss of 20 to 40 Pa, thereby ensuring that the building is always maintained under negative pressure. In addition, these self closing louvers will close when the facility doors are opened for access to the facility resulting in air been drawn through the facility doors and hence prevent the release of odours through the open door. The air curtains will automatically start operation when the door opens. Air curtains have been shown to be 90% effective in reducing odour leakage through open doorways. Coupled with negative air extraction, we are confident this design will prevent odours will leaking from the building doorways when opened.

4. The building ventilation system will be zoned into distinct extraction zones which are:
    - General ventilation air from the waste reception hall
    - General ventilation from the ranking, mixing and screening hall
    - General ventilation air from the finished compost screening and loading hall
    - Focused extraction from the enclosed in vessel composting tunnels

    This will enable the focused extraction of odours for treatment. High-risk odour air streams are separated from low load odour sources for treatment minimises the risk of untreated/partially treated odours passing through the exhaust point.

5. Enclosure of high-risk odour processes through double containment of emission sources includes:
    - In vessel composting tunnels,
    - Access corridor to the in vessel composting tunnels and dry fermentation facility.
      Ensuring that high strength odourous do not result in contamination of the building headspace and thereby further reduces the risk of odour release.

6. High risk high odour load air streams will receive two stages of treatment to ensure sufficient odour removal. In vessel composting tunnel airstreams will be directed to a acid scrubber for the removal of Ammonia and Amines which could cause issues with the biofiltration system by poisoning the media the medium proposed in this design can be flushed since it has excellent structural integrity, free draining and will not compact). All blow down liquor can be incorporated back into the compost process to improve the overall nitrogen content of the composting material (i.e. acid scrubbing will produce liquid fertilizer Ammonium sulphate). This minimises the amount of wastewater produced by the site and is in keeping with the principle of efficient operation. The high odour load air stream will then be passed through the biofiltration system for second stage treatment. This system will be operated on a 50 second empty bed retention time and provide sufficient treatment of the airstream. This air

stream will also be mixed with general building ventilation air to ensure consistent odour load and to minimise cyclic loads on the biofiltration system.

7. Installation of SCADA system control and monitoring to ensure successful operation. In addition, differential pressure sensors will be installed upon the building envelope to ensure monitoring of effective negative pressure on the building at all times.
8. Development of an overall odour management plan and preventative maintenance strategy based on the methodologies contained within this document.

The odour abatement techniques proposed in this document have been designed to minimise maintenance, commissioning, start-up and shutdown activities. The cost effectiveness of the chosen technology will be influenced by the following parameters:

Capital costs: site work, modifications to existing buildings, ventilation systems, ductwork, chemical storage and dosing systems, installation, control interfaces, engineering, commissioning and performance monitoring.

Operation and maintenance costs: chemicals, media replacement, electrical running costs, maintenance, component replacement, and maintenance materials.

Other factors: life expectancy, performance, reliability, ease of operation, and effects on WWTP operations.

All such factors have been taken account of within the design of the Odour control equipment for the facility.

4.6.2 RDF Facility design

The following key infrastructure will be incorporated into the overall design of the facility design in terms of odour management and control. These include:

1. Installation of a high integrity building fabric providing near 100% leak free integrity. In this proposed design, no leakage will occur from the building skin as the building fabric will prevent any odour leakage.

2. Installation of high speed rigid rapid roller doors where necessary will provide added protection from odour release through the access doors of the facility.

3. The building ventilation system will be zoned into one extraction zones which is:
    - General ventilation air from in and around the first stage mechanical separation process.
4. The thermal drying process will be maintained under slight negative pressure and all process air generated will be ducted to high efficiency cyclones and a biomass boiler.
5. Installation of negative air combined dust / carbon filtration system.
6. Installation of SCADA system control and monitoring to ensure successful operation of the odour control system.
7. Development of an overall odour management plan and preventative maintenance strategy based on the methodologies contained within this document.

4.7 Odour control system design specifications

4.7.1 Design calculations for the Dry fermentation odour control system

4.7.1.1 Acid scrubber

The following minimum design performance and specification will be attainable on the acid scrubbing plant to be fitted into the odour control unit for the treatment of odours from the in vessel composting tunnels (*see Table 4.4*).

Table 4.4. Acid scrubber process characteristics for Ammonia and Amines Stripping of in vessel composting tunnel air.

Inputs	Values	Results	Values
Air Flow rate	13,000 Am^3/h	$(NH4)_2SO_4$ in Blow down	3.10%
Inlet NH_3 Concentration	400 ppmv (304 mg/Nm^3)	NH_4HSO_4 in Blow down	2.20%
Liquid Recirculation Rate	56 m^3/h	H_2SO_4 in Blow down	0.10%
Blow down Rate	0.20 m^3/h	Total Ammonia in Blow down	9,564 mg/L (as N)
Liquid Temperature	55 °C	TDS in Blow down	5.40%
pH in Sump	2.0	HTU	171 mm
Make-up H_2SO_4 Conc.	77%	Inlet Static Pressure	0.0 mbar
Packing Height	1400 mm	Expected NTU	***8.66***
Packing Width	1400 mm	Calculated NTU	***8.66***
Packing Height	2000 mm	Outlet NH_3 Concentration	**0.10ppmv (0.10 mg/Nm^3)**
Safety Factor	1.35	Removal Efficiency	**99.90%**
Packing Volume	3.9 m^3[1]	Pressure Gradient	1.50 mbar/m
Packing Type	Q-PAC	Packing Pressure Drop	3.0 mbar
Liquid Hold up	3.20%	Theoretical Fan Power	1.90 kW
Liquid Residence Time	11 sec	H_2SO_4 Consumption	16.40 kg/h (9.63 L/h)

4.7.1.2 Biofiltration system (biotrickling mode)

The following minimum design performance and specification will be attainable on the biofiltration system to be fitted into the odour control unit for the treatment of odours from the dry fermentation and composting plant (*see Table 4.5*). The design parameters for the biofiltration system is included in *Table 4.5* in order to enable independent auditing of the overall design.

Table 4.5. Biofiltration system process characteristics.

Biotrickling filter characteristics - Biotrickling filter bed 1 to 4				
Design characteristics	**Area (m^2)**	**Bed height (m)**	**Bed volume (m^3)**	**Typical requirements**
Bed dimensions	480	3.0	1,440	-
Media type	LECA Filterlite 10 to 20 mm particle size+ Exhausted activated general purpose carbon 4 mm pellet size.[1]	-	-	-
Void volume (following settlement)		83% pore space providing excellent structure for biomass attachment. The media is designed to be free draining to minimise the presence of anaerobic zones which would be common in wood chip based beds due to high moisture content	-	-
Design Treatment volume	28.88 m^3/s	104,000 m^3/hr	-	-
Empty bed residences time (sec)	-	-	50	**Usually greater than 36 seconds (100 m^3/m^3[media]/hr**
True Retention time (sec)	-	-	41.50	Dependent of media used - 83% void volume for this media.
Surface loading rate (m^3[air]/m^2[media]/hr)	-	-	216	-
Volumetric airflow rate (m^3[air]/m^3[media]/hr	**-**	**-**	**72**	**Usually less than 100**

Reference: Devinny, J.S., Deshusses, M.A., & Webster, T.S., (1999). Biofiltration for air pollution control. CRH Press.
Sheridan, B.A., Curran, T.P., Deshusses, M.A., Dodd, V.A., Biofiltration of air: current operational and technological advances. In review. Reviews in Environmental Technology.

Notes: [1] denotes that spent activated carbon from existing carbon filtration systems treating odourous air from waste transfer stations will be utilised at a 5 to 10% mix throughout the biofiltration system. This will be used for two primary reasons:

A) The spent activated carbon will be rich in odourous compounds typical of the waste reception and compost screening halls. This will significantly speed up the acclimatisation period of the biofiltration system to treating such odours (i.e. typically within 24 hours).

B) In addition, the activated carbon will minimise any cyclic load effects upon the biofiltration system. By incorporating activated carbon high odour loads, which would typically be generated throughout the day, will be sorbed by the activated carbon. At night-times when operations are low, the microbial consortium within the biofiltration system bed will feed on the excess available compounds within the activated carbon (thereby cleaning it from the next morning high loading). This will ensure that sustained biomass is available within the biofilter bed when loads are high. Without this technique, it is common to encounter cyclic load effects on the outlet due to diffusion limiting effects as a result of insufficient biomass during cyclic high loads as biomass will die and grow depending on load but as a result of lag time in growth, cyclic peaks pass through the biofilter bed untreated. The activated carbon keeps the feedstock concentrations sustained within the bed so that when load is low, the microbial consortium strip the feedstock from the carbon thereby keeping biomass concentrations high within the bed medium for periods of high loads. This has been used successfully within biofiltration systems in the past but not extensively used due to the cost of activated carbon. In this case, the tenderer has a supply of activated carbon from waste transfer station odour control units. The Dublin office of the Irish EPA has facilitated the used of this methodology on another waste licensed composting site.

4.7.2 Design calculations for the RDF odour control system

The odour control system for the RDF facility is currently in final design and as such no design information is available for review. As part of the SEW process with the EPA, all such information will be provided in confidence.

4.7.3 Contingency arrangement for removal of biofilter media

In terms of contingency for removal of the biofiltration system bed medium, the following elements have been incorporated into the design:

- The bed medium chosen will last a minimum of 10 to 15 years. The actual bed medium itself will not breakdown.
- The bed medium can be blown into the biofilter and sucked out of the biofilter using conventional blowers,
- The biofilter plenum floor provides sufficient structural integrity to allow the operation of a bobcat and mini digger if required.
- The biofilter end walls have been positioned so as to allow bed medium to be directly dumped to the lower floor allowing for quick removal and handling to occur indoors.
- The biofiltration system has been designed so as to deliver air into specific quadrants (4 off). This allows for the operation of the odour control system at reduced capacity when bed changeout is in operation.

In terms of removal, it is anticipated that the bed will be sucked out of position over a period of 2 days using three blowers. When removed the overall bed can be refilled easily within one day using three blowing systems and wheel machinery. Reduced treatment capacity is provided within the design and the utilising of an high building integrity and management techniques will ensure no release of odours from the facility.

As part of the contingency arrangement, the temporary addition of CLO_2 to the first stage acid scrubber will ensure that the odours released from the biofilter treatment of odours from the in-vessel composting vessels will meet the specifications. A Two bed systems will also be installed so as to allow one bed to operate while the other is out of commission. Bypass temporary ductwork will facilitate the bypassing of either system to ensure standby capacity.

The wetting of the biofiltration medium will occur during the blowing process. When filling has been completed, the sprinkling system will be reinstalled (easily removable and connectable) and continuous recirculation of liquid and nutrients through out the bed will ensure equal and sufficient moistening of the bed medium. The overall seeding process will occur through recirculation of laboratory concentrated biomass delivered through the sprinkling system specifically grown on the air stream to be treated thereby ensuring minimisation of acclimatisation period and reduced full treatment lag times of approximately 24 hour. During the fill phase suspended activate sludge (SAS) from the local wastewater treatment plant will also be applied to the bed medium. This third generation biofiltration system facilitates optimal design in terms of inlet air distribution, bed medium, process control and standby treatment capabilities.

4.8 Brief overview of control philosophy of proposed SCADA system for Odour Control systems to be located in Panda Waste Dry Fermentation and RDF Facility.

The SCADA system for the odour control unit will be based on Invensys InTouch software, which is an open and extensible HMI with cutting-edge graphical capabilities providing incredible power and flexibility for application design.

InTouch software offers connectivity to the broadest range of automation devices in the industry. In terms of the I/O server and drivers the Woodhead Direct-Link™ SW1000 communication drivers will be used which provides data acquisition between Windows based applications (i.e. InTouch software) and industrial devices connected to Ethernet TCP/IP and Serial networks. The Data Access server will be the Woodhead DAServer .

The I/O server will communicate with Advantech ADAM 4000/5000 modules. The ADAM-4000/5000 series modules use the RS-485 communication protocol, the industry's most widely used bi-directional, balanced transmission line standard. RS485 lets the ADAM-4000 series modules transmit and receive data at high rates over long distances (i.e. up to 4 kilometres).

A SCADA system will be installed upon both the odour control system upgrade to be installed on the proposed Facility odour control system. The SCADA system will be installed on a PC located within both the Facility control room building and main offices.

The SCADA system will be primarily used for the control, acquisition and trending of data collected from each odour control system.

The use of the SCADA system will allow the following generic control and monitoring of the odour control system. This includes:

- Extract flow rates will be automatically controlled through the on screen tag but in addition these can also be set manually via the inverter drives.
- Logging of process data to include static pressure, flow, temperature, fan speed, Power consumed, pH, liquid flow, static pressures and hours of operation.
- This will allow for historical graphing and trending of overall equipment operation both continuously and historically. All data collected will be dumped to Excel type (*.CSV) files for secure storage.

4.8.1 Dry fermentation and RDF Odour control systems monitoring and control

It is proposed to install the following static pressure sensors within the odour control system to be located in the Facility. These include:

- Differential pressure sensor across the building envelope in order to ascertain effective level of negative pressure applied to the building.
- Static pressure sensor on outlet duct work from in vessel composting tunnels. This will allow for automatic adjustment of the biofilter and Acid scrubber fans to ensure negative pressure upon the extraction line at all times. This will ensure minimization of odour leakage from composting tunnels.
- Static pressure measurement between outlet of Acid scrubber and inlet to biofilter. In conjunction with the static pressure reading before the acid scrubber, this will allow for the display of differential pressure head loss across the acid scrubber. This will be used to estimate wash down self-clean cycle time upon the acid scrubber.
- Temperature and Static pressure measurements throughout the RTO system including inlet air plenum, each ceramic canister and within the combustion chamber.
- Static pressure monitoring across each high efficiency cyclone to ensure optimal operation capacity.
- Static pressure measurement upon the ductwork run extracting odourous air from the in vessel tunnels and general building ventilation air for each process.
- Static pressure sensors upon the inlet to all biofilters quadrants (between fan and biofilter). This will allow for the measurement of pressure head loss across the biofilter medium continuously and will be used as an alert mechanism for particulate build-up and wash down sequence. The control of biomass and particulate can be achieved through the use of the plenum floor and bed flushing.
- Static pressure sensor in the headspace of the biofilter. This will be used to control the bifurcated fan extraction capacity to ensure a slight negative pressure in the headspace of the biofilters. It will also aid equal air distribution within the bed medium through equalization of pressure in the headspace of the bed. The VSD controlled

bifurcated fans will automatically increase or decrease in speed depending on headspace static pressure. In addition, in conjunction with static pressure readings on the inlet of the biofilter bed mediums, overall differential pressure across the bed medium can be displayed.

In addition the following additional sensors will be included within the design. These include:

- Liquid pressure sensor across the multistage gauze strainer system on biofiltration irrigation line. This will be used to alarm when the gauze strainer requires cleaning and also to display any significant changes in liquid backpressure as a result of nozzle blockage.
- Continuous pH monitoring of recirculation liquid in the acid scrubber. This will be used to control the dosing of H_2SO_4 to ensure effective and efficient scrubbing of Ammonia and amines from the highly contaminated primary and secondary composting tunnels.
- Continuous monitoring of liquid recirculation flow rate to ensure liquid delivery within the acid scrubber and also to control the speed of the recirculation pump. This is a more energy efficient method of controlling pump speed as opposed to using a control valve. Using a gate or globe type control valve results in wastage of energy to pump at full speed against a semi-closed valve.
- Continuous monitoring of acid storage tank high, high and low, low levels to ensure acid availability for scrubbing at all times. This will be linked into an alarm whereby early warning of acid depletion will be alarmed. In addition, the acid storage tank bund will also be monitored for tank failure.
- Continuous monitoring of water storage tank high, high and low, low levels to ensure water availability for biofiltration system.
- Continuous monitoring of temperature and pressure in biomass boiler system.
- Continuous monitoring of pressure and temperature on combined dust / carbon filtration system.

All monitoring equipment will have established design values and alarm tags incorporated into the SCADA to ensure optimal control and troubleshooting of the odour control system (i.e. established and balanced set points from initial commissioning). All alarms will be recorded and logged and if any odour complaints are recorded, then the specific operation of the odour control system at the time of the complaint can be verified through the review of historical data.

The following general control mechanisms will be utilised for the control of the BTF odour control system. These include:

- The exhaust airflow rates from the composting tunnels to be varied dependent on process stage.
- The overall flowrate of gases fed to the acid scrubber and biofilter to be varied in conjunction with the flow being fed from the composting tunnels.
- The makeup cooling air from the composting building to be fed post acid scrubber via mechanically actuated damper.
- The exhaust rate from biofilter to be varied in response to the static pressure measured above the biofilter bed.
- The extraction rate from the general composting building to be varied in line with operation of the equipment within the composting building (excluding the operation of the composting tunnels). The ability for the system to go into night/weekend setback automatically but with the proviso of manual override in the event of changed working practices.
- The irrigation system will be set to operate on an automatic period, however the SCADA system is capable of allowing irrigation periods to be varied in response to flow and humidity parameters if required.
- For the operation of the ammonia scrubber both scrubber liquor flowrate and pH of the scrubbing liquor will be monitored and will be both, automatically and manually variable.
- Provision for control of ventilation airflow rate dependent on effective negative pressure application upon the composting building.

The PC's running the SCADA software will be password protected to prevent unauthorized alterations to the operation of the odour control systems.

As with other parameters manual override of the systems will be built into the programming including trending, alarm set points and historical data recording.

5. Results of odour dispersion modelling for Panda Waste Dry Fermentation and RDF Facility operation.

AERMOD Prime (USEPA ver. 12060) and Aermap was used to determine the overall odour impact of:

- The Dry Fermentation and RDF Facility design,

Impacts from individual stacks processes and combined are assessed in accordance with the following requirements. These include:

1. EPA guidance documents "Odour impacts and odour emission control measures for intensive agriculture, EPA, 2001,

2. AG4 - Air Dispersion Modelling from Industrial Installations Guidance Note (AG4) and

3. H Horizontal Guidance notes Parts 1 and 2, UK Environment Agency

Based on these publications, a value of less than 1.50 Ou_E/m^3 at the 98^{th} percentile of hourly averages for 5 years of screened hourly sequential meteorological data was examined with worst case year Dublin 2004 used for data presentation.

5.1 Odour dispersion modelling results for Scenarios 1 and 2.

AERMOD Prime (USEPA ver. 12060) was used to determine the overall odour impact of the proposed Panda Waste Dry Fermentation and RDF Facility design.

The output data was analysed to calculate the following:

Ref Scenario 1:

- Predicted odour emission contribution of overall proposed dry fermentation and RDF facility design operation to surrounding population (*see Tables 4.2 and 4.3*), 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 8.2*).

All dispersion-modelling computations give the odour concentration at each 50-meter x y Cartesian grid receptor location that is predicted to be exceeded for 2% (175 hours) and 0.50% (44 hours) of hourly sequential meteorological data over seven years.

This will allow for the predictive analysis of any potential impact on the neighbouring sensitive locations while either the 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.

5.1 Meteorological data

Five years of hourly sequential meteorological data from Dublin 2002 to 2006 inclusive was used in the modelling screen which will provide statistical significant results in terms of the short and long term assessment. The worst case year 2004 was used for data analysis. This is in keeping with guidance. In addition, AERMOD incorporates a meteorological pre-processor AERMET PRO. The AERMET PRO meteorological preprocessor requires the input of surface characteristics, including surface roughness (z0), Bowen Ratio and Albedo by sector and season, as well as hourly observations of wind speed, wind direction, cloud cover, and temperature. The values of Albedo, Bowen Ratio and surface roughness depend on land-use type (e.g., urban, cultivated land etc) and vary with seasons and wind direction. The assessment of appropriate land-use type was carried out to a distance of 10km from the meteorological station for Bowen Ratio and Albedo and to a distance of 1km for surface roughness in line with USEPA recommendations.

The wind rose plot and statistical aspects of the meteorological file are contained in *Section 9*.

6. Discussion of results from dispersion modelling study

This section provides discussion on the results obtained during the study.

6.1 Predicted odour impact assessment of proposed Panda Waste Dry Fermentation and Composting Facility (ref: Scenario 1)

The plotted odour concentrations of ≤ 1.50 Ou_E m^{-3} for the 98^{th} for the proposed Panda Waste Dry Fermentation and RDF Facility operation is illustrated in *Figure 8.2*.

As can be observed in *Figure 8.2*, it is predicted that odour plume spread is in a easterly direction of approximately 40 to 50 metres from the boundary of the facility with no sensitive receptors impacted by the plume. All resident locations in the vicinity of the proposed facility operations will perceive an odour concentration less than 1.50 Ou_E/m^3 at the 98^{th} percentile of hourly averages for 5 years of screened hourly sequential meteorological data. In accordance with odour impact criterion in *Sections 5*, and in keeping with currently recommended odour impact criterion in this country, no long-term odour impacts will be generated by receptors in the vicinity of the proposed facility operations.

It is therefore concluded that following the implementation of key odour minimisation, mitigation and management techniques, that all residential and business receptors in the vicinity of the proposed facility will not experience nuisance odours with all receptors perceiving an odour concentration less than 1.50 Ou_E/m^3 for the 98^{th} percentile of hourly averages for 5 years of screened hourly sequential meteorological data (*see Table 6.1 and Figure 8.2*).

The implementation of an odour management system and plan for the operating site will ensure that this is maintained throughout the life of the facility.

Table 6.1. Predicted ground level concentrations of odour at the 98^{th} percentile of hourly averages for worst case meteorological year Dublin 2004.

Receptor identity	X coord (m)	Y coord (m)	Predicted 98^{th} percentile odour concentration (Ou_E/m^3)
R1	297498.3	269436.6	0.73
R2	297573.5	269493.2	0.58
R3	297654.7	269498.3	0.67
R4	297395.3	269510.8	0.51
R5	297355.4	269515	0.48
R7	297281.2	269519.7	0.42
R8	297299.3	269380.5	0.47
R9	297744.7	269499.2	0.62
R10	297629.6	268891.5	0.56
Limit value (Ou_E/m^3)	**-**	**-**	**Less than or equal to 1.50**

7. General conclusions

The following general conclusions were drawn from the study:

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 Panda Waste Dry fermentation and Refuse derived fuel 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 throughout the world (references included with documentation). The overall incorporation of robust preventative maintenance procedures, containment measures, focused extraction, zoned ventilation, SCADA control, monitoring, trending and data-logging and multiple stages of treatment will ensure that odours will not cause impact on the surrounding area and that the odour control systems (biotrickling filter and Biomass thermal oxidiser) will operate at optimal capacity.

3. The Dry fermentation and RDF facility design will ensure that all ground level concentration of odours at the nearest sensitive receptors will be less than 1.50 Ou_E/m^3 at the 98^{th} percentile of hourly averages for five years of screened hourly sequential meteorological data in the vicinity of the facility. The implementation of odour management, minimisation and mitigation techniques and technologies outlined in the overall facilities operation will achieve the specified odour impact criterion to prevent nuisance odours at nearest residential and business neighbours (*see Figures 8.2*).

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

8. Odour contour plots from dispersion modelling assessment using AERMOD Prime dispersion modelling software and 5 years of screened meteorological data for Panda Waste Dry Fermentation and RDF facility operation - Location layout map

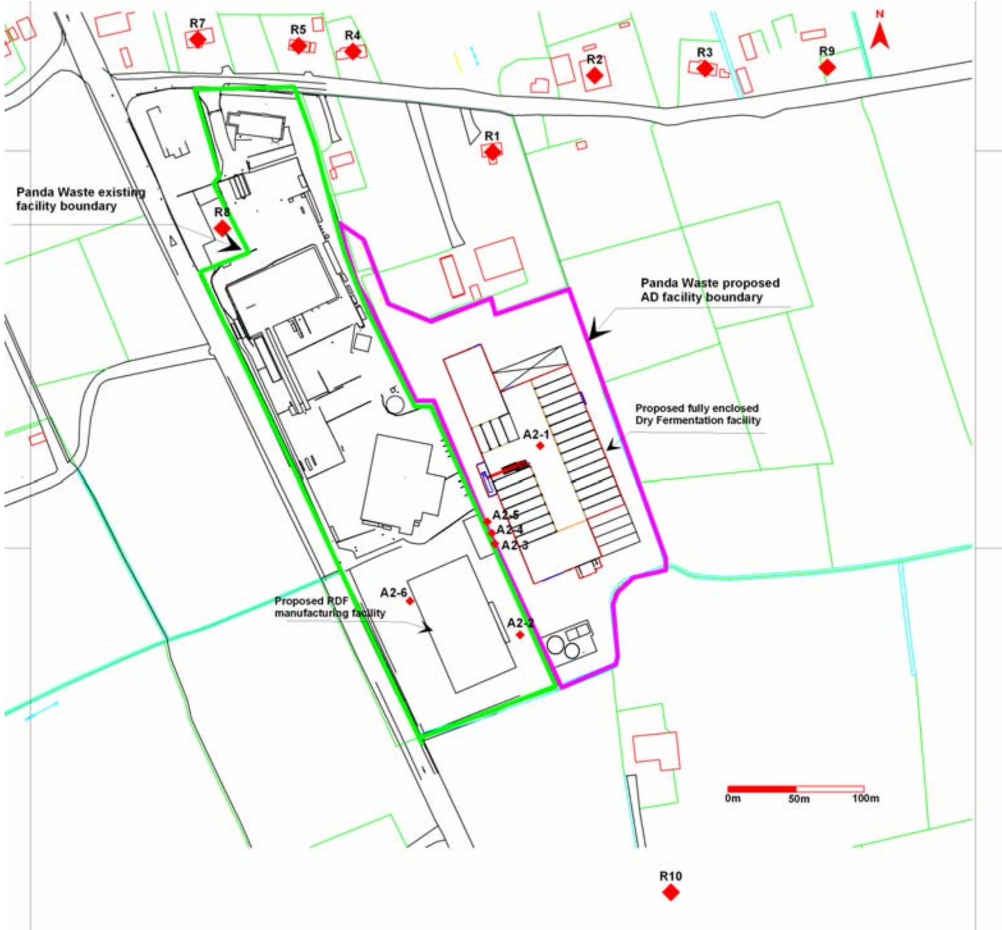

Figure 8.1. Aerial diagram of proposed Panda Waste Dry Fermentation and RDF Facility design and proposed boundary ( )

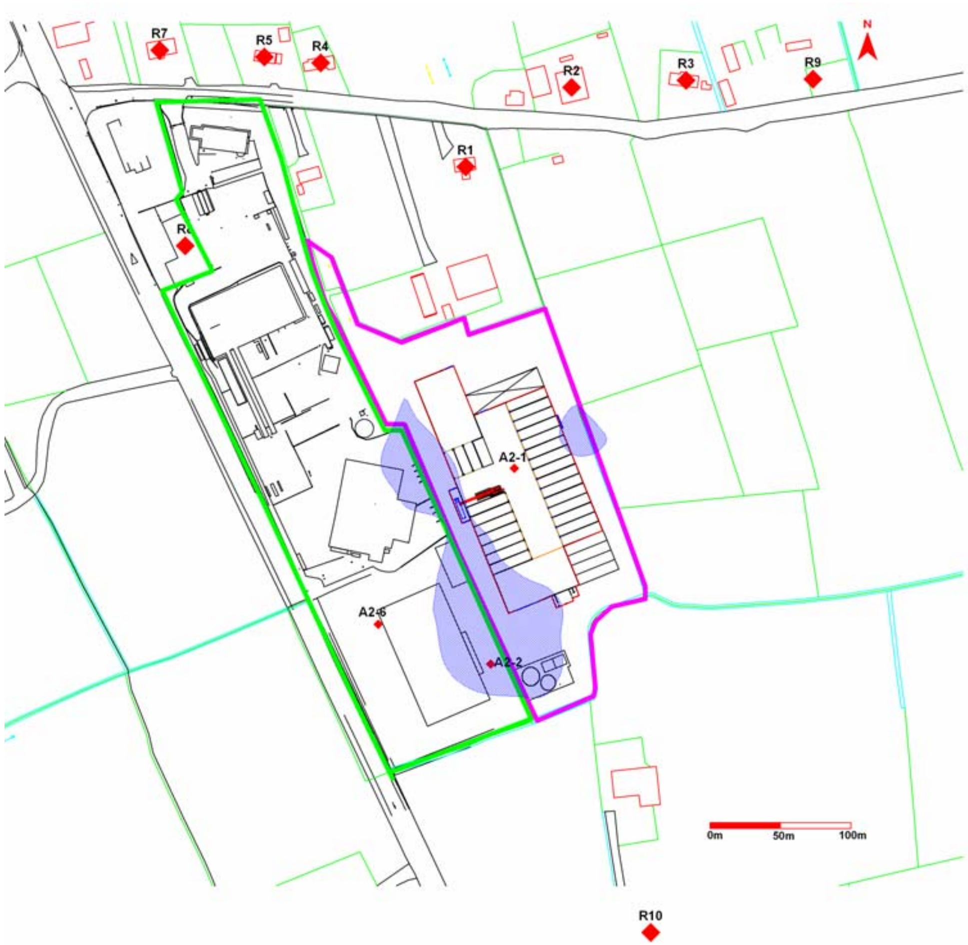

Figure 8.2. Predicted odour emission contribution of proposed overall Panda Waste Dry Fermentation and RDF Facility operation to odour plume dispersal for the 98th percentile for an odour concentration of ≤1.50 Ou_E m^{-3} (▬) for worst case meteorological year Dublin 2004.

9. Meteorological data examined and used in the dispersion modelling exercise

Table 9.1. Tabular illustration of Dublin Airport meteorological files for Years 2002 to 2006 inclusive (5 years).

5 year Meteorological file for Dublin Airport 2002 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	0.67	0.50	0.99	0.44	0.07	0.02	2.70
22.5	0.15	0.48	1.04	0.48	0.16	0.00	2.31
45.0	0.11	0.31	1.27	0.67	0.21	0.01	2.57
67.5	0.07	0.24	1.55	0.86	0.38	0.05	3.15
90.0	0.13	0.44	2.28	0.95	0.31	0.11	4.22
112.5	0.17	0.68	2.62	0.80	0.16	0.04	4.48
135.0	0.22	0.79	4.10	2.61	0.76	0.14	8.63
157.5	0.22	0.70	2.39	1.61	0.58	0.08	5.58
180.0	0.20	0.45	1.30	0.77	0.32	0.05	3.09
202.5	0.17	0.42	2.26	2.14	0.93	0.23	6.15
225.0	0.19	0.62	4.21	4.53	2.18	0.61	12.34
247.5	0.20	0.64	4.91	5.29	2.73	0.87	14.63
270.0	0.19	0.73	5.39	4.27	2.00	0.63	13.20
292.5	0.19	0.68	4.23	2.13	0.66	0.13	8.03
315.0	0.26	0.53	2.77	1.33	0.26	0.04	5.20
337.5	0.23	0.37	1.51	0.78	0.15	0.04	3.07
Total	**3.39**	**8.58**	**42.82**	**29.66**	**11.86**	**3.04**	**99.36**
Calms	--	-	-	-	-	-	**0.56**
Missing	-	-	-	-	-	-	**0.08**
Total	**-**	**-**	**-**	**-**	**-**	**-**	**100.00**

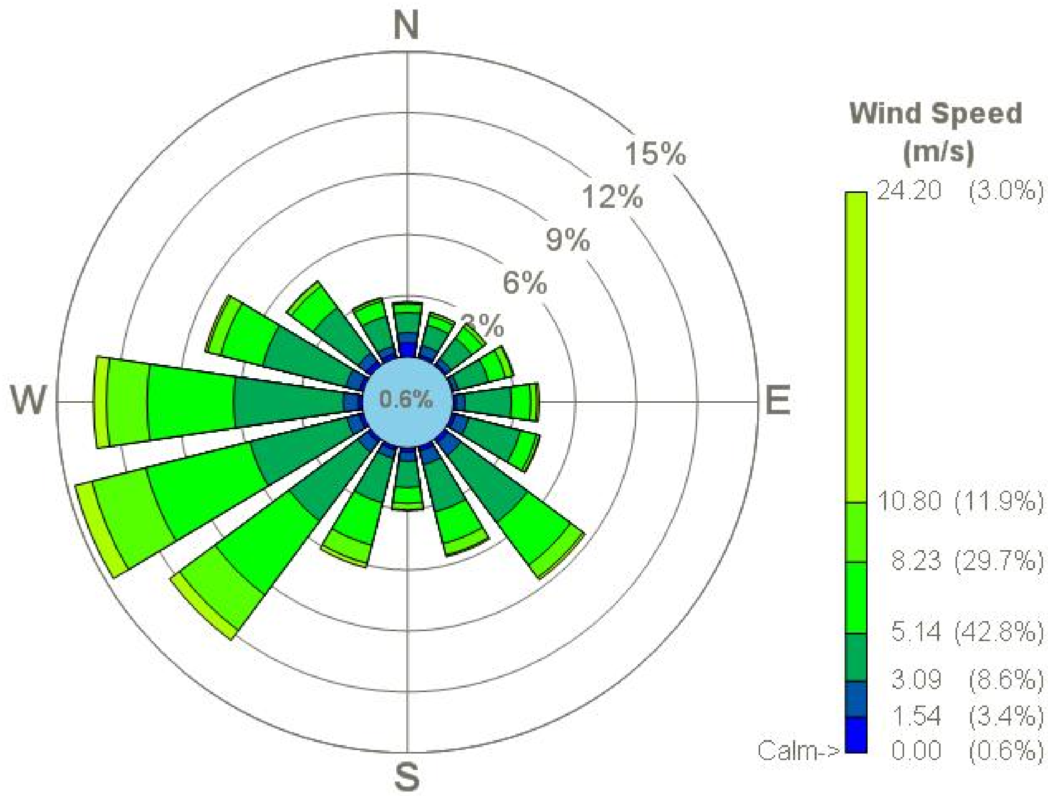

Figure 9.1. Windrose illustration of meteorological files Dublin Airport 2002 to 2006 inclusive.