Deep Moor In-Vessel Composting Facility

Odour and Bioaerosol Assessment for

Viridor Waste Management

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1 Air Quality

1.1 Background

RPS Planning and Development has been instructed by Pell Frischmann Consulting Engineers Limited to undertake a site specific assessment of airborne emissions from an in-vessel composting facility proposed to be constructed at the Deep Moor Landfill site. The facility will be managed and run by Viridor Waste Management. The assessment is required as part of the planning application to determine the suitability of the site for the proposed use.

This report will discuss the methodology and results of the assessment carried out on the subject site. The assessment aims to identify potential impacts from airborne releases commonly associated with these kinds of facilities on relevant environmental receptors following current UK practice and protocols.

The assessment is based on the technology proposed and the plant design and description provided by the technology providers, Celtic Composting Systems (CCS).

1.2 Introduction

An assessment of the potential air quality impacts associated with the proposed in-vessel composting facility at the Deep Moor Landfill site has been undertaken. The assessment considers the proposed composting facility with particular regards to the following:

- Emission of odour
- Generation and release of bioaerosols from the composting process

The mechanisms considered within the assessment are:

- pollutants are released to the atmosphere in sufficiently high concentrations that have the potential to affect local receptors
- atmospheric dispersion will dilute emissions to different levels at different locations depending on the meteorology of the area.
An assessment of releases and dispersion of odour and bioaerosol is usually required where emission source(s) from a composting facility are located in an area within which sensitive receptors are residing or working. Potential impacts from the releases and dispersion of the pollutants (with considerations to the prevailing meteorological conditions for that location, and the proximity of the locations sensitive to the emission sources giving rise to health impact or nuisance) are therefore assessed.

Bioaerosols assessment is only required where the boundary of the facility is within 250 metres of a sensitive receptor. The composting association defines sensitive receptors as “any building, other structure or installation, in which at least one person normally lives or works, other than a building, structure or installation within the same ownership or controls as the operator/ owner of the composting facility.”

Two sensitive receptors were identified within 250m of the facility. These were the Landfill site offices and the Household Recycling Centre. A bioaerosols assessment has therefore been undertaken.

1.3 Emissions from Deep Moor In-Vessel Composting Facility

The site is proposed to accommodate a composting facility comprised of enclosed in-vessel composting bays which process waste on a controlled batch basis with enclosed tipping and processing areas.

The proposed facility is designed to have an enclosed Reception area, where tipping, mixing and tunnel filling will occur, a Tunnel Composting System and Aerated Static Piles. The Tunnel Composting System and Aerated Static Piles will both be serviced by separate biofilters (Tunnel biofilter and ASP biofilter). It is expected that the principal sources of odour at the site will be from the two-biofilter surfaces. The location of the emission points can be viewed in Figure 1.

1.4 Emission Controls
The waste reception and processing will take place within enclosed buildings. Air is extracted from these buildings in order to achieve sufficient air changes per hour to maintain a good working environment and to maintain negative air pressure to prevent any fugitive odours.

The Aerated Static Piles (ASP) will be contained within open bunds, these however will be maintained under negative pressure. The extracted air will be fed to the ASP biofilter.

Odour and bioaerosols can be produced during many of the early stages of processing, particularly the reception, shredding and mixing of wastes. All these activities will take place inside the sealed buildings; all exhaust air from these areas will be passed through a bio-scrubbing system and then on to biofilter before emission. The ASP air will be air-cooled prior to entering the biofilter.

The biofilters are designed to carry out a “final polishing” of all exhaust air streams from the plant and will vent directly from the surface to atmosphere.

The use of biofiltration had been documented to reduce odour emissions from some compost facilities by 98% or better. Therefore biofiltration is considered to be an effective treatment technology that can be used to obtain very high levels of odour reduction. Aeration increases the oxygen in compost piles, thus preventing formation of some odorous compounds.

The operation of a biofilter is relatively simple. Odourous process air, which has been forced through the material being composted, is collected and passed through the biofilter. In biofiltration, a humid, odorous air stream is passed through a porous material (e.g. wood chips, bark, and compost), which supports a complex microbial community.

Micro-organisms in the biofilter live on a thin layer of water known as a biofilm and break down odorous chemicals via enzymatic activity and oxidation. Under optimal conditions complete odour reduction occurs resulting in formation of carbon dioxide, water and excess biomass.

1.5 Sensitive Receptors
The composting association defines sensitive receptors as “any building, other structure or installation, in which at least one person normally lives or works, other than a building, structure or installation within the same ownership or controls as the operator/owner of the composting facility.

Therefore the nearest above-identified receptors surrounding the facility boundaries are considered in this assessment. A summary of the location of these receptors is presented below in Table 1. A location plan for the receptors is presented in Figure 1.

### Table 1 – Sensitive Receptors and Distance to Deep Moor In-vessel Composting facility

<table>
<thead>
<tr>
<th>Ref</th>
<th>Receptor</th>
<th>Exposure Type</th>
<th>NGR x</th>
<th>NGR y</th>
<th>Distance * (m)</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Belle Vue Lodge</td>
<td>Residential</td>
<td>E252602</td>
<td>N121427</td>
<td>428</td>
<td>North</td>
</tr>
<tr>
<td>2</td>
<td>Ward Farm</td>
<td>Residential</td>
<td>E253422</td>
<td>N121035</td>
<td>470</td>
<td>East</td>
</tr>
<tr>
<td>3</td>
<td>High Bullen</td>
<td>Residential</td>
<td>E253296</td>
<td>N120478</td>
<td>580</td>
<td>South east</td>
</tr>
<tr>
<td>4</td>
<td>Recycling Centre</td>
<td>Industrial</td>
<td>E253008</td>
<td>N120778</td>
<td>150m</td>
<td>South</td>
</tr>
<tr>
<td>5</td>
<td>Landfill Offices</td>
<td>Industrial</td>
<td>E252979</td>
<td>N120826</td>
<td>93m</td>
<td>South</td>
</tr>
<tr>
<td>6</td>
<td>Peagham Barton</td>
<td>Residential</td>
<td>E252463</td>
<td>N120361</td>
<td>735</td>
<td>South West</td>
</tr>
</tbody>
</table>

*The distance is measured from the boundary of the receptors to the nearest emissions source.*
Figure 1 – Location of Sensitive Receptors and emission sources
2 Assessment Methodology

2.1 Introduction

This section describes the methodology and assumptions made for the odour and bioaerosol assessment.

2.2 Site Conceptual Model

The key aim of any environmental impact assessment is to identify and assess potential harm to human and other environmental receptors from any identified sources at the assessed site. The assessment procedure utilises the source-pathway-receptor concept in constructing a site conceptual model (SCM) and assessing potential impact.

The conceptual model, focussing particularly on site specific characteristics, is based on an initial evaluation of available data that characterises the sources of emission and identifies all possible pathways connecting the sources to sensitive receptors, both on and beyond the site. As the assessment progresses the conceptual site model is continually refined within the context of the impact linkage.

To present information in a manner consistent with the Source-Pathway-Receptor concept and to assist in evaluating the possible impacts of releases from the site on human wellbeing, the SCM establishes, in a qualitative manner, the sources of emissions, potential pathways of exposure, and potential receptors as follows:

- Principal sources of emissions;
- Substances of primary concern (odour, bioaerosols, etc);
- Behaviour of the emitted substance within the affected media (air);
- All potential receptors;
- Location of potential exposure points;
- Likely migration pathways for the emitted substances to move off-site;
• Plausible pathways connecting sources and sensitive receptors;
• All significant impact linkages associated with the site.

2.3 Dispersion Model Selection

Dispersion modelling allows concentrations to be calculated at specific receptor or gridded locations from emissions from a number of specified sources.

The new generation of air dispersion models are able to more accurately estimate vertical air movements and stability characteristics than has previously been possible.

One of the main products recognised by the Environment Agency is the US Environmental Protection Agency’s AERMOD dispersion model.

This model uses hourly sequential meteorological data to take account of complex turbulence and atmospheric stability effects as well as being able to incorporate terrain and building effects for some sources.

Hourly odour concentration output data from such dispersion models are usually processed to provide a statistical measure of the data in the form of a percentile value. In the UK, the Environment Agency recommends that the 98th percentile be used for odour assessment.

2.4 Emissions Sources

The technology designers, Celtic Composting Systems have provided flowrates and other emission parameters.

Data on the performance of the proposed biofilters has been gathered from a number of pilot studies and in-situ assessments undertaken by the technology developer. Odour emissions are based on typical odour outputs from composting material of between 8,000 and 20,000 OU/m³ subjected to scrubbing and biofiltration in series at a removal efficiency of 90-95%.

The expected flow rates for the Tunnel biofilter will typically vary between 6,000 and 9,000 m³/h depending on temperature feedback and re-circulation influences. The odour output is expected to be in the range of 400-1000 OU/m³ based on a combination of scrubbing and biofiltration.
The **ASP biofilter** will have an expected flow rate of between 12,000 and 17,000 m$^3$/h, depending on temperature feedback and re-circulation influences. An odour emission of between 300 and 800 OU/m$^3$ is expected.

For the purposes of the assessment it has been assumed that the flow rates and odour emission concentrations will be at there maximum expected levels to represent a worst case scenario of emissions.

Bioaerosol emission concentrations used in this assessment have been based on industry standard commonly used emission values for similar type of facilities.

The parameters assumed within this assessment are presented in Table 2.

**Table 2 – Summary of Emissions To Air**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ASP Biofilter</th>
<th>Tunnel Biofilter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source Location (NGR)</td>
<td>E 252876</td>
<td>N 121086</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E 252953</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N 120918</td>
</tr>
<tr>
<td>Mass flow (m$^3$/hour)</td>
<td>17,000</td>
<td>9,000</td>
</tr>
<tr>
<td>Emission Area (m$^2$)</td>
<td>384</td>
<td>150</td>
</tr>
<tr>
<td>Odour strength (OU/m$^3$)</td>
<td>800</td>
<td>1000</td>
</tr>
<tr>
<td>Odour mass emission (OU/s.m$^2$)</td>
<td>9.84</td>
<td>16.67</td>
</tr>
<tr>
<td>Bacteria (Cfu/m$^3$)</td>
<td>5000</td>
<td>5000</td>
</tr>
<tr>
<td>Bacteria mass emission (Cfu/s.m$^2$)</td>
<td>61.49</td>
<td>83.33</td>
</tr>
<tr>
<td>Fungi (cfu/m$^3$)</td>
<td>5000</td>
<td>5000</td>
</tr>
<tr>
<td>Fungi mass emission (Cfu/s.m$^2$)</td>
<td>61.49</td>
<td>83.33</td>
</tr>
</tbody>
</table>
2.5 Meteorological data

The most important meteorological data affecting the atmospheric dispersion of pollutants include the wind direction, speed and the atmospheric stability.

The wind direction will determine the main sectors of the compass into which the emitted substance is transported and dispersed. The wind speed will affect the ground level concentrations by affecting the dilution rate. The atmospheric stability identifies the degree of atmospheric turbulence generated by heating and cooling of the underlying surface and frictional forces as the air moves over the surface.

The year of meteorological data that is used for a modelling assessment can have a significant effect on source contribution concentrations. Model simulations were performed for emissions from the Deep Moor in-vessel composting facility using three years of data (2002 - 2004 inclusive) from the weather station at St Mawgan. This data was deemed to be the most representative of the Deep Moor site.

Windroses have been constructed for each of the three years of St Mawgan weather data used in this assessment (Figure 2).
2.6 Topography

The presence of elevated terrain can affect ground level concentrations of pollutants emitted from sources. Although the site itself has no significant gradients, the surrounding topography of the area around the application site was observed to have gradients of some degree. Therefore it was considered to be of possible significance with regard to modelling and was entered into the model.

A digital DEM terrain file was created from NTF terrain tile SS42 supplied by eMapsite.com.

Terrain within a radius of 1km radius was taken into consideration in the model.
2.7 Surface Roughness

The nature of the surface of the terrain can have a significant influence on dispersion by affecting the velocity profile with height and the amount of atmospheric turbulence.

The location of the proposed composting facility is bordered by agricultural land, therefore, to account for the surrounding nature of the proposed site, a surface roughness length of 0.0725 meter for cultivated land has been assumed for the dispersion modelling.

2.8 Receptor Grid

The AERMOD modelling was undertaken with a regular Cartesian grid of 2000m by 2000m spaced at 25m apart in the x and y direction respectively (total number of gridded receptors is 6400). An additional four sensitive receptors were also located in the surrounding area of the site to identify the concentration of odour at these locations (Refer to section 1.5).

2.9 Modelling Details

Dispersion modelling of emissions resulting from two area sources (biofilters) allowed odour concentrations to be calculated at specific receptors or gridded locations.

Odour modelling at the proposed Deep Moor in-vessel composting facility was carried out using AERMOD. The version used (5.1.5) was that supplied by Trinity Consultants.

The following assumptions have been made in the modelling process:

- Three years (2002 – 2004) of hourly sequential metrological data from St Mawgan weather station have been used in the assessment.
- Effects on dispersion resulting from terrain elevations were included.
- Emission rates were based on the emission data provided by Celtic Composting Systems.
• Model outputs were calculated across the site on a 2000 m by 2000 m gridded network of receptors, spaced at 25m apart in the x and y direction (total number of gridded receptors = 6400).

• It was assumed that odour will be released from the two biofilters at all times, including non-operational hours.

• It was assumed that flow rates and odour emissions would be at the maximum expected levels.
3 The Odour Assessment

3.1 Methodology

The UK has no statutory standards for assessing odour nuisance. Elsewhere few standards exists owing to the difficulty in quantifying odour nuisance and problems associated with the measurement of odour and assessing compliance with any odour nuisance standards that may be applied.

The Environment Agency “Draft Horizontal Guidance for odour”\(^3\) was used for technical guidance on the assessment procedure.

The new generation air dispersion model AERMOD was used to model odour dispersion in the atmosphere. This model is one of the EA recommended models for odour assessment. This model uses the hourly sequential meteorological data to take account of complex turbulence and atmospheric stability effects and incorporate terrain and building effects for some sources. The EA recommended 98\(^{th}\) percentile of the hourly average was used for this assessment.

3.2 Odour Assessment Units

Odour is very difficult to accurately quantify due to the subjective nature of its effects. The response of people to concentrations of odorous compounds can vary enormously between individuals and groups. This is due to peoples’ differing perception of what constitutes an unpleasant smell and how sensitive they are to it. To overcome these problems, a number of measurement units are used in odour assessments. A description of these units and details on how they are derived are given below.

\(D_{50}\) and \(OUsD_{50}\) is the concentration at which an odour becomes just detectable to 50\(^{th}\) of a population. This concentration of an odorous substance is given the value of 1 odour unit (OU). \(D_{50}\) (i.e. D50 is equal to 1OU).

Concentrations are presented in a number of reference documents for a wide range of odorous compounds and substances.
Multiples of the $D_{50}$ concentration provide a measure of the strength of the odour in OUs. For example, a doubling of the $D_{50}$ concentration would be 20 OUs whereas a tenfold increase would be represented by 10 OUs.

For many odorous compounds and mixtures of substances, $D_{50}$ values have been empirically calculated by exposing people to diluted concentrations of the odours in laboratory conditions. The experimental technique used to achieve this is called olfactometry and this has provided a number of sources of $D_{50}$ (i.e. 1 OU) values that are presented in the literature.

For waste treatment facilities such as composting plants, the mixture of compounds that produce potentially offensive odours can vary and are not necessarily dominated by a single chemical species. However, data on the concentration of odours from such facilities using olfactometry is available from a number of sources.

For the odour assessment at the subject site, the odour emissions provided by Celtic Composting Systems, discussed in Section 2.4 (Table 2) have been used.

### 3.3 Odour Nuisance

The main problem associated with determining whether exposure to an odour is unacceptable, is the varying detection sensitivity of the general public. The $D_{50}$ criterion goes some way to address this by accepting that 50% of the population may detect an odour at a concentration that would be imperceptible to the remaining people.

In UK law, unacceptable odour is described as being a “nuisance”. The definition given for this in the Public Health Act 1936 (subsequently transposed to the Environmental Protection Act 1990) describes such an odour as being “prejudicial to health or a nuisance”. The determination of whether or not an odour constitutes a nuisance is usually dealt with in the first instance by local authority Environmental Health Officers or by Environment Agency inspectors, and hence incorporates some degree of subjectivity.

In terms of OUs, the Environment Agency has proposed, in their draft guidance document, to apply an “annoyance potential” criterion of between 1.5 and 6 $\text{OU.m}^{-3}$ to odours from a variety of sources, depending on their relative offensiveness. However, these are not absolute values and need to be
assessed in relation to the specific character of an odour, the frequency and
duration of its emission and the sensitivity of a particular area to the odour.

The Environment Agency “Guidance for auditing odour dispersion modelling
and assessment” states that ‘An odour may be identified by a typical observer
at its recognition threshold, which tends to be about three times its detection
threshold (3 ouE/m³). As a rule of thumb, 5 ouE/m³ may be described as a ‘faint
odour’ and 10 ouE/m³ a ‘distinct odour’. Rapidly fluctuating odours may be more
noticeable than steady ones at low concentrations.’

It should be noted that odours are generally not additive, as stated in the
cannot be added to an existing background or ‘ambient’ odour level to give a
figure for total odour. People normally have a tendency to ‘screen out’ those
odours which are always present or which are normal to that environment.

3.4 Assessment Criteria

Not all odours have the same potential to cause annoyance. For instance,
odours from a chocolate manufacturer or brewery would generally be
considered less offensive than odours arising from activities involving
putrescible waste.

The Environment Agency provides installation-specific odour exposure
“annoyance potential” criteria, ranging from 1.5 OU.m⁻³ for more offensive
odours to 6 OU.m⁻³ for less offensive odours.

These indicative criteria are considered for the 98th percentile of hourly
concentrations and may be adjusted for local factors such as the sensitivity of
the site, the receptor community, or the magnitude and nature of the odour
under investigation.

The composting facility is a controlled process in which extracted air is initially
passed through a wet scrubbing system before being passed through biofilters.
The odour released is more likely to be of a less offensive odour which is
earthly in nature.

3.5 Predicted Odour Concentrations
The 98th percentiles of predicted hourly odour concentrations for 2004 at the identified receptors are presented in Table 3. Modelling demonstrated that on average, 2004 gave rise to the highest concentrations.

The predicted hourly odour concentrations for each of the modelled years (2002, 2003 and 2004) are presented in Appendix A (Table A).

### Table 3 - 98th Percentile Hourly Odour Concentration OU/m³

<table>
<thead>
<tr>
<th>Ref</th>
<th>Receptor</th>
<th>Exposure Type</th>
<th>Odour (OU.m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Belle Vue Lodge</td>
<td>Residential</td>
<td>0.19</td>
</tr>
<tr>
<td>2</td>
<td>Ward Farm</td>
<td>Residential</td>
<td>0.15</td>
</tr>
<tr>
<td>3</td>
<td>High Bullen</td>
<td>Residential</td>
<td>0.18</td>
</tr>
<tr>
<td>4</td>
<td>Recycling Centre</td>
<td>Industrial</td>
<td>1.23</td>
</tr>
<tr>
<td>5</td>
<td>Landfill Offices</td>
<td>Industrial</td>
<td>2.26</td>
</tr>
<tr>
<td>6</td>
<td>Peagham Barton</td>
<td>Residential</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Pollution isopleths showing the spatial variation of the 98th percentile for 2004 are presented in Figure 3 in Appendix B. This year was considered to be representative of the dispersion patterns for all years, due to all years modelled showing similar dispersion patterns.

The results show that compliance even with the most stringent criterion of 1.5 OU.m³ would be achieved at all the residential receptors.
4 Bio-aerosols Assessment

4.1 Introduction

Currently, there are no available UK statutory levels or target guidelines for bioaerosols that are considered protective of human health or the environment. Also, emission levels from the different types of composting facilities are yet to be established. Understanding the release mechanisms, the dispersion, deposition, viability and potential impact from bioaerosols emissions on human health and the environment is a developing field of work that is still at a research stage.

A review of the EA published literature\textsuperscript{1,4,5,6,7}, the Health & Safety Executive (HSE)\textsuperscript{9} study on the behaviour of bioaerosols emissions and other relevant literature was undertaken to identify the most applicable assessment approach for the subject site. The following paragraphs provide a brief description of the reviewed literature before drawing conclusions in Section 4.6. This then forms the basis for the modelling assessment criteria, which is then set out at Section 4.7.

4.2 Bioaerosols in Composting Facilities

Due to the need to meet government targets and the Landfill Directive, the amount of waste treated by composting is likely to increase significantly over the coming years.

While being perceived as having the potential to adversely affect the local environment and public health through the different emissions including bioaerosols, composting facilities are of great benefit for the environment.

To evaluate the potential impact of such facilities on the environment and public health, the Environment Agency (EA) has funded a number of research projects to evaluate the composting process\textsuperscript{1, 6}. Also the HSE has published a critical review of published data pertaining to occupational and environmental exposure to bioaerosols from different composting facilities\textsuperscript{8}.

One of the EA research projects\textsuperscript{1} covered a review of previous works in the literature and a study of the emissions from three composting plants. The selected sites were two turned-windrow, green waste composting facilities and...
one in-vessel composting facility treating a mixture of mixed municipal solid waste and source-separated organic waste. Other research work by the EA and the HSE concentrated on emissions from open windrows.

The EA report\(^1\) stated that review of the available data on the levels at which health effects are observed showed that there is limited consensus on appropriate reference of the levels at which health effects occur.

There are difficulties due to the variable response of individuals and the wide range of organisms that can be present. Also the nature of the human response can change with past exposure (sensitisation), thus the dose-response relationship is not clear at this stage.

However, on the basis of the available literature, reference levels for total bacteria, total fungi and Gram-negative bacteria of 1000 cfu/m\(^3\), 1000 cfu/m\(^3\) and 300 cfu/m\(^3\) respectively have been derived as nominally acceptable concentrations. Levels over 1,000,000 cfu/m\(^3\) may cause sensitisation. The term ‘cfu/m\(^3\)’ refers to the commonly accepted measure for bio-aerosols now in use.

The concentrations measured by the EA upwind and downwind of certain sites exceeded the reference values on many occasions. While these reference values are based on peer-reviewed scientific papers derived from a variety of studies, they are likely to be conservative given that health effects are not reported downwind of sites despite elevated levels of bioaerosols and that studies of background levels are often higher than these levels.

The concentrations of bioaerosols measured at the assessed composting sites exceeded these reference levels.

A survey of the workers at the green-waste sites stated that no problems were observed that might be associated with the emissions. The workers at the in-vessel site noted some adverse reactions only to particular operations (clearing blockages) where they had to work within the composting vessel. The main implications for workers are that respiratory protection needs to be used.

The EA noted that modelling the dispersion of bioaerosols proved difficult due to the influence of two factors:
• Clumping of organisms to form larger particles and thus leading to settling of the particles (non-gaseous behaviour).

• Loss of viability of organisms with time.

Due to these factors a simple straight line fit to the logarithm of the monitoring data was proposed and performed by the EA to provide an estimate for the downwind dispersion. This simple modelling indicates that under most conditions the concentration of bioaerosols reaches the reference level discussed above within 250m of the composting plant.

4.3 The EA Assessment of the Impact of Bioaerosol

The results of the above referenced EA report show that the Gram-negative reference level (300 cfu/m$^3$) is exceeded at all the tested sites. Significantly high levels were however only found in few samples, some of which were associated with significantly elevated background levels.

Also the reference level of 1000 cfu/m$^3$ for bacteria was exceeded on all occasions on all the assessed sites. Occasionally the concentrations of bacteria did exceed the limit suggested by Sigsgaard et al. (1990) (5-10$^3$ cfu/m$^3$) – at the peaks by orders of magnitude in certain operational areas. However the bulk of the results were in the range of 10$^4$-10$^5$ cfu/m$^3$.

The concentrations of fungi exceeded the reference level of 1000 cfum$^3$ at all sites and on all occasions. However, the concentrations of fungi on all the sites were in the range 10$^3$-10$^6$ cfu/m$^3$, which is below the sensitisation level suggested by Lacey et al (1990) and Rylander (1986). Thus the public is unlikely to be exposed to levels that could cause sensitisation when passing the plant.

The EA reported that if the impact of a composting facility on the surrounding population is to be determined, the behaviour of the emission needs to be modelled. Unlike many processes the emission rate cannot be readily identified as the emission source is not contained or well defined.

In the absence of a specific model, the EA used the Screen 3 dispersion model to calculate dispersion through fitting a standard model to the observed ground level concentrations. It was recognised that modelling of bioaerosols would pose some problems to existing models given that organism viability and
particle deposition would be potentially significant factors. The process of trying to fit the model results to the observed data was performed to achieve good fit between the model and the experimental data.

From this exercise, the EA concluded that the model fitting process was particularly unsatisfactory and the curve shapes were difficult to match to the experimental data. The reasons for this are complex but two factors were identified to be important in distinguishing bioaerosols modelling from other gaseous environmental pollutants: these are particle deposition and loss of viability.

From studying the bioaerosol samplers, the EA field experiment report has identified that emission is characterised by large particles with many organisms attached or clumps of organisms. This may result in a significant proportion of the biologically active particles larger than 20µm level and deposition through gravity would therefore become more significant. One of the implications of this is that the levels of bioaerosols might be expected to decline more quickly through deposition than would be predicted by simple Gaussian plume models.

Travel in the atmosphere can kill many organisms and the rate of loss viability is dependent on many factors such as relative humidity, sunlight and temperature. Thus the viability of bioaerosols will reduce with time, in addition to the physical dispersion.

The EA reported that the complexities introduced by the particle (agglomeration) settling and loss of viability made the use of standard dispersion modelling difficult. Simple Gaussian plume modelling is therefore unlikely to be helpful in predicting the eventual concentration of bioaerosol at distance from a composting site, and when used will tend to overestimate the concentrations for remote sites.

Due to these complexities a simple straight line fit to the logarithm of the data (least square error) was used as the means of estimating the distance to reference concentrations. The calculated distance to reference level for different composting operation areas are presented below:

<table>
<thead>
<tr>
<th>RPS Planning and Development</th>
<th>Deep Moor In-vessel Composting Facility</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 2007</td>
<td>JER3046</td>
</tr>
</tbody>
</table>

Table 4 - Distances to reference levels for composting operational areas
The above table shows that the reference levels for fungi, bacteria and Gram negative bacteria from the biofilter (in an in-vessel plant) were achieved within 20-28m, 14-93 and 0-29m of the operational area of the site.

4.4 The HSE Review

A study undertaken by the HSE and the composting Association with the objective of critically reviewing published literature related to studies of airborne micro—organisms or their constituent parts (bioaerosols) associated with organic waste composting facilities. One of the considerations was that airborne dispersal of bioaerosols from compost facilities could affect neighbouring facilities or residents, leading to health concerns.

Further objectives were to review computational modelling tools for estimating dispersion of bioaerosols from composting facilities and to recommend suitable models. Existing experimental data, previously derived from environmental sampling at composting sites by the Composting Association were re-examined to provide comparison between experimental and modelled data.

Concern has been raised by residents in the vicinity of composting sites that composting activities could increase levels of bioaerosols, such as airborne Aspergillus fumigatus spores. Most reports show numbers to have declined to ‘background’ within 200 m from a compost bioaerosol source, although some report levels above background at greater distance. Background or typical ambient bioaerosol levels may differ by orders of magnitude depending on location, weather and season, which hinders interpretation. Few published studies exist where the health of residents near composting sites has been
investigated, but where such work has been done there is no evidence of ill health compared to controls.

The report stated that bioaerosols concentrations decline with distance from source due to atmospheric dispersion and dilution and that mathematical and computational models can be used to estimate this dispersion and to examine the effects that different atmospheric stability classes have on reduction of bioaerosol concentrations.

Only limited published data are available to attempt to estimate bioaerosol emission rates from compost at different stages of the composting process. In this study, preliminary application of a computational model was made to evaluate published data and to compare the results from the model to experimental data previously derived by the authors at composting sites. Under certain atmospheric stability classes modelled, representing infrequently encountered worst case conditions, bioaerosol concentrations would not be reduced to the background value within 250 m. However, there is significant natural variability in both background concentrations and releases from composting.

The report concluded that further work needs to be done to establish source terms for application in computational dispersion models. Data on emission rates and their natural variation need to be obtained. These could include laboratory tests to estimate the bioaerosol concentration and size distribution associated with mechanical handling of known quantities of compost material, and also estimate emission rate. If data on emission rates and their variation become available then further dispersion calculations should be performed. These should examine predicted concentrations in the context of differing atmospheric conditions and the likelihood of different exposure levels and durations.

4.5 Other Studies on Bioaerosols Associated with Municipal Waste Composting

The HSE report\(^8\) reviewed the results of a number of composting facilities including in-vessel and enclosed plants and reported the following:

Millner et al (1994) {switched ref’g systems – check from this point onwards} conducted a comprehensive review of published data and concluded that the data indicated that at distances of 76-152m from the compost facility
perimeters the airborne concentration of *A. fumigatus* were at or below background concentrations.

In a UK study, Gilbert and Ward, 1999 and Gilbert et al, 2002 found that 200 m was the distance by which concentrations of *A fumigatus* and total mesophilic bacteria were found to reach background concentration.

Haas et al (1999) measured airborne thermophilic actinomycetes in the vicinity of composting facilities over a one-year period in Austria, using Andersen impaction samplers. Median values of actinomycetes close to an open composting plant were less than 100 cfu/m3 with a maximum count of 1308 cfu/m3.

Lavoie and Alie (1997) investigated bioaerosols at two household waste sorting and composting plants in Canada, both sites comprising a reception area and a fermentation building. Site A had fermentation cylinders and indoor windrows, while site B had indoor windrows and outdoor curing. Bioaerosol sampling was carried out using Andersen samplers. At both sites peak levels of airborne micro-organisms occurred in the reception and fermentation areas and this was regardless of season.

Indoor levels of bacteria and total fungal concentrations including *A. fumigatus* levels were significantly higher than in the outdoor air. Bioaerosol concentrations in air 100 m downwind from the sites were not affected by operations.

In comparison, Tovalen et al (1998) reported a thorough investigation of bioaerosols from composting source separated biowastes in Finland. The compost was processed outdoors.

Concentrations of airborne microbes were highest during crushing of fresh waste and turning of compost. Both bacterial and fungal levels ranged between $10^3$-10$^5$ cfu/m$^3$, with levels higher in the summer when the compost was dry.

Danneberg et al (1997) found that the exhaust air emitted from a biofilter contained 33 cfu/m$^3$ bacteria and 600cfu/m$^3$ *Aspergillus fumigatus* (fungi) in comparison to 76,000 cfu/m$^3$ and 2000cfu/m$^3$ of these bioaerosols in the location of the rotating sieve of a box-system composting plant.
Maricou et al (1998) reported that the airborne counts of total bacteria, fungi and yeast at a large indoor composting plant were up to 100 times higher within the inside of the composting halls in comparison to the levels outside.

Schilling et al (1999) compared an enclosed composting plant with biofilter with a partly open plant. The researcher found that fungal spores and *Aspergillus fumigatus* were up to 500 and 400cfu/m$^3$ at 50m from the enclosed plant in comparison to 6,000 and 7000cfu/m$^3$ of these bioaerosols at a greater distance of 100m from the partially closed plant.

Similar decreases in concentrations of bioaerosols at composting facilities have been measured directly. Lacey and Williamson (1995) observed a reduction of airborne fungi and bacteria to concentrations less than 10% of those measured within 1m of a turned pile of compost. Beffa et al (1998) noted a 100-1000 decrease in concentrations of *A fumigatus* 10m from a turning machine.

4.6 **Concluding Remarks**

From the EA work and the HSE review for a number of composting facilities discussed above, it can be concluded that although using simplistic dispersion modelling of the Bioaerosol plume, it was proven to be very conservative for Bioaerosols, and, that modelling can be used to predict concentrations in the context of differing atmospheric conditions and the likelihood of different exposure levels and durations.

The level of gram negative (G-) bacteria is reported to constitute a small fraction of the total bacteria in a number of research literatures including the EA work. The latter reported the concentration of G - bacteria to be more than an order of magnitude lower than the total bacteria. Other authors reported similar levels. Considering that the target level for these bacteria is slightly lower than the target level for total bacteria, their emission will not be modelled where the predicted concentration of total bacteria is found to be below its acceptance criteria.

4.7 **Assessment Criteria**

The EA report stated that review of the available data on the levels at which health effects are observed showed that there is limited consensus on appropriate reference levels or the levels at which health effects occur. There
are difficulties due to the variable response of individuals and the wide range of organisms that can be present. Also, the nature of the human response can change with past exposure (sensitisation) thus the dose-response relationship is not clear at this stage. However, on the basis of the available literature, reference levels for total bacteria, total fungi and Gram negative bacteria of 1000 cfu/m$^3$, 1000 cfu/m$^3$ and 300 cfu/m$^3$ respectively have been assumed. These levels are often exceeded in natural outdoor situations where health effects are not generally noted and thus the levels may be conservative but given the uncertainty in the literature, are in line with the precautionary principle.

The report stated that there have been many studies examining the effects of bioaerosols, but due to the lack of any defined dose-response relationship it has been impossible to set exposure thresholds, apart from advising that exposure should be minimised. Only two occupational exposure limits have been suggested for airborne micro-organisms. These are 300cfu/m$^3$ for gram-negative bacteria (Rylander et al. 1983, Palchak et al. 1990) and $10^3$-$10^4$ cfu/m$^3$ for fungi (Lacey, 1981). Malmberg et al. (1988) suggested that from examination of farmers lung cases, an occupational exposure limit for fungal spores of $10^6$-$10^8$ cfu/m$^3$ was appropriate.

Tests (Malmros, 1990) have shown a clinical effect on lung function at airborne concentrations above these values.

On the basis of observation at waste-sorting plants, Sigsgaard et al. 1990 suggested limits of 1000 cfu/m$^3$ gram-negative bacteria and average daytime total bacteria of 5000-10,000cfu/m$^3$.

The sensitisation level for fungi is uncertain but Rylander 1986 and Lacey et al. 1990 suggested that the levels $10^6$-$10^8$ cfu/m$^3$ were significant.

The EA report$^1$, suggested limit values of 1000 cfu/m$^3$ bacteria, 1000 cfu/m$^3$ fungi and 300 cfu/m$^3$ Gram-negative bacteria. However, it stated that it is uncertain what the “safe” levels are, because there is such a large disparity in the literature and these values therefore represent a conservative estimate given the available data.
The suggested limits are sometimes given as threshold limit values (TLV). However, Sigsgaard et al., 1990, did base his proposed limits on an occupational average (8-hour) rather than TLV.

The EA stated that as the relationship between time average exposure and peak exposure is not fully known, possibly the best guide of exposure comes from the levels experienced by the workers. These operatives, apparently, do not experience health effects in normal operations. Noted symptoms were only associated with extreme exposure conditions (such as during unblocking operations).

The HSE document presented a number of other occupational values commonly used in Europe.

These are summarised in Table 5 below.
### Table 5 - Summary of suggested exposure limits for workplace and ambient bioaerosol exposure

<table>
<thead>
<tr>
<th>Suggested Value</th>
<th>Bacteria cfu/m³</th>
<th>Gram negative bacteria cfu/m³</th>
<th>Fungi cfu/m³</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold values</td>
<td>1,000</td>
<td>1,000</td>
<td></td>
<td>Rylander et al 1980, 1983</td>
</tr>
<tr>
<td>Suggested OELS in Scandinavia</td>
<td>1,000</td>
<td>10⁷</td>
<td></td>
<td>Rylander et al 1994</td>
</tr>
<tr>
<td>Threshold values</td>
<td></td>
<td></td>
<td>5,000</td>
<td>Peterson &amp; Vikstrom 1984</td>
</tr>
<tr>
<td>OEL</td>
<td></td>
<td></td>
<td>1,000</td>
<td>Makros 1992</td>
</tr>
<tr>
<td>OEL</td>
<td></td>
<td></td>
<td>2 x 10⁴</td>
<td>Dutkiewitz &amp; Jablonski 1989</td>
</tr>
<tr>
<td>Threshold values</td>
<td>1,000</td>
<td></td>
<td></td>
<td>Lacey et al 1992</td>
</tr>
<tr>
<td>Suggested OEL (biotechnology)</td>
<td>300</td>
<td></td>
<td></td>
<td>Palchak 1990</td>
</tr>
<tr>
<td>Suggested OEL 8 beverage</td>
<td>5-10,000</td>
<td>1,000</td>
<td></td>
<td>Sigsgaard 1990</td>
</tr>
<tr>
<td>Health based OEL*</td>
<td>2 x 10⁵</td>
<td>5 x 10⁴</td>
<td></td>
<td>Dutkiewitz 1997</td>
</tr>
<tr>
<td>Recommended maximum for residences, school and offices</td>
<td>4500</td>
<td></td>
<td></td>
<td>Finnish Ministry of Social Affairs and Health 1997</td>
</tr>
<tr>
<td>Provisional Dutch guidelines for indoor air in the work environment</td>
<td>10,000</td>
<td></td>
<td></td>
<td>Dutch Occupational Health Association NWA 1989</td>
</tr>
<tr>
<td>Suggested OEL in Scandinavia</td>
<td></td>
<td></td>
<td></td>
<td>Rylander 1994</td>
</tr>
</tbody>
</table>

* OEL Health based when continuous exposure to micro-organisms concentrations above 10⁷ cfu/m3 occurs work-related respiratory disorders in workers are very common
The EA Technical Guidance on monitoring of particulate matter in ambient air around waste facilities recommended, in its associated Fact Sheets applicable to composting facilities, an 8-hour average of 1000cfu/m$^3$ for bacteria and a 'not to exceed' threshold of 300 and 1000cfu/m$^3$ for G- bacteria and fungi respectively. It stated, however, that the limit values quoted are “yardstick” values only.

### 4.8 Predicted Bioaerosol Concentrations

To assess the model output against their relevant assessment criteria, the highest 8-hour average concentration of total bacteria and the highest 1-hour average concentrations fungi and were derived for all the modelled receptors. The predicted concentrations for 2004 are presented in Tables 6 and 7 below. Modelling demonstrated that on average, 2004 gave rise to the highest concentrations.

The predicted concentrations of total bacteria, G- bacteria and fungi for each of the modelled years (2002, 2003 and 2004) are presented in Appendix B and C (Tables B and C) respectively.

#### Table 6 - The 1st highest 8-hour average – Total Bacteria

<table>
<thead>
<tr>
<th>Ref</th>
<th>Receptor</th>
<th>Exposure Type</th>
<th>Bacteria (cfu.m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Belle Vue Lodge</td>
<td>Residential</td>
<td>4.24</td>
</tr>
<tr>
<td>2</td>
<td>Ward Farm</td>
<td>Residential</td>
<td>5.80</td>
</tr>
<tr>
<td>3</td>
<td>High Bullen</td>
<td>Residential</td>
<td>7.36</td>
</tr>
<tr>
<td>4</td>
<td>Recycling Centre</td>
<td>Industrial</td>
<td>50.76</td>
</tr>
<tr>
<td>5</td>
<td>Landfill Offices</td>
<td>Industrial</td>
<td>90.03</td>
</tr>
<tr>
<td>6</td>
<td>Peagham Barton</td>
<td>Residential</td>
<td>3.95</td>
</tr>
</tbody>
</table>
Table 7 - The 1st highest 1-hour average – Fungi

<table>
<thead>
<tr>
<th>Ref</th>
<th>Receptor</th>
<th>Exposure Type</th>
<th>Fungi (cfu.m⁻³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Belle Vue Lodge</td>
<td>Residential</td>
<td>15.40</td>
</tr>
<tr>
<td>2</td>
<td>Ward Farm</td>
<td>Residential</td>
<td>23.86</td>
</tr>
<tr>
<td>3</td>
<td>High Bullen</td>
<td>Residential</td>
<td>39.71</td>
</tr>
<tr>
<td>4</td>
<td>Recycling Centre</td>
<td>Industrial</td>
<td>167.76</td>
</tr>
<tr>
<td>5</td>
<td>Landfill Offices</td>
<td>Industrial</td>
<td>278.60</td>
</tr>
<tr>
<td>6</td>
<td>Peagham Barton</td>
<td>Residential</td>
<td>27.64</td>
</tr>
</tbody>
</table>

Pollution isopleths for 2004, showing the spatial variation of the highest 1-hour average for fungi and the highest 8-hour average for total bacteria are presented in Figures 4 and 5 respectively. This year was considered to be representative of the dispersion patterns for all years, due to all years modelled showing similar dispersion patterns.

The results show that the concentrations of these pollutants reach very low levels within a very short distance from the installation boundary. The compliance criterion of 1000 cfu/m³ for both total bacteria and fungi would be achieved at all of the identified sensitive receptor locations.

It should be noted that compliance with the relevant criteria was achieved despite the conservative compliance criteria utilised for the assessment.
5 Summary & Conclusions

RPS Planning and Development has been instructed by Pell Frischmann Consulting Engineers Limited to undertake a site specific assessment of airborne emissions from an in-vessel composting facility proposed to be constructed at the Deep Moor Landfill site.

The report described and evaluated the odour and bioaerosol impacts of the proposed facility.

The assessment has involved the use of an air dispersion model (AERMOD version 5.1.5), which is approved by the Environment Agency, to predict the prevailing odour and bioaerosol situation across the site and the surrounding area caused by emissions from the operational facility.

All site data such as the site layout, flow rate and odour concentration were based on the plant design and description provided by the technology provider, CCS.

Data on the performance of the proposed biofilters has been gathered from a number of pilot studies and in-situ assessments undertaken by the technology provider.

The assessment assumed that flow rates and odour emissions would be at the maximum expected levels.

Modelling output data shows that the 98th percentile hourly odour concentrations are significantly below the nuisance criteria at all sensitive receptors.

The bioaerosol modelling results show that the highest 8-hour and 1-hour average of total bacteria and fungi releases are well below their relevant assessment criteria. These results were achieved even with a number of conservative assumptions such as assuming unaffected viability of the dispersed microorganisms and ignoring potential loss due to deposition. These two factors may significantly reduce the concentration of bioaersols further from the site as proposed by the EA¹.
It can therefore be concluded that potential odour and bioaerosol impact from the proposed composing plant on the surroundings is not anticipated to be of potential significance.
References


8Health & Safety Executive, 2003. Occupational and environmental exposure to bioaerosols from composts and potential health effects- A critical review of published data. Research report 130 prepared by the Composting Association and health and safety laboratory for the HSE.


Literature referenced in the above documents


Rylander R, 1986 Lung diseases caused by organic dusts in the farm environment. American Journal of Industrial Medicine, 10, 221-227


Appendices

Appendix A  Table A  98<sup>th</sup> Percentile 1hour odour concentrations OU/m<sup>3</sup> (2002, 2003 & 2004)


Appendix C  Table C  1st highest 1-hour average – Fungi (2002, 2003 & 2004)

Appendix D  Figure 3 – Odour (1hr, 98<sup>th</sup> %ile) (2004)

Appendix E  Figure 4 – Total Bacteria (8hr, 1<sup>st</sup> Highest) (2004)

Appendix F  Figure 5 – Fungi (1hr, 1<sup>st</sup> Highest) (2004)
## Appendix A

### Table A - 98th Percentile Hourly Odour Concentration OU/m³

<table>
<thead>
<tr>
<th>Ref</th>
<th>Receptor</th>
<th>Exposure Type</th>
<th>Odour (OU.m⁻³)</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Belle Vue Lodge</td>
<td>Residential</td>
<td></td>
<td>0.15</td>
<td>0.15</td>
<td>0.19</td>
</tr>
<tr>
<td>2</td>
<td>Ward Farm</td>
<td>Residential</td>
<td></td>
<td>0.16</td>
<td>0.11</td>
<td>0.15</td>
</tr>
<tr>
<td>3</td>
<td>High Bullen</td>
<td>Residential</td>
<td></td>
<td>0.13</td>
<td>0.08</td>
<td>0.18</td>
</tr>
<tr>
<td>4</td>
<td>Recycling Centre</td>
<td>Industrial</td>
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<td>1.05</td>
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<td>1.23</td>
</tr>
<tr>
<td>5</td>
<td>Landfill Offices</td>
<td>Industrial</td>
<td></td>
<td>2.16</td>
<td>1.67</td>
<td>2.26</td>
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<tr>
<td>6</td>
<td>Peagham Barton</td>
<td>Residential</td>
<td></td>
<td>0.07</td>
<td>0.08</td>
<td>0.08</td>
</tr>
</tbody>
</table>
### Appendix B

**Table B - The 1st highest 8-hour average – Total Bacteria**

<table>
<thead>
<tr>
<th>Ref</th>
<th>Receptor</th>
<th>Exposure Type</th>
<th>Bacteria (cfu.m⁻³)</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Belle Vue Lodge</td>
<td>Residential</td>
<td>4.34</td>
<td>4.05</td>
<td>4.24</td>
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</tr>
<tr>
<td>2</td>
<td>Ward Farm</td>
<td>Residential</td>
<td>4.37</td>
<td>10.16</td>
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<td></td>
</tr>
<tr>
<td>3</td>
<td>High Bullen</td>
<td>Residential</td>
<td>6.08</td>
<td>8.21</td>
<td>7.36</td>
<td></td>
</tr>
<tr>
<td>4</td>
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<td>Industrial</td>
<td>49.52</td>
<td>43.40</td>
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</tr>
<tr>
<td>5</td>
<td>Landfill Offices</td>
<td>Industrial</td>
<td>62.94</td>
<td>60.28</td>
<td>90.03</td>
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</tr>
<tr>
<td>6</td>
<td>Peagham Barton</td>
<td>Residential</td>
<td>5.59</td>
<td>5.70</td>
<td>3.95</td>
<td></td>
</tr>
</tbody>
</table>
## Appendix C

**Table C - The 1st highest 1-hour average – Fungi**

<table>
<thead>
<tr>
<th>Ref</th>
<th>Receptor</th>
<th>Exposure Type</th>
<th>Fungi (cfu.m⁻³)</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Belle Vue Lodge</td>
<td>Residential</td>
<td></td>
<td>12.49</td>
<td>14.34</td>
<td>15.40</td>
</tr>
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<td>2</td>
<td>Ward Farm</td>
<td>Residential</td>
<td></td>
<td>21.29</td>
<td>31.34</td>
<td>23.86</td>
</tr>
<tr>
<td>3</td>
<td>High Bullen</td>
<td>Residential</td>
<td></td>
<td>42.57</td>
<td>36.23</td>
<td>39.71</td>
</tr>
<tr>
<td>4</td>
<td>Recycling Centre</td>
<td>Industrial</td>
<td></td>
<td>218.69</td>
<td>198.81</td>
<td>167.76</td>
</tr>
<tr>
<td>5</td>
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Appendix D  Figure 3 – Odour (1hr, 98th %ile) (2004)
Figure 4 – Total Bacteria (8hr, 1st Highest) (2004)
Appendix F  Figure 5 – Fungi (1hr, 1st Highest) (2004)