An industry guide for the prevention and control of odours at biowaste processing facilities

The Composting Association

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An industry guide for the prevention and control of odours at biowaste processing facilities

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Environment Agency

Disclaimer – Adherence to the recommendations within this industry guide does not imply endorsement by the Composting Association; neither does it necessarily ensure compliance with the appropriate odour management legislation. It is strongly recommended that this industry guide be read in conjunction with the appropriate publications and that the Environment Agency is contacted for further advice.

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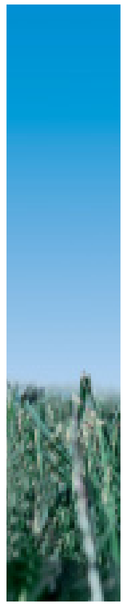
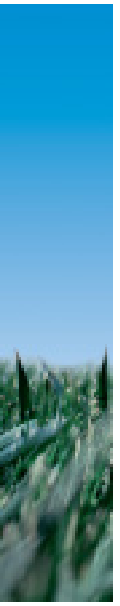
PREFACE

Odour is one of the most common, immediate and potentially damaging emissions at composting sites. It should not come as a surprise that it is also one of the most widespread sources of public complaint about their environment. Odour is also well represented in concerns raised during public consultation exercises and may be a determining factor in planning applications, permit determinations and even prosecutions.

There will always be the potential for odorous releases at composting sites. As such, site operators will need to instil confidence with both neighbours and the relevant regulatory authorities that sites can be managed without causing unacceptable levels of odour. Any failure of individual sites to realise this important standard reflects badly on the industry as a whole and can make communities understandably reluctant to accept new sites in their neighbourhoods.

In order to manage odour effectively, knowledge of what odour is, how individual people react to it and how it can be measured is essential. This industry guide will not consider each and every one of the many variations on composting, but it will highlight the main issues and suggest appropriate strategies. It will be the responsibility of site operators to assess individual circumstances and consider how best to take advantage of the opportunities for odour prevention and control which exist.





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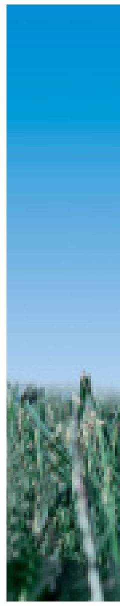
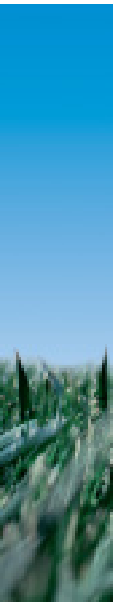




PART 1

ODOURS AND THEIR CONTEXT

1 INTRODUCTION

Biowaste processing facilities within the UK are growing both in number, and in many cases, size. The recent survey carried out by The Composting Association in 2006[1] showed a 35% increase in the amount of biodegradable material treated at composting facilities within the UK. In 2006 in excess of three million tonnes of biodegradable waste will have been treated in composting facilities in the UK.

1.1 The role of this guide

There is a considerable need to encourage additional biological waste treatment facilities within the UK to assist in meeting its obligations for diverting biodegradable municipal waste from landfill under the Landfill Directive[2]. One of the most commonly cited reasons quoted for failure to achieve planning permission to build new processing facilities, or even expand existing facilities, is that of the perceived and real issues surrounding odour generation. A failure by industry to address adequately this issue will have a significant detrimental effect on its expansion and development. Compliance with statutory legislation cannot be ignored and this industry guide will assist industry to meet its obligations and deal with problems should they arise.

The aim of this guide is to provide a readily available document that can be accessed freely by all stakeholders. As a companion to The Composting Industry Code of Practice[3] this document will provide practical guidance on ways of minimising the generation of odorous chemicals, controlling emissions of these chemicals, and managing the impact of emissions on the environment.

1.2 Who it applies to

The primary audience for this industry guide will be composting site operators, including both licensed and exempt sites. This document will help these operators to carry out their composting processes in a manner that minimises odour generation, release and subsequent annoyance. Regulatory officers, local environmental health practitioners, planning officers and the general public will also find this information valuable.

1.3 The status of this guide

The Composting Association has published this guide for information purposes only. Its production has been sponsored by the Environment Agency, but is not endorsed by them and does not carry any formal legal status. The Composting Association will continue to update this guide in response to new technical developments and policy changes as they occur. The ultimate objective of this document is to provide information that is practical, credible and influential with the regulators, the wider biowaste treatment industry and the general public.

1.4 The type of sites it applies to

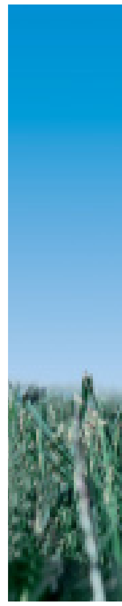
This guide applies to aerobic composting facilities of all sizes where biological treatment takes place. This includes fully licensed and licence-exempt sites, whether they are small-scale on-farm, community or large-scale centralised operations. Anaerobic composting activities are not covered at this time.

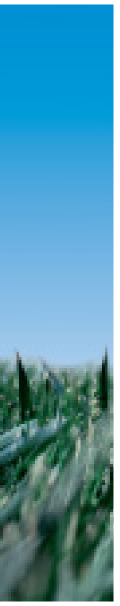
This guide also addresses odour issues resulting from the composting of animal by-products or catering waste, where part of the process involves treating and managing feedstocks within an 'enclosed' (in-vessel) facility. These facilities often have significant containment where emission controls are part of the initial treatment technology. At the other end of the spectrum there will be open-air turned-windrow facilities, which are handling a variety of feedstocks processed and stored outside with minimal emission containment.

This guide is primarily written for the consideration of composting source segregated biowastes but it can also be applied to the mechanical and biological treatment (MBT) of mixed wastes that may require shorter processing times.

Sites at which this guide may be applicable:
- Centralised licensed composting
- On-farm licensed and exempt
- In-vessel composting open-air windrow composting
- Mechanical and biological treatment

[1] *Boulos S, Pocock R & Gilbert E.J* ***The State of Composting and Biological Waste Treatment in the UK 2004/05*** *The Composting Association (2006) ISBN 0-9547797-3-8*
[2] *The EU Landfill Directive (EC/31/99)*
[3] *Duckworth G* ***The Composting Industry Code of Practice*** *The Composting Association (2005) ISBN 0-9547797-2-X*





2 THE LEGAL FRAMEWORK

Odours arising from composting sites are regulated under a number of laws. This section aims to outline which legislation is relevant and give a brief description of their requirements. The references given should be used for a more thorough or authoritative description.

2.1 Waste management

2.1.1 Environmental Protection Act

Section 33(1) (c) of the Environmental Protection Act 1990 makes it an offence to manage waste in a manner likely to cause harm to human health or the environment, including offence to the senses. As with statutory nuisance, this does not apply to sites that are regulated under the Pollution Prevention and Control Regulations (see below).

2.1.2 Pollution Prevention and Control Regulations

The Pollution Prevention and Control (PPC) Regulations 2000 (as amended) primarily apply to large and complex composting operations, such as MBT facilities. These sites operate under a permit which requires the operator to use best available techniques (BAT) for the control of odours. In England and Wales the Environment Agency has issued draft PPC guidance H4

2.1.3 Waste Management Licensing Regulations

Under the Waste Management Licensing Regulations 1994 (as amended), any composting site that processes controlled waste, and is not regulated under PPC or cannot qualify for an exemption, must be granted a licence from the waste regulator[4] before they can begin operations. That licence will include specific odour conditions. In England and Wales there are currently two types of licence:

A fixed licence, in which the following general condition is currently being applied: *'Emissions from the activities shall be free from odour at levels likely to cause annoyance outside the site, as perceived by an authorised officer of the Agency, unless the licence holder has used appropriate measures to prevent or where that is not practicable, to minimise, the odour.'*

If an operator cannot comply with any of the fixed licence conditions, or meet any one of the fixed licence criteria (e.g. 250 metres from receptors), then they must apply for a bespoke licence. Further information can be found on the Environment Agency's web site.

2.1.4 Licence exemptions

Under a provision in the Waste Management Licensing (WML) Regulations, specific listed lower risk activities can be undertaken without a licence if the activity is registered with the waste regulator. Exemption 12 currently allows for the composting of limited amounts of biodegradable wastes without the payment of a fee[5]. Numerous restrictions apply, including the objective of 'not causing nuisance through noise or odours'.

2.1.5 Environmental Permitting Programme

Significant changes to the way waste management activities are regulated in England and Wales are proposed to come into effect in 2008 through the Environmental Permitting Programme. The proposed Environmental Permitting Regulations aim to provide a single permitting regime to replace both the PPC and WML regulations, while still implementing relevant European directives such as Integrated Pollution Prevention and Control (IPPC) and the Waste Framework Directive (2006). While it is a stated intention of this programme to avoid changing any environmental standards, it remains to be seen how this will be achieved. Regulations are expected to be laid before Parliament in the autumn of 2007 with a view to bringing them into force in April 2008.

2.2 Statutory nuisance

Under Section 79 of the Environmental Protection Act 1990, local authorities have a duty to take reasonably practicable steps to investigate complaints of various nuisances, including 'any dust, steam, smell or other effluvia arising on industrial, trade or business premises and being prejudicial to health or a nuisance'.

If the local authority is satisfied that the problem amounts to a statutory nuisance they are obliged to serve an abatement notice. This may require the activity causing the nuisance to stop altogether, or that good practice is adopted to prevent a nuisance. Those upon whom an abatement notice has been served have the right of appeal within twenty-one days of it being served. Industrial, trade and business premises may use as a defence upon appeal or prosecution for non-compliance, proof that 'best practicable means' were used to prevent or counteract the effects of a nuisance.

PPC permitted sites are not subject to statutory nuisance provisions.

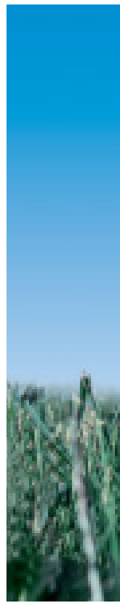
2.3 Planning permission

Composting sites that receive waste from third parties must have planning permission, as the deposit of waste material on land involves a material change of use and is therefore classed as 'development'. Composting site operators should, however, check with their local planning authority whether planning consent is necessary, as in a few cases it is known that some authorities have decided that small-scale, exempt operations do not involve a 'material' change of use of farmland.

During the processing of a planning application the local planning authority will consult various parties, including the local environmental health department and the regulator. At this stage it is likely that the response will include a recommendation to include certain conditions on the granting of a planning permission. It is usual that such conditions impose restrictions on operations to ensure the control of odours, dust, noise and bioaerosols.

For a small-scale proposal that is likely to be operated under a licence exemption, it is more likely to find a detailed odour control condition, but for larger operations that will need a Waste Management Licence, the planning authority is likely to rely on the controls in the conditions of the licence.

In the event that operations take place that do not comply with the restrictions imposed by condition, the local planning authority has the power to serve a Breach of Condition Notice, and in extreme circumstances, a temporary (28-day) Stop Notice. In the event that these notices are not complied with, the council can then take the offender to the magistrates' court, where fines can be imposed.



[4] *In England and Wales this is the Environment Agency, in Scotland it is the Scottish Environment Protection Agency, and in Northern Ireland it is the Environment and Heritage service*

[5] *Detailed guidance on this exemption is available from the Environment Agency web site: http://www.environment-agency.gov.uk/subjects/waste/1416460/1334460/1416503/1097663/?lang=_e*

3 WHAT IS ODOUR?

3.1 Odour recognition

Odour is the perception of certain chemicals within the olfactory area of the sinuses. In order to be perceived in this way a chemical must meet with three criteria:

1) Be released into the air
2) Dissolve in the olfactory mucus (mostly water) and
3) There must be a receptor nerve cell available that can detect it

While these requirements might seem pretty exclusive, the extreme sensitivity of receptors in the nose to many chemicals means that only a very small quantity needs to be taken in.

The olfactory sinus area contains about 350 different types of receptor cells. Three different receptor types are shown schematically in Figure 1. An individual odorous chemical might only trigger one or two of the most sensitive receptor cell types at very low concentrations, while it may stimulate a wider range of receptors as the concentration increases. Individual receptor types are not uniquely sensitive to specific chemicals but some chemicals will stimulate them strongly while others stimulate them moderately or not at all. The pattern of receptor nerve responses is processed in a small organ at the base of the brain known as the olfactory bulb, which then relays messages to the brain.

The way in which odorous chemicals are recognised can be described by imagining a piano keyboard with 350 keys (instead of the normal 88), each of which represent a different receptor cell type. There is therefore the potential for a large number of different odour 'chord combinations', which could be 'played' by individual chemicals or mixtures. The result is our ability to distinguish between thousands of different smell combinations.

Odour
A volatile substance or mixture of volatile substances that are perceived through a person's sense of smell
Malodour
An odour that is deemed by an individual to be unpleasant and offensive in its nature.

3.2 Odour characterisation and perception

There is general agreement that rotting carcasses have a foul smell while roses are much more pleasant. The generally agreed degree of pleasantness or unpleasantness of an odour is referred to as its hedonic tone. Numerical scores within hedonic tone tables can be fairly arbitrary, but represent a helpful hierarchy of pleasantness, which is generally agreed across a surveyed population (examples are shown in Table1.). This agreed hierarchy represents inherited attractions or aversions, as well as group cultural odour preferences that are learned. However, individuals may make their own personal associations with an odour that are either positive or negative. These associations may involve strongly negative responses to specific odours, irrespective of hedonic tone, or even positive reactions to odours that most people would find highly offensive.

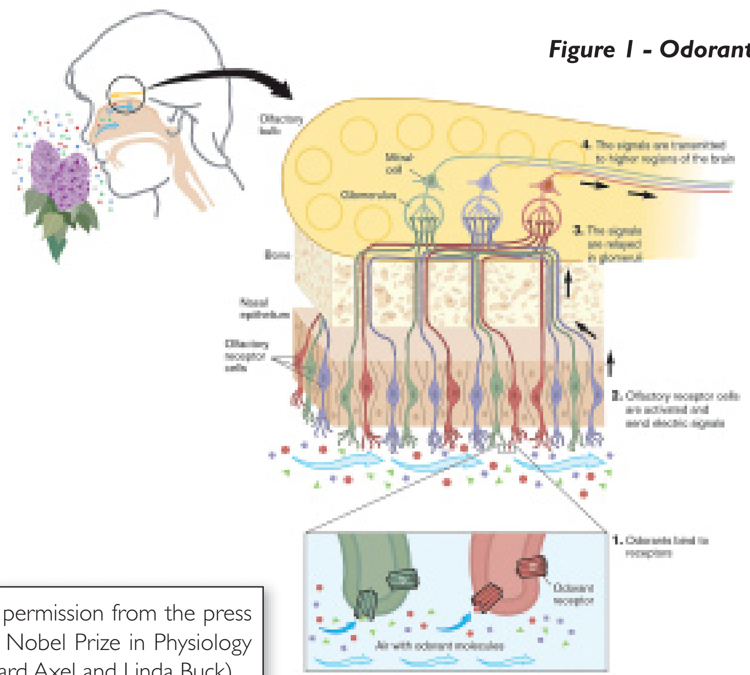


Figure 1 - Odorant receptors and organisation of the olfactory system

Reproduced with permission from the press release: The 2004 Nobel Prize in Physiology or Medicine (Richard Axel and Linda Buck)

Both generally agreed and individual hedonic tones are important because they convey meaning at a very basic level in our minds. For example, it is good that most of us have an aversion to rotting food because that helps us to avoid eating it and becoming sick. However, these negative associations or aversions can cause unpleasant and damaging experiences when it is impossible or inappropriate to avoid the source of the odour.

Table 1 Pleasant and unpleasant odour descriptors relating to hedonic score[6]

Description	Hedonic score*
Bakery (fresh bread)	3.53
Cherry	2.55
Coffee	2.33
Leather	1.30
Mushroom	0.52
Alcohol	-0.47
Wet paper	-0.94
Oily, fatty	-1.41
Fishy	-1.98
Cadaverous (dead animal)	-3.75

** The higher the positive score, the more pleasant the odour and similarly the greater the negative figure, the more unpleasant the odour.*

The processing of olfactory signals is complex and not completely understood but nevertheless quite a lot is known about the process of odour perception. The olfactory bulb is connected directly to the hippocampus and amygdala areas of the brain, which form part of the limbic system. This connection bypasses the thalamus, which acts as a relay for all of the other senses. These parts of the brain are responsible for emotion and the formation of memories. This may explain why people reacting to odours are often emotional and may describe odours in terms of their own personal experiences. The close association between odour, emotion and memory may also help to explain why some individuals who have had a particularly bad odour experience on one occasion, may subsequently give a vigorous response to the same odour at much reduced concentrations.

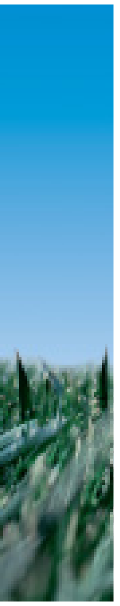
For the purposes of this industry guide it is important to appreciate that emotional responses to odours are entirely normal. This effect may be compounded if the odours are associated with unpleasant situations experienced by the individual on previous occasions. For this reason, some individuals who complain most adamantly about odours frequently cite concerns about adverse health impacts. General dissatisfaction with their health can also predispose people to be more annoyed by unwanted odours, perhaps because they feel more threatened by what the odours represent. It should be noted that odours emitted at biowaste processing facilities have not been linked to any adverse health effects in neighbouring populations.

3.3 Adapting to odours

The piano analogy introduced earlier can also help to illustrate the concept of 'olfactory adaptation'. When a piano key is struck, a note is played. If this key is held down, then the note fades until the piano gradually goes silent. In a similar way, a person who is exposed to an odorous chemical may initially be very aware of the smell, but that awareness may quickly fade unless the concentration is increased. If the odour is temporarily removed and then brought back (as when a piano key is released and then struck again) the odour tends to become more noticeable again. The time required to recover from this type of adaptation is typically proportionate to both the intensity and duration of exposure.

Individuals, who work in immediate proximity to odour sources, particularly when those workplaces are indoors, will become less aware of the odour as adaptation progresses. Unfortunately, any offsite receptors (people), particularly those who are outdoors, will experience a constantly changing concentration because of dispersion patterns in the air. They will not tend to experience adaptation to the same degree because the variable experience of odorant chemical

[6] *The Environment Agency, Internal guidance for the regulation of odour at waste management facilities, version 3.0 (2002)*



concentrations is more like repeatedly striking and then releasing a piano key.

Workers who are exposed to relatively high concentrations of odorous chemicals for extended periods of time will typically experience long-term adaptation which is specific to those odours. Using the piano analogy, it would be as if the keys relating to a specific chord were worn out due to excessive use. The rest of the piano would work fine but that one chord could not be played. This is because the body stops producing odour receptors which are heavily stimulated over a period of time. Full recovery from long-term adaptation typically requires 30 to 40 days without exposure to the odour.

It is important that composting site operators understand both long and short-term adaptation because it can help to explain why offsite residents find odours annoying while staff on-site don't find them particularly strong. It is also important to keep this type of adaptation in mind when selecting individuals to investigate odours in the community or even at the site boundary. Staff who work on-site may be uniquely unqualified to assess these particular odours in the community because they will normally experience both short and long-term adaptation.

3.4 Why odours are formed during composting

Odorous chemicals from composting sites generally arise from three different sources or processes. By developing a good understanding of these processes as they apply to a composting site, odours can be more effectively managed.

1) **Odours present in fresh feedstock materials:** Most feedstock materials naturally contain odorous chemical components such as limonene from citrus fruits or pinene from woody materials. Most of these chemicals are not considered to be particularly offensive and may be pleasant in the proper context. However, when mixed together and exposed to people who don't particularly want to smell them, the result can be offensive. Similarly, when wholesome food smells (e.g. citrus) are mixed with odours associated with putrefaction, the result is a rotten food smell.

2) **Odours produced through the normal breakdown process:** The early stages of composting necessarily involve the breakdown of larger molecules, such as fats, carbohydrates and proteins, into smaller molecules, which are then used as a food source for the composting micro-organisms. This doesn't happen directly; rather they are converted into a series of intermediate breakdown products, many of which are intrinsically odorous. Odorous compounds produced include amines, fatty acids, hydrogen sulphide, ammonia and dimethyl disulphide (DMDS). Each of these compounds will have a specific odour characteristic, some being more intense than others. For example, fish normally contain a sort of antifreeze chemical called trimethylamine N-oxide, which is odourless. However, when it is initially broken down by bacteria, trimethylaminuria is produced, which results in the familiar 'fishy' odour.

3) **Odours produced through anaerobic conditions:** When bacteria and fungi break down raw materials in compost they need an oxidising agent, oxygen (i.e. they need to breathe), and the primary product is carbon dioxide, which is odourless. When oxygen is in short supply or absent, some of the composting micro-organisms either adapt their metabolism (the facultative anaerobes), or shut down altogether and true anaerobes, which were hitherto dormant, will then become active. Anaerobic metabolism differs from aerobic metabolism, as a range of substances is used instead of oxygen. This therefore results in different by-products being released, which depend on the type of feedstock, the degree to which oxygen is available, and the bacteria involved. Unfortunately many of these substances are odorous. Often anaerobic metabolism will release fatty acids, many of which are volatile. For example, butyric acid has the well-known putrid 'sweaty feet' odour, whilst acetic acid has a sour vinegar smell. Sulphur-containing compounds, in particular, are recognised as being a particular cause of malodours at biowaste processing facilities: hydrogen sulphide produces the well-known smell of rotten eggs, whilst and methyl mercaptan smells of skunk.

Fortunately, most odours from all three sources can be fairly rapidly broken down by active aerobic bacteria. By understanding how these three processes apply to a site, an operator will be better able to manage the production, containment and breakdown of odorous chemicals. This is discussed in Part II of this guide.

4 MONITORING AND MEASURING ODOURS

4.1 Monitoring emissions

Monitoring is the process of observing changes that may occur over time. It should form part of a site's standard operating procedures (working plan) in order to assess:

- The effectiveness of operational practices to prevent and contain odours, and
- The nature and extent of a problem should it arise

In general there are two main types of emissions: point and area sources. Emissions from a biowaste facility will usually be from area sources such as the storage area used for the reception of feedstock and windrows. There will however be some point emissions from biofilters and overpressure ports on in-vessel plants. An operating windrow turner would be classified as a moving point source.

The source type will, in part, determine the method used to measure odours. For example, where odorous emissions exit a containment system through a specific point or points (e.g. a stack), then the odour concentration can be sampled and measured by dynamic olfactometry in the laboratory should it be necessary. However, the concentrations of odorous substances in ambient air (away from the immediate area where they are being released) are normally too low to make useful measurements using dynamic olfactometry. Therefore, the most useful assessments are normally made in the field.

In some instances more detailed chemical analysis of odorous emissions can provide useful information on the character of an odour, help to validate odour concentration measurements and give important clues on what is causing the odours to be generated in the first place.

These techniques are described below.

4.2 Measurement techniques

In order to monitor odours effectively one or more different techniques may need to be employed to measure composition and concentration. Generally speaking there are four recognised methods for measuring odours. Each method should be used as appropriate under the particular conditions prevalent, as each has associated advantages and disadvantages.

4.2.1 Field assessment

The use of an appointed person is required to walk around the perimeter of the site and note down what odours they detect (expressed as presence/absence, character and intensity), along with prevailing weather conditions[7].

This method provides a rudimentary overview of odours at the boundary of the site and is suitable for daily monitoring purposes as it is simple and cheap to carry out. Assessments of this sort are often used to make a judgement about the annoyance potential for a particular odour exposure.

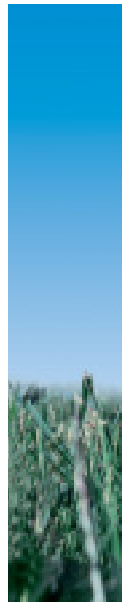
This method will have poor sensitivity if carried out by a person who has become 'adapted' to on-site odours, as described previously. Also, in the event of a complaint being received about odour emissions at a biowaste processing facility the waste regulator or local authority officer investigating odour complaints may be unable to validate complaints using this techniques due to the inherent high variability in releases and dispersion patterns. Even in situations where odours can be detected, intensity is particularly difficult to assess because of adaptation and the individual sensitivity of the investigator.

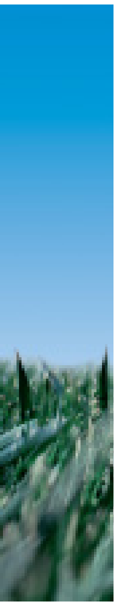
Defra are producing more formal guidance on how to best undertake these field assessments.

4.2.2 Dynamic dilution olfactometry

This is a more precise method of measuring odours that involves a standardised method using a 'sniff panel' in a laboratory. Odorous air is collected in sealed bags made from a special polymer that has, in itself, no intrinsic smell and does not bind to any volatile substance. These bags are filled using either a pump or by placing the bag in a chamber under negative pressure. The bags are then taken back to the laboratory for analysis.

[7] *For further information see: Internal Guidance for the Regulation of Odour at Waste Management Facilities July 2002 VERSION 3.0. Environment Agency*





A minimum of four panellists sniff the odorous air which is diluted with odour-free air and then comment upon the smell. The panellists must be carefully selected based upon their ability to smell a reference chemical (n-butanol), and must meet certain criteria, such as not having a cold or wearing perfume. The strength of the odorous gas is then expressed in 'dilutions to threshold' (DTT). The threshold level is defined as that at which the diluted odour is only detectable by 50% of the population. Odour measurements using dynamic olfactometry is described in the British Standard BS EN 13725:2003[8]

This method is expensive and time consuming to carry out (as it relies upon the services of a number of people and use of specialist equipment) and does not yield immediate results. The method is not suitable for ambient air monitoring.

4.2.3 Non-specific electrochemical detector arrays (electronic noses)

Multiple electrochemical sensors can be used to recognise patterns resulting from exposure to volatile chemicals. Unfortunately, these detectors may respond to both odorous and non-odorous chemicals so interpretation of results is very difficult. Nevertheless, they are becoming more affordable, can provide continuous monitoring and can provide useful process control information in some situations.

4.2.4 Measuring specific chemicals

There are a number of methods that can be used to measure the concentrations of specific chemicals. These have been developed principally for occupational exposure assessments; however, for composting processes, ambient monitoring of specific chemicals is seldom a useful exercise. This is primarily because the range of odorous chemicals is potentially wide and odour thresholds are often extremely low. Exceptions to this may be situations where a site has a specific problem which results in large releases of chemicals such as ammonia, acetic acid or hydrogen sulphide. In these cases, careful planning is essential to ensure that any monitoring will be both useful and cost effective.

[8] *BS EN 13725:2003 Air Quality.* ***Determination of Odour Concentration by Dynamic Olfactometry***

4.3 Modelling odour exposure

Models, such as the United States Environmental Protection Agency's AERMOD PRIME dispersion model, are often used to either estimate the impact of proposed emissions on local communities or to explore the relative benefits of various odour minimisation options. They have also been used to investigate causes of odour nuisance/annoyance.

Predictions are normally expressed as 98th percentiles of hourly average concentrations over a year unless the chemical compounds causing the odour nuisance/annoyance are known. A contour line of 98th percentile concentrations for three odour units means that out of all of the hours in a year (8,760 hours), the average concentration for 98% of those hours will be below three odour units (three dilutions to the average detection threshold). For 2% of the hours (175 hours), the average hourly concentration will be three odour units or above. The outputs from odour modelling are typically represented as an OS map overlaid with contour lines of percentile concentrations, similar to the topographic lines on an OS map showing hills and valleys. One should note the uncertainties in the predicted contours when interpreting such maps.

The Environment Agency has published exposure guideline values that may be used to suggest that the predicted levels of odour exposure will not pose a serious detriment to the local community. However, comparison of modelled exposure levels with exposure guideline values requires careful consideration of the uncertainty of the results. The main source of uncertainty in model predictions is the emission source terms.

a) Difficulty of obtaining reliable and representative estimates of emissions

The reliability of modelled exposure assessments can only be as good as the emissions data on which they are based. In the case of open-air composting sites, obtaining reliable odour emissions data can be particularly difficult. Odour concentrations can be sampled from flux boxes on the surface of outdoor compost windrows, followed by laboratory dilution analysis. Both of these steps will inherently introduce a degree of uncertainty in the results. However, difficulties in obtaining representative samples of surface emissions that are inconsistent across the surface of a windrow can vastly exceed any uncertainty due to the laboratory analysis. Furthermore, emissions may change from day to day or even minute to minute as conditions change.

When dealing with in-vessel composting sites, sampling uncertainties may be much more under control because they often have an emissions stack, or at least the surface of a biofilter which can be representatively sampled. Of course these emissions measurements will only be useful for exposure modelling purposes if fugitive odorous emissions from the site are under control to the degree where their relative contribution is low. Also, odorous emissions from the release point will either need to be consistent or the pattern of emissions well characterised.

There are also practical difficulties in obtaining representative estimates of spatially and time varying emission rates for use in dispersion modelling.

b) Source attributions

The problem of obtaining reliable estimates for emission rates becomes more severe in the investigation of odour complaints. This is because one needs to consider source attribution when there is more than one possible source of odour emissions.

Besides the aforementioned main source of uncertainty, other sources of uncertainty in model prediction (e.g. model representation, meteorological data) need to be considered in the interpretation of model results. Hence, the results of an odour exposure modelling exercise are best used as a general indicator rather than a pass/fail assessment.

There are large uncertainties in the predicted concentrations of odorous compounds. However, such model uncertainties do not present a significant hurdle in the interpretation of modelling outputs when the modelling technique is used to assess the relative merits of various odour control measures. By running a model once with expected emissions from a site without controls and again with a specific emissions control strategy in place, the cost effectiveness of a wide range of odour control options can be evaluated very cheaply.

4.4 Community exposure and annoyance

When considering assessment methods which focus on the community, it can be difficult to discern the extent to which these are complaints. Reports from the community on odour exposure and annoyance are often the most important indicators of odour problems. For a range of reasons it is not possible to establish numerical standards for the number of odour complaints that are considered unacceptable, but these reports should never be ignored or disregarded.

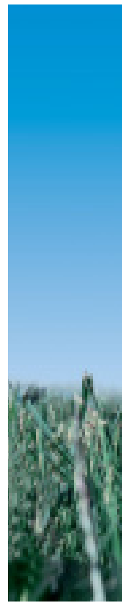
Site operators often express concern about the number of unjustified odour complaints that might be motivated by other reasons (e.g. a forthcoming property sale). However, it is much more common for annoyed individuals not to raise complaints. Reasons for this might include not knowing who to contact, not believing any effective action will be taken, or concern that they might be ridiculed. Some individuals, such as those in institutions, the elderly or children may not have access to any means of making their concerns known. In order to obtain credible data, the barriers to receiving complaints must be assessed and lowered whenever possible.

Odour complaint data are frequently incomplete because it is divided between those complaints that are made to the waste regulator, to the local authority or directly to the operator. This division of complaints will vary considerably from site to site but no record can be considered complete unless the operator has accounted for all of these reporting routes. The subject of minimising annoyance is dealt with in more detail later in this guide.

4.4.1 Odour diaries

Where members of the community are frequently reporting odours, it may be useful to provide them with diaries and ask them to record details of when they experience odours. This values the role of individuals within the community who are willing to help and can provide valuable insight into the conditions which result in community odour exposure. This data can then be more closely correlated with meteorological data and site activities than is often possible with complaint data.

Odour diaries are most effectively used as a short term



monitoring approach while problems are occurring. Participants in this scheme may quickly lose enthusiasm for it, either because odour is no longer a problem or because their efforts to feed back their odour experiences are having no beneficial effect.

4.4.2 Community surveys

Surveying a community on their experience of odours and annoyance may provide useful insight across a wider range of residents. However, a number of factors can influence the results of such a survey and should be considered at both the planning and interpretation stages.

- What is the context of the survey? (e.g. is there a planning hearing coming up?)
- Are there aggravating factors which could increase the level of nuisance? (e.g. noise, traffic, operator reputation within the community)
- What are the demographics of the community which might bias the results up or down?
- Is the purpose of the survey disguised or open?
- What medium should be used for the community survey? (door-to-door, postal, internet)

Community surveys must be carefully crafted to avoid guiding or biasing the comments of people being surveyed. Memories can fade so it is important to consider how far back the survey is asking respondents to recall. Frequent surveying is expensive and can cause people to be less willing to participate.

PART II

SITE MANAGEMENT AND GOOD PRACTICE

5 INTRODUCTION

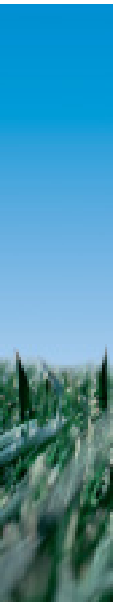
Good practice involves recognising and taking advantage of all of the opportunities for odour management that readily present themselves. By systematically considering the complete chain of events at a site, from odour generation to annoyance, a site operator is more likely to recognise the full range of inexpensive and convenient options available. At rural green waste sites, for example, these measures alone may be enough to avoid annoying neighbours. Where they are not, a systematic approach will also help identify the most cost effective combination of additional measures and avoid expensive options which provide only limited benefit.

The steps outlined in Table 2 provide a helpful framework for this assessment. Not all of these steps offer the same level of opportunities for odour management. For example, a great deal can be done to minimise the quantities of odorous chemicals formed on site or to minimise their release, whereas little can be done about dispersion. Even so, relatively ineffective measures to enhance dispersion (e.g. planting a row of trees) may still be worth doing if the cost is sufficiently low. It is also strongly advised that operators focus their odour management efforts at the earliest possible stages as these tend to be much more reliable and cost effective. Individual odour control techniques may address more than one of the steps in Table 2 at the same time.

Table 2 Conceptual model for minimising annoyance

SOURCES	**Formation:** The way processes are managed can encourage the breakdown of odorous chemicals or generate more. **Transfer to air:** If odorous chemicals can be kept in a liquid or solid state they will not be released. **Release to atmosphere:** Containment and scrubbing are often necessary to reduce odour emissions. This option can be very expensive
PATHWAYS	**Dispersion:** The movement and dilution in ambient air is a natural phenomenon. It is only possible to influence this in a limited way. The action of wind and the topography of the surrounding area will have the greatest influence. **Exposure of individuals:** Short of asking people to leave the area or to stay indoors with windows closed, there is little which can be done to modify exposure. However like dispersion, be aware of influencing factors such as patterns of exposure.
RECEPTORS	**Perception:** Intervention at this stage is generally inappropriate as containment is that much harder to achieve. Nevertheless, understanding perception is one of the key factors in the effective management of odours. **Adding a meaning:** Natural gas is deliberately odorised and customers are encouraged to take action if they smell it because it means danger. Most odours, however, do not represent a hazard in the same way and credible information about the source can help to reduce anxiety. **Personal coping strategies:** Some individuals will cope with the stress of odours by trying to remove the odour (e.g. complaints), and tend to become annoyed at lower levels of exposure. Others will seek to modify their own emotional response, and be less sensitive to annoyance. Personal tendencies to react one way or another can be influenced by factors such as economic interest, perception of threat or whether they are working or resting at the time of exposure.
IMPACTS	**Nuisance:** A variety of standards may be used to describe unacceptable levels and patterns of odour exposure. One common approach is to use a combination of 'FIDOL' (frequency, intensity, duration, offensiveness and location) to judge whether exposure is unacceptable. These exposure standards are not clearly defined in legislation and will ultimately need to be ratified or challenged by the courts. **Secondary consequences:** Chronic odour exposure may result in economic and social consequences for an area, such as the potential to devalue nearby property prices.

Composting can be effectively managed such that that odours are minimised and acceptable



Effective odour control is achieved by minimising as many of the links between odour formation and annoyance as possible. By applying a wide range of measures, and not relying entirely on a single approach, odour management can be more effective, robust and inexpensive. The rest of this section will discuss ways site operators might:

- Anticipate odours
- Effectively plan for their management, and
- Control odorous chemicals through the effective use of aerobic microbes

In order to develop an effective approach to odour management it is important for operators, the regulators and the community to have clear and realistic expectations of what can be achieved. Operators may start with high expectations for their odour control technologies, which are not delivered in practice. Unless these expectations are matched with results from an early stage there is potential for conflict. High capital cost is also no guarantee that controls will be effective if important details are overlooked.

5.1 Good practice techniques

There are a number of good management practices that can be used in order to prevent the generation and subsequent release of odours off site. Many of these techniques are complementary and should be viewed as a toolkit to assist the site manager in minimising the generation and release of odorous chemicals.

In practice, it is essential that the direct source of any odours generated be identified as quickly as possible. For example, in reception areas that receive significant input volumes, there may be only a small quantity of waste that is giving off volatile organic compounds. Unless the odour source is clearly identified, its treatment cannot be managed effectively.

There will be times when only a small fraction of the delivered waste is odour generating. Rather than treating all the delivered waste to combat this issue, the offending material can be isolated and dealt with separately. Although the delivery of highly malodorous feedstock is not desirable, in practice it is likely that there will be times when it cannot be avoided. Site operators will need to have suitable contingency plans in place to deal with this (see troubleshooting later in this guide). The quantity and holding times for feedstock stored on site prior to processing will affect the potential for this material to cause offensive odours. The three main tools for effective odour management on a biowaste processing facility are:

* Anticipation
* Effective planning
* Management of the process

The application of these tools will be illustrated in the following sections.

5.2 Partnerships with feedstock suppliers

The content and nature of the feedstock delivered to the processing facility will vary according to the source and the time of year when it is delivered. Many biowaste processing sites will rely on local authorities for a large percentage of their feedstock. This will vary from one site to another, but as local authorities come under increasing pressure to divert biodegradable waste from landfill under the Landfill Directive 1999, an increasing volume of biowaste will be local authority derived.

An element of the partnership between the processor and the local authority will involve contractual agreements. This will cover such items as acceptable inputs, duration of contract, estimated amount to be delivered to the processor, with a minimum and maximum tonnage clause included. Part of the contract will specify the inputs that are not acceptable, including contaminants such as plastic, hardcore and non-biodegradable items. It is recommended that there should be an additional clause inserted which discusses the delivery of 'malodorous' material onto the processing site.

> It is recommended that within any contractual agreement there should be an additional clause inserted which discusses the delivery of 'malodorous' content material onto the processing site.

Contractual agreements are also sometimes cited as a reason for accepting waste when the site is already at full capacity, resulting in operational problems and excessive holding times. These difficulties must be anticipated at the contract negotiation stage in order to avoid being put in the position where choice between fulfilling contractual agreements in the short term or putting the future of the site at risk as a result of permit violations and odour incidents.

It must be within the site manager's power to reject any material that will jeopardise his ability to manage the site and prevent the emission of unacceptable odours. It will be important that such agreements are addressed early on in any contractual agreements and that clearly defined measures are established to prevent confusion or misinterpretation at a later date.

Composting biowastes requires the input of a variety of feedstocks, of which the majority is plant derived. Accordingly, seasonal variations and ambient temperatures play a significant part in determining the quantity and composition of waste processed. It is becoming more common for organic wastes from households to be collected on a bi-weekly basis at the kerbside. Although this assists local authorities in reducing costs associated with their collection, it can create problems for a site operator due to the high content of putrescible waste that may be anywhere up to two weeks old when delivered to site.

> Key questions to ask feedstock suppliers
> - What are the minimum and maximum volumes that will be delivered on site?
> - What is the anticipated uplift in volume likely to be in the spring and autumn?
> - What rejection criteria, including contamination and unacceptably malodorous feedstock, are mutually acceptable?
> - What are the delivery schedules over bank holidays?

5.3 Receiving and storing feedstocks

It is essential that odorous wastes, or those which could become odorous before processing, be immediately identified upon delivery to the site. It may be possible to anticipate these characteristics in many wastes, and this should be documented. If highly odorous waste streams are a small proportion of the overall volume of feedstocks received, it may be appropriate to deal with these materials separately. The holding times of all odorous or potentially odorous wastes must be carefully controlled.

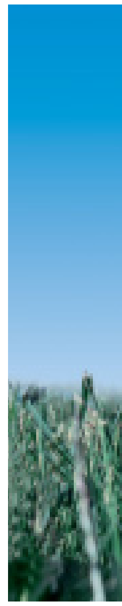
The design of the feedstock reception area should be considered as an integral part of site planning and design. Adequate provision must be made for the acceptance of seasonal peak volumes of delivery such as those occurring during the spring and autumn seasons. In addition space needs to be made available for the storage of amendment material for use in blending feedstocks prior to shredding.

Storage bays constructed out of timber or pre-cast concrete provide an effective solution to keeping several amendment materials. Preferably these should be stored under cover to prevent their deterioration. Most amendment materials will be relatively stable in storage but adequate provision must still be made to prevent excessive deterioration. Deteriorated amendment materials or leachate from these piles can still be a source of odour.

The holding time for feedstock material stored prior to processing is a significant factor in a site's potential for odour generation. Untreated material left decomposing prior to shredding can increase the generation of odours. By aerating some feedstocks prior to processing a site manager may be able to extend holding times for a few days, or even a week or more depending on the nature of the material, (it should be noted that working plans will often dictate the acceptable holding times agreed with the regulator). Pile sizes should be kept relatively small (exact limits will depend upon the feedstock structure and porosity) and carefully monitored for excessive temperature rises. Small green waste sites that rely on contractors for shredding may find this particularly helpful. However, if the feedstocks contain bagged wastes or have poor structure then the air will be unable to reach many parts of the pile, resulting in localised anaerobic conditions which release odours when the pile is moved.

When odorous material is stored for any length of time prior to shredding, covering the pre-shredded pile of feedstock with either woodchip or oversize composted material can make a significant reduction in the release of odorous chemicals from the stockpile.

Bank holidays will often mean that deliveries of feedstock are made a day later than normal and are likely in addition to be of increased volume. In spring and summer when this



additional feedstock comprises significant volumes of grass, particular care should be taken to carry a sufficient stock of amendment material to blend with the feedstock. It is accepted practice to mix wood chip[9] material with incoming feedstock at up to 50% by volume to ensure that porosity is maintained within the feedstock mass. This can be carried out prior to shredding and will maintain the feedstock in an aerobic condition for longer than would otherwise be the case.

Some local authorities now collect green waste in biodegradable bags. This is a perfectly acceptable practice, which is now well established. However once the bags have been opened, their contents may be anaerobic and very malodorous. This sort of material will require immediate blending under containment with amendment material to dilute the odorous characteristics of this feedstock.

5.4 Shredding and blending feedstocks

The action of shredding is essential for most feedstock materials, to reduce the size of the incoming feedstock and allow the addition of water to optimise the moisture content. In addition it will assist in the blending and mixing of the feedstock. This activity increases the surface area of the material, allowing for faster degradation to take place.

Shredding in itself can often give rise to malodours, especially if the feedstock being shredded has stood for some time. This initial phase of composting is the time when highly odorous compounds such as volatile fatty acids (acetic acid, propionic acid) and odorous nitrogen containing chemicals are generated in abundance. Their reduction, treatment and capture needs to be carefully managed to ensure problems do not arise within this critical time frame. Failure to address the issue at an early stage will inevitably lead to problems later, affecting the subsequent management of the composting process.

In practice, a site operator may have only limited control over the characteristics of individual waste streams (e.g. available carbon, nitrogen, size etc). In order to manage these variations, it will often be necessary to blend wastes of different characteristics or amendment materials in order to achieve a good mix for composting. It is therefore essential to manage the feedstock composition in such a way that regardless of the incoming feedstock delivered the correct mix is achieved prior to shredding taking place.

Although there may be an opportunity to blend materials post shredding to create the optimal feedstock mix, this will rarely be carried out in practice as post shredding the feedstock will be either filled directly into an in-vessel container or formed into windrows to commence the active composting phase of the process.

5.5 Optimising feedstock blends

Composting is a dynamic changing process and is dependent on its surrounding environment. Microbial activity that causes decomposition is dependent on temperature, moisture and oxygen to work effectively. The management of this environment is the key to establishing the optimal conditions for reduced odour generation, however, the rate of decomposition will vary according to the feedstock type, which is highly variable in its moisture content and composition when delivered to site. Skilful feedstock formulation and mixing is essential to establish and sustain the conditions necessary to maintain low odour levels. For example, feedstock that is delivered to site over-wet or with an excessive quantity of high nitrogen content material will be more prone to generating unacceptable odours. These are discussed in detail below.

5.5.1 Carbon: nitrogen ratio (C:N)

A normal carbon to nitrogen ratio (C:N ratio) for composting is regarded as being between 25–40:1; feedstock falling outside this ratio will generally require special handling. A balanced C:N ratio is essential for effective composting to take place.

The C:N ratio has a great influence on the speed and efficiency of the composting process. Ratios below 25:1 will require very intensive management (e.g. constant turning) because the composting process will proceed very rapidly, and there will be an excess of nitrogen that can readily form ammonia and other odorous compounds. In these mixtures, the rapid consumption of oxygen and high level of heat released can make temperature control difficult and may result in anaerobic conditions. High nitrogen feedstocks may also tend to be denser and wetter in composition, making the supply of adequate oxygen even more difficult.

[9] It may be necessary to check with the waste regulator as to whether amendment materials are permitted on site as part of its licence or permit.

Conversely, mixes with ratios above 40:1 will tend to compost more slowly. These mixtures may have difficulty achieving thermophilic temperatures and compost maturation could be significantly delayed. This C:N ratio is based on that proportion of the carbon in a material which is readily available for composting. Carbon rich materials such as cellulose (wood) and lignin (straw) will be only partially available for biodegradation.

Both carbon and nitrogen can be measured in the laboratory and appropriate mixtures calculated. However, this process is both expensive and probably unnecessary unless new or novel feedstocks need characterising. Reference tables have been published and examples are shown in Table 4.

Table 4: List of typical C:N ratios for various feedstock types[10]

Material	Average C:N ratio	Possible range
Grass clippings	17	10-25
Leaves	55	40-80
Shrub trimmings	50	30-85
Hardwood chips	560	450-820
Softwood chips	640	212-1300
Newsprint	625	400-850
Corrugated cardboard	560	-
Vegetable waste	12	-
Municipal food waste	15	-

The wide range of target C:N ratios and the variability of feedstocks mean that operator experience and skill, and close monitoring of the composting process are the primary requirements for optimum results. If the process seems to be experiencing problems associated with excessive nitrogen, then amendment with high carbon materials may be necessary. Stores of woodchip and or oversize composted material should be available to amend and blend with feedstocks that are too high in nitrogen. High volumes of waste such as grass or food waste will be wet, dense and high in nitrogen. These materials will need careful amendment with a carbon rich porous feedstock such as woodchip to prevent anaerobic conditions prevailing within the feedstock blend.

*[10] NRAES (Natural Resource, Agriculture, and Engineering Service) **On-Farm Composting Handbook** (1992) NRAES-54. PO Box 4557, Ithaca, NY (USA) 14852-4556. www.nraes.org.*

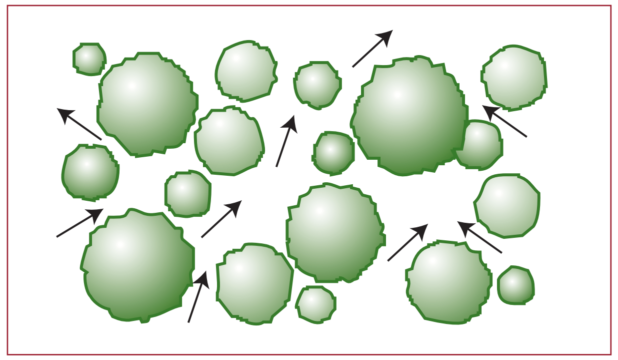
5.5.2 Size, density and porosity

Porosity is a key factor in the generation of odours. In order to maintain aerobic conditions and maximise composting efficiency, the density of the material must be optimised from the beginning. Prevention of odours at this stage is always better than remedial action later.

Effective mixing and blending of feedstocks helps establish uniform porosity. This creates air channels within the feedstock and allows adequate flow of air throughout the pile to maintain ideal respiration conditions (Figures 2 and 3).

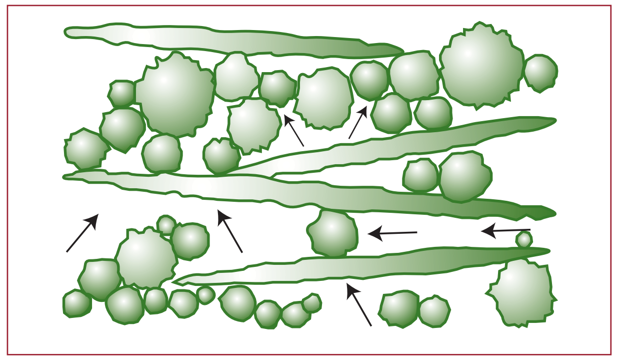
Moisture from the incoming feedstock will also have a significant affect on bulk density. A typical optimum bulk density that is desirable at the windrow formation stage for open air windrow composting would be between 500–650 kg/m3. This means that most particles will be between 25 and 40 mm in diameter. The feedstock composition, initial

Figure 2 - Ideal particle structure formation



Loosely packed particles of similar size form a structure that allows airflow through the pile

Figure 3 - Poorly structured particle formation



Tightly packed particles create pockets from which stale gases are unable to escape and fresh air is unable to enter. This encourages anaerobic organisms to flourish.

shredding screen selection and subsequent blending of feedstocks will determine the density achieved.

5.5.3 pH

pH is a measurement of the acidity or alkalinity of a solution; the lower the pH number the more acidic the material is, whilst a pH of 7 is considered to be neutral.

Within the preferred range of pH 6 to 8, the composting process is relatively insensitive to pH. It is normal for the pH value of composting waste to decrease (become more acidic) in the early phases of composting, as volatile, and odorous fatty acids such as acetic acid or propanoic acid are produced, and then rise and become alkaline as nitrogen containing compounds are metabolised. As the compost reaches maturity the pH tends to fall back down to nearer neutral. A skilled operator may be able to use pH as a general indicator of compost maturity, but this should be backed up by other tests.

Some sites that deal with a high proportion of meat and fish waste have reported successful amendment with lime to provide a more neutral composting environment in the early stages. When acids are neutralised by the lime, they are not released into the air and do not contribute to odorous releases. Over-liming may result in excessive releases of ammonia. As more source segregated food waste collection schemes are implemented, the use of this technique for pH management may become more relevant.

5.5.4 Moisture

Moisture is an essential ingredient for successful composting. Water acts as a medium for the many biochemical reactions taking place within the composting mass. A lack of moisture within the feedstock will slow down microbial activity within the stack, delaying compost stabilisation and allowing odorous chemicals to persist for longer. Excessive moisture will inhibit the movement of oxygen, decrease stack porosity and may give rise to odorous leachate.

It is not unusual for a certain amount of water to be needed at the initial blending stage, this will vary according to the feedstock that is being processed. This water addition should be carried out in a way that allows it to be fully incorporated into the feedstock. Too much water in any one time will cause excessive run-off and reduce feedstock porosity. As a rule of thumb water additions during all stages of the composting process need to be carried out on a little and often basis. The management of moisture levels throughout the active composting phase is very important.

The optimal moisture content for feedstock should be 55 to 65 percent (w/w) at the initial formulation stage. This can be easily measured by taking a handful of compost and squeezing it. Within this optimum range, no liquid should be emitted from the compost, but the hand should be left damp. Material wetter than this will encourage the formation of anaerobic pockets, which will inevitably generate malodorous compounds.

The moisture content and structure of the feedstocks should be assessed on a continuous basis. This is part of a good quality management system that should be in place on any well-operated site.

5.6 Feedstock processing

5.6.1 Open windrow composting

The derivation of material actively managed on these processing sites will be predominantly plant materials. Since the introduction of the Animal By-Products Regulations[11] no food or catering waste can be treated outside of an in-vessel composting plant until it has been sanitised. Some sites may take a fraction of vegetable waste and compost this in open windrows but this is only permissible only if a Hazard Analysis Critical Control Point (HACCP) Plan can demonstrate that there is no risk of this material having been in contact with animal by-products or food waste during its production or processing.

As a result, open windrow feedstock inputs will tend to follow the natural growing season with peak inputs arriving from April to June and again in September to October. The influx of excessive volumes of feedstock during peak periods may mean that there is a prolonged waiting period prior to shredding and blending taking place. This should be avoided wherever possible, as it will inevitably lead to malodour occurring as feedstock awaits processing. Material delivered during months

[11] *Animal By-Products Regulation (EC) No 1774/2002, (Document SANCO/2006/10452 R1*

HACCP key definitions

HACCP was developed by for the USA's manned space programme in the 1960s by the Pillsbury company.

Definition: HACCP planning is a system of product safety assurance based on the prevention of problems.

Hazard: A potential source of harm.

Risk: A combination of the probability of occurrence of harm and the severity of that harm.

Hazard analysis: The process of collecting and evaluating information on hazards and conditions leading to their presence.

of peak arisings will also naturally tend to contain material which has a lower C:N ratio and poor structure due to the additional grass content.

5.6.2 In-vessel composting

These facilities will be treating a much more diverse range of inputs within their process. The most common addition will be that of food or catering waste collected from households co-mixed with botanical garden waste. During the winter months, the percentage of green waste within the co-mixed collection will fall dramatically. The more putrescible and odorous food and catering waste will then be diluted with a smaller amount of green waste making the waste received more odorous.

Although the reception and processing area at an ABPR approved facility will be fully enclosed, optimal composting can only take place when the blend of feedstocks has a C:N ratio of about 25-40:1. In the above scenario an amendment material may need to be used to increase the C:N ratio and also increase the porosity of the waste. Sites which process these feedstocks should carry adequate stocks of suitable amendment material for this purpose.

6 MANAGING THE COMPOSTING PROCESS

6.1 Introduction

Of the entire composting process, the initial stage of composting (commonly referred to as the 'sanitisation phase') is often the most problematic for the generation of odours. This is due to the higher respiration rate experienced within the feedstock which will consume the available oxygen much faster than at later stages of the process. The net result is that the potential to produce malodorous volatile compounds will be greater than at any other stage.

In the UK, prepared feedstock will either be loaded into an in-vessel facility, for initial processing, or formed immediately into windrows, which are usually outdoors.

With enclosed systems, there is typically a far greater level of process control than windrow systems. Containment features required for the Animal By-Products Regulations also provide opportunities for using remediation technologies to treat exhaust gasses to minimise release. However, contained treatment systems are expensive and efficient use must be made of the time feedstock spends in these systems. The sooner that this phase can be completed to the point where less rigorous controls are required, the sooner expensive infrastructure can be made available for fresh incoming feedstocks.

Many of the measures suggested in this section for effective odour management will also contribute towards efficient active phase composting. Through proper control of aeration, moisture and temperature, this phase can be completed efficiently and with a minimum of odour generation.

6.2 Monitoring the process

For aerobic composting, an inadequate supply of oxygen can greatly increase the quantity of odorous chemicals and dramatically slow down the process of metabolising existing odorous chemicals in feedstocks. The recording of anaerobic conditions combined with site activity records and offsite data such as complaint records may provide convincing evidence of a chain of cause and effect events.

Conversely, records of process conditions (oxygen, ammonia, temperature, moisture, bulk density, texture, etc), compost maturity (field or laboratory respirometry) and direct odour assessments of materials (compost or feedstock samples taken to an offsite odour assessor) can provide convincing evidence of a system that is well managed and under control.

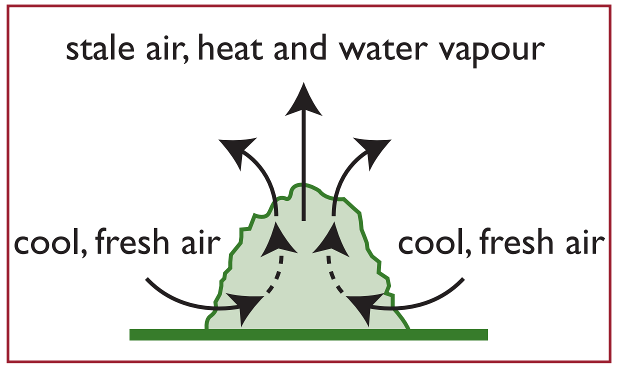
6.3 Managing aeration

There are many ways to aerate composting feedstocks in enclosed facilities. These will be dependent upon the technology supplier and design specifications of individual plants. As such any detailed description is outside of the scope of this guide, although many of the principles here will still apply. These principles of compost aeration will therefore be illustrated here in the context of outdoor windrows.

6.3.1 Passive aeration

Natural or passive aeration is the method by which windrows or piles of compost obtain their oxygen. This process is commonly referred to as the 'chimney effect': passive stack aeration relies primarily on internal convection currents to pull cold air in from the base of the stack as warm air rises and exits the stack from the top (Figure 4). In warm weather, as the temperature differential closes between the ambient air and the temperature of the compost stack, the ability of this convection current to work effectively is dramatically reduced and may be unable to satisfy the biological oxygen demand of the aerobic composting micro-organisms. This means that the stack is likely to turn anaerobic much faster in summer than in winter. Inadequate ventilation can reduce the ability of the windrow to lose excess heat and cause anaerobic conditions to develop.

Figure 4 Schematic diagram of 'the chimney effect'



One technique for reducing the risk of this happening is to reduce the overall dimensions of the windrows during the summer months to assist in keeping the 'chimney effect' operational. A 20–25% reduction in windrow height and width from a typical 3.5 metre wide by 4 metre high windrow during the summer months should be targeted to have any real significance on reducing potential odour generation under these conditions. The surface area: volume ratio of the windrow will determine at what speed heat is lost or retained within the windrow, the speed at which the windrow dries out. For example in winter, it may be preferable to maintain larger windrows in order to maintain hotter conditions within the composting mass. The size of the windrow will be predetermined to a degree by the machine used to turn it.

As the process progresses and the biological activity slows down, it may be possible to combine windrows to assist in heat retention. However, the size of a windrow should never exceed a level which can be effectively turned.

In some cases stack aeration may be enhanced by using woodchip as a base under the windrow. This will allow air to enter the windrow more readily through this open porous material, and help to keep the compost aerobic during times when climatic conditions make passive aeration harder to achieve. This technique is often used under forced aeration systems where turning is less frequent.

These basic techniques will greatly assist in maintaining the compost aerobic during the high temperature phase of the process. In the event that feedstocks are used which have a higher than normal respiration rate, often with reduced structure and porosity (such as grass cuttings), oxygen demand may be greater than what can be supplied through passive aeration and may fail to satisfy the needs of the aerobic composting micro-organisms. In this event additional measures will be necessary to prevent the compost becoming anaerobic. Failure to address this problem will inevitably lead to odorous gases being generated and released to atmosphere.

To overcome this problem, air can be introduced into the compost through either mechanical turning of the windrow, or actively forcing air into the compost through a forced aeration systems.

6.3.2 Forced aeration

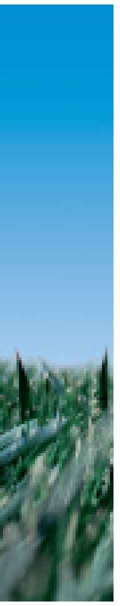
The main objective of forced aeration is to promote aerobic conditions within the compost mass and reduce the incidence of anaerobic pockets which can generate odorous compounds. Additional benefits of using this process are reducing the need to turn the windrow after it has been formed and saving the associated labour and mechanical turning costs. In addition, the potential to release odours can be significantly reduced if sufficient composting can take place before the windrow is turned or moved.

In positive aeration systems either perforated pipes are laid out on the ground, or covered channels with vent holes are laid in the concrete pad at appropriate spacing intervals. These are connected to a fan that forces ambient air through the aeration pipes or channels and into the composting materials. This system may modulate its operation either through a timer or by the electrical input signal received from an oxygen or temperature meter buried within the compost. Although this system has genuine benefits through its ability to increase stack aeration, it is limited in its capacity to capture or treat any emissions coming from the compost. This is essential if odorous emissions are to be effectively contained and a number of variations on this method are used to enhance containment.

In negative aeration systems, air is sucked through the composting mass from the atmosphere, where it can then be treated, typically in a biofilter. Additional vertical probes can be inserted within the compost mass if needed to ensure thorough aeration in all parts of the windrow.

The most significant advantage this system has over positive flow aeration is that by capturing the emissions from the compost stack, these can be treated as necessary to reduce any malodorous emissions prior to releasing them to atmosphere. Some systems on the market have the ability to reverse the fan direction. This enables the system to work in a positive aeration mode toward the end of the composting process when the likelihood of releasing offensive odours is reduced.

Costs will vary according to the specific requirements and manufacturer selected, but a guideline cost of between 50-70p/input tonne should be expected for this technology (this



Case study examining the use of forced aeration

Background

A fully licensed composting site in East Anglia that processes in excess of 20,000 tonnes of organic waste has been undergoing extensive trials with a forced aeration system. This site deals with a wide variety of feedstocks including fruit and vegetable waste as well as the more conventional green waste material. Due to the high moisture and poor structure of some of the incoming feedstocks, it is important that feedstock aeration is well managed from the outset of the process. The potential to cause odours from this type of material is particularly high and so the use of supplementary aeration was deemed appropriate to ensure adequate odour control was in place.

'We were all amazed at how quickly the material had degraded and that there were no anaerobic odours within the compost windrow' was how the site owner described the effect of this abatement technology on his operation. The aeration pipes were placed at two metre intervals along the length of the windrow and inserted 1.5 m vertically into the windrow.

'We have been delighted with the simplicity of the system, not only will the installation save us time and money, but it will also allow us to control the composting process and help improve the timeliness of the operation and significantly reduce the generation of offensive odours'.

includes the capital cost for the initial purchase of the equipment, running costs and depreciation over a five-year period.) An additional cost benefit regards the savings made from not turning the compost, such as labour and fuel.

6.3.3 Mechanical aeration

One of the most commonly used techniques for introducing oxygen into the compost is through mechanical turning, either through the use of a dedicated turning machine or a front-end loader or shovel. Turning involves lifting the composting feedstocks into the air, where they are allowed to drop back down in order to introduce fresh air, release trapped heat, moisture and stale air, and homogenise the mix. Materials that have settled and compacted are separated restoring larger air spaces within the compost mass. This will allow the passive aeration process to work more effectively and prevent the materials from becoming anaerobic and malodorous.

If feedstock is particularly wet at formation, and therefore likely to be dense in structure, additional turns may be required to assist in dispersing some of the water as water vapour from the composting mass. Turning also helps to dissipate excess heat from the windrow, but the amount of air introduced directly from the turning activity will typically be consumed in a matter of minutes during the active composting phase.

In order to maintain an aerobic state within a passively ventilated composting mass, frequent turning of the compost is normally required. Particularly during the initial stages of the active phase, the frequency of turning is one of the most time sensitive operations carried out on a passively ventilated composting windrow. As a general rule, turning the feedstocks frequently (twice a week) during the initial active or sanitisation phase of the composting cycle will assist greatly in maintaining the desirable aerobic conditions. However the turning process can itself release odorous chemicals if the windrow has anaerobic pockets within the windrow core.

In some instances where malodours at the start of the process have been found to be very high during the initial turning phase, it has been beneficial on some sites to leave the shredded material for one week prior to turning. This gives the odorous chemicals from the initial breakdown of waste more time to become degraded.

Turning will gradually reduce the particle size of the feedstock. This will reduce the porosity and structure of the material and as therefore reduce the efficiency of passive aeration. This is not a significant influencing factor for normal sized windrows, as by this stage of the process (6–8 weeks after forming) the oxygen demand of the feedstock will have declined dramatically.

Where needed, turning the compost provides an ideal opportunity for the evenly distributed addition of water to the compost. This will avoid any unnecessary run-off of excessive water from the compost.

6.4 Managing moisture

During the active composting phase, oxygen consumption rates are high and an excess of moisture can reduce porosity and lead to anaerobic conditions prevailing within the feedstock. The micro-organisms responsible for the breakdown of the organic matter will then become deprived of oxygen; leading to the production of odorous volatile organic compounds.

The addition of water during the composting process should be carefully managed and regulated. Site run-off water and compost leachate can be an important additional source of moisture. This is both cost saving and beneficial to the process. The addition of water on a little and often basis is far better than single heavy applications. A fine spray is preferable for any additions and the feedstock should not become saturated. Spraying the surface of feedstock piles can help to form a temporary barrier to the release of odour. However this moisture may not penetrate the windrow due to the 'thatching effect' as water runs off the surface of the windrow rather than being absorbed.

Any additions of water for moisture control should ideally be carried out whilst the compost is being turned or mixed, as this will ensure that the addition is evenly blended and uniform in application. Most shredding and turning machines have the facility to do this.

An additional benefit of water addition is the suppression of dusts generated during the turning process.

6.5 Managing leachate

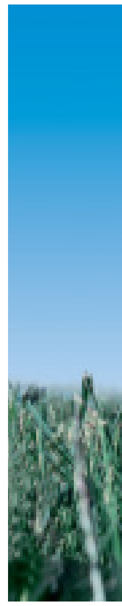
Water that has percolated through a composting pile either from precipitation or moisture derived from the composting process is referred to as leachate. This nutrient-rich material has the potential to cause malodour if not properly managed, as it will have a high oxygen demand. Using collected leachate and run-off from within the composting site for moisture balancing of the feedstock is a well-established practice.

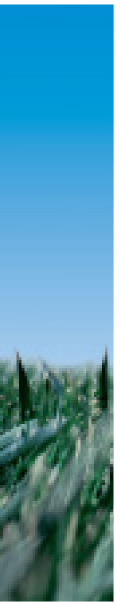
It is generally good practice to screen out solids from leachate prior to storage, in order to reduce its oxygen demand and therefore its tendency to go anaerobic during storage. Even so, leachate liquor will often become stagnant and anaerobic unless it is either kept aerated or kept moving by means of a circulation pump. It is therefore advisable to install a submersible aeration pump with an ejector unit into the lagoon. This works on the principle of drawing air into a 'draw-down pipe' through a pump that mixes the air and water together. The mixed air and water are then ejected back into the lagoon increasing the oxygen content of the water after treatment. This technology although simplistic in operation, provides an effective safeguard against the formation of odours within the leachate lagoon. Additionally emptying the lagoon of all its contents and removing accumulated sediment every 1–2 years is recommended, as this organic matter will be decomposing on the bed of the lagoon and will be difficult to aerate.

Reed beds have been employed for many years to clean contaminated waters, such as sewage effluent. This cleaning process relies on naturally occurring micro-organisms within the reed bed feeding upon the nutrients in the effluent, as it slowly filters through the bed. They are employed successfully at composting sites abroad to treat compost leachate.

Although leachate does pose a potential contamination risk to the compost if used prior to the sanitisation phase in ABP regulated facilities, it is also a valuable asset to assist in enriching and activating inactive compost during times when there are less nitrogen-rich feedstocks being delivered to the site. Captured liquor (leachate and run-off) should be used prior to the sanitisation phase of the process, due to the potential to reintroduce pathogens to the process. At ABP-approved facilities it is often a requirement that any liquor can only be applied prior to filling into the composting vessel due to the potential contamination risk.

Poorly drained sites that collect leachate in puddles can potentially be a source of odour generation, as this will





Types of reed beds

There are two basic designs: the vertical flow and horizontal flow reed bed. These can be used separately to treat, domestic effluents, landfill leachate, storm waters, winery effluents, farmyard or compost yard runoff. Both types of reed bed usually employ a settlement tank prior to any treatment taking place. The size of the tank required is determined by the flow in litres per day. Allowing the raw effluent to stand means solids either float, forming a crust, or sink, forming sludge. The solid material needs to be removed on a regular basis e.g. once a year to prevent any reduction in holding capacity.

A vertical flow reed bed is made up of layers of various sized gravel. The largest at the bottom, decreasing to sharp sand at the top into which common reed or similar plants are planted. In the vertical flow system the effluent must be spread evenly over the reed bed surface. Some vertical flow systems have a network of perforated pipes surrounded by large stones to encourage even distribution. Even so, regular, if not daily, supervision of the system is required to prevent the build up of biomass on the surface of the reed bed or saturation of the gravel layers, thus preventing downwards movement of the effluent.

Horizontal flow reed beds have a much larger footprint than vertical flow beds. They are shallower and constructed in a completely different way. The effluent enters at one end, immediately sinks below the surface before travelling horizontally through the root zone of the reeds or similar plants. This system requires much less work. An occasional weeding of tree seedlings and other plants is all that is required on a regular basis. Should the reeds begin to look a little tired they can be cut back and the debris cleared to increase vigour.

The building of a reed bed is a job that requires specialist advice and will require consultation with the regulator prior to installation.

stagnate over time and release unpleasant odours. For this reason all composting pads should have a sufficient fall on them to allow leachate to drain freely to a collection gully that will, in turn, drain into a lagoon (a fall of 1 in 100 is acceptable). Washing down the concrete pad and associated drainage pipes can also be carried out if this area of the site becomes odorous. Mobile road sweepers, which collect surface water, are also useful tools to maintain tidy, puddle-free concrete areas.

6.6 Managing temperature

The control of temperatures within the composting process is fundamental to ensuring the rapid degradation of feedstocks. This will only happen if the temperature is measured.

Temperature monitoring is important for three reasons: Firstly it informs the operator about the type of microbiological activity which is taking place within the composting mass. Secondly, the temperature will assist in providing assurance to the operator that suitable sanitisation temperatures have been achieved, and at a later stage as temperatures decline, that the compost is reaching maturity. A reduction in windrow temperatures during the sanitisation or stabilisation phase may indicate that due to less availability of oxygen and subsequent microbial activity a turn is required to reintroduce oxygen, reform the air ways and remix the feedstock within the windrow.

Lastly, by ensuring that mesophilic temperatures are achieved wherever possible, the composting process will proceed rapidly and metabolise any odorous chemicals.

7 ENVIRONMENTAL FACTORS

7.1 Site location

The selection of an optimal site location for a biowaste processing facility is important, but an operator's options may often be quite limited. In practice site locations will be determined by planning regulations and the ability to find a suitable site that is included within the local waste plan.

Where a new site is to be built, then issues regarding the local topography, location of sensitive receptors, vehicle access and site services will need due consideration.

7.2 Weather conditions

Site operators should consider carefully prevailing weather conditions when conducting certain site activities. Failure to consider weather conditions when these activities are progressing may have a detrimental effect on the surrounding environment and its occupants through the dispersal of odorous chemicals. When discussing weather conditions, this can be broken down into three main areas:

- Precipitation
- Wind
- Ambient temperature

7.2.1 Precipitation

The effects of precipitation on odour dispersal from a biowaste processing facility are numerous. The effect of precipitation at the time of potentially odorous activities such as shredding or turning will generally be positive. Moisture droplets will help to entrain any arising volatile organic compounds and reduce their release off site. Precipitation will also assist in reducing dust generation on site during shredding and turning. On the negative side, the collection of stagnant puddles of leachate or run-off on composting pads as a result of excessive precipitation should be avoided as in time they may give rise to odour emissions.

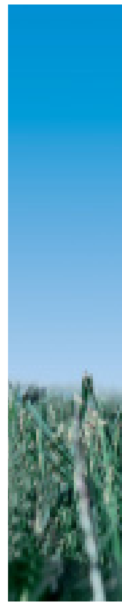
Over wet feedstock will generally be more likely to become anaerobic faster, as the flow of air through the feedstock mass will be inhibited. Excessive precipitation on compost in windrows will rarely affect the internal moisture percentage to any great extent because they will tend to shed excessive moisture through the 'thatching effect'.

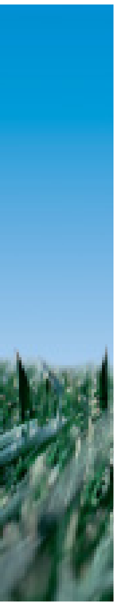
7.2.2 Wind

The direction and strength of wind on a composting site will have significant implications on the surrounding neighbours in the event that odour emissions are released off site. There are recognised atmospheric stability categories that define the specific characteristics of air; each of these will have an effect on the dispersion of odours from a processing facility. These categories range from extremely stable (category G) up to extremely unstable (category A), with five intermediate categories (these are shown in Appendix 1.)

The ultimate objective of all site operators should be to avoid releases of malodorous emissions which could be perceived as offensive at nearby receptors. As routine practice, and part of the site HACCP plan, wind direction and strength should be considered as a key determinant as to which particular activity is carried out on a daily basis. If the prevailing wind is blowing towards sensitive receptors, then high-risk activities such as turning or shredding should be avoided. There will always need to be a balance between what is realistically achievable without compromising the ability to carry out key activities on time.

There are numerous weather stations available at an affordable price that record key parameters such as wind direction and strength. Correct siting of weather stations is crucial to delivery of reliable and beneficial information. As a rule of thumb, wind speed and direction should be measured at a distance 10 times the height of any nearby buildings. If mounted on a building, it will need to be mounted two and a half times the height of the building. Information can be downloaded and stored for future reference and may be used to correlate a particular incident with the prevailing weather conditions. A simpler and complementary solution which can be of practical benefit to site operatives is installing a 'wind-sock' on-site. This should be sited so that operatives can see it easily from all areas of the site and that it is appropriately positioned to work effectively. Wind direction and strength will have a greater impact on odour dispersal and its effect on the wider community than any other climatic condition.





7.2.3 Ambient temperature

The effect of temperature on the generation of odours is significant. Although there is little a site operator can do to change the weather, operators can plan to manage key activities on site to minimise the detrimental impact they will have on the surrounding environment and human health.

Warm temperatures give rise to an increase in the generation of odours from biowaste processing facilities for a variety of reasons. Warm temperatures affect the condition of collected feedstock, particularly those from household sources. Collection bins left outdoors in warm conditions for up to 14 days will significantly increase the potential for malodours in summer. Similarly, any delays in processing received waste will be more problematic in warm weather. Sites with contained reception and processing areas should ensure that both their containment and emissions scrubbing systems are sufficiently robust to deal with these seasonal loadings. Sites without containment may need to negotiate contingency plans with their contracting local authorities to divert malodorous wastes or increase collection frequencies during peak times. High ambient temperatures can also affect the availability of oxygen as discussed under windrow management. More frequent turning during warmer temperatures may be required for this reason and others already discussed relating to the reduction in passive aeration.

In the event of cold ambient temperatures, the risk of odour emissions is greatly reduced due to the reduction in biological decomposition of feedstock. However it is equally important to manage the incoming feedstock to ensure the biological activity within the compost mass is optimised. Failure to react to changes in climatic conditions will have a detrimental effect on the composting process and may lead to a reduction in the efficiency of the composting process.

In colder weather (typically from +5 degrees Celsius to below freezing) activity will be significantly retarded on open windrow composting sites. Sufficient density to retain heat within the feedstock mass is essential so that the high temperatures that are required to sanitise the composting materials are attained. Odour emissions from colder stacks may not appear to be significant, but may give rise to odour problems at a later stage of the composting process. Slower breakdown and release of volatile organic compounds will manifest itself during the maturation stage of the process when normally there would be fewer odour emissions.

The effect at in-vessel facilities is less pronounced, as temperature control within the enclosed reactor is more refined and the vessel will be insulated to conserve heat. As a result of these factors, it is able to cope with external temperature fluctuations better than on open windrow composting sites during the active composting phase.

7.3 Good housekeeping

This term covers a variety of topics concerning the maintenance of a tidy, secure and safe working environment. As far as its relevance to odours and their prevention goes, good site management and planning, compost reception treatment and storage all need to comply with the following:

* Containing materials appropriately
* Reducing spillages to a minimum
* Minimising leachate 'ponding'
* Treating feedstocks as soon as possible
* Preventing a build up of old material on-site (unless they are being retained as amendment material)

Attention to detail on all the above items will assist in contributing to a reduction in the generation of odorous chemicals.

8 TREATING EMISSIONS

8.1 Introduction

The first priority of any site manager should be to identify and take advantage of all reasonable opportunities to prevent the formation of odours in the first place. The good practice guidelines outlined previously should be carried out as routine, however, additional measures may be necessary from time to time, or where certain feedstocks are concerned. The odour treatment technologies discussed here may be necessary and useful additions to measures to reduce the formation of odorous chemicals discussed earlier. However, relying entirely on treating odours is a risky and potentially costly strategy.

An operator needs to have realistic expectations of what any particular odour treatment strategy can achieve in order to be able to assess its suitability. Similarly, being candid with the community about the realistic possibility of odour will help to avoid the otherwise inevitable loss of credibility and trust. It is also important to be sure the technology selected is the right one for each site / composting operation and is also suited to the weather conditions. i.e. something that works in the south of England may not be suitable or require some adaptation for use in the north of Scotland.

Some of the considered solutions may involve significant capital expense, but this in itself is no guarantee that the outcome will be satisfactory. Keep in mind, however, that the cost of non-compliance in relation to odour generation can, in some instances, lead to site closure, which helps to put expenditure on odour prevention and mitigation into perspective.

In order to get the most out of any odour abatement system, it will need to be well maintained and actively managed. In addition, all sites need to have a contingency plan built into their working plan that enables them, at short notice, to cope with an unforeseen event. This would normally be carried out as part of the HACCP plan.

As in all aspects of biowaste processing, there needs to be a recognition that both the materials and ambient conditions are continuously changing. For this reason the operator must never be complacent with the system that is in place and be prepared to make modifications as required.

8.2 Biofilters

Biofilters are organic, microbially active substrates that filter odorous air. They are used as a primary mechanism for converting odorous compounds into less odorous or odour-free compounds. As the air passes through the aerobic biofilter substrate, odorous chemicals dissolve in the water layer and micro-organisms within the substrate metabolise the odour molecules before the air is discharged to atmosphere.

Biofilters are biologically active and will require active management. The micro-organisms within the biofilter are fed through metabolising odorous compounds. If a biofilter is accustomed to coping with moderate loadings on a continuous basis, in the event of a sudden loading occurring, it will not be able to respond quickly to this dramatic change in condition.

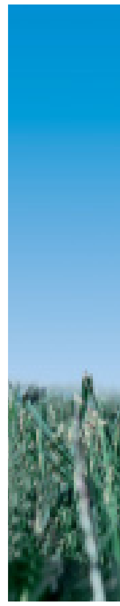
There are two types of biofilters both of which work on the same principle:

- Closed biofilters, where the filtration medium is housed within a structure. This will typically have an inlet port for the dirty air, and an exhaust port for the treated air that has been through the filter medium.
- Open biofilters, where the medium is exposed to atmosphere, sometimes at the sides as well as the top. Gaseous emissions will escape freely from this on all exposed surfaces.

The latter system will have a lower capital cost and may be used periodically in the event of particularly odorous feedstocks being admitted to the processing facility (for example, as part of a contingency plan).

Some closed systems pass the filtered air and steam through a condenser unit to provide a further layer of environmental protection. This will also ensure that no steam plume is visible coming from the treatment plant as this may cause concern to neighbours.

A biofilter's effectiveness depends on the biofilter substrate being actively managed. Biofilters are static in design and closed units will normally be constructed with a concrete or steel retaining wall. The efficiency of a biofilter can be measured by dynamic dilution olfactometry of the inlet and outlet. All



biofilters will have some odour of their own, but when properly maintained this should be minimal and not particularly offensive.

Biofilters generally work at 85–95% efficiency levels providing that they are proactively maintained. Take nothing for granted and ensure that standard operating procedures are in place for their monitoring and maintenance.

8.2.1 Biofilter substrates

The filter medium is there to provide a carbon rich, low nitrogen substrate on which micro-organisms will grow and flourish. A number of different materials have been used successfully in the past as filter media and the selection may depend on what material is available locally and at what cost. These can be either man-made or natural in origin. It may be useful to erect a small trial filter bed to test the selected medium's performance characteristics before committing to the construction of a full-scale biofilter. Below is a non-exhaustive list of suggested materials, which may be used as a mixed fraction the filtration medium, or on their own:

- Oversize screened compost
- Peat
- Shredded pallet wood
- Shredded roots from hard wood trees
- Coconut fibre
- Bark
- Shredded tyres
- Heather
- Calcified seaweed

In order for the filter to work effectively and to provide the maximum surface area for the air to pass over, there needs to be a mix of coarse and fine material within the matrix. Too much fine material will impede the progress of air through the material; too much coarse material and the air will not be filtered effectively. The use of materials which are too degradable should also be avoided as they will also reduce airflow and necessitate changing the filter media more frequently – every 2–3 years is the norm.

8.2.2 Biofilter management

A biofilter is a microbial system which requires active management. Failure to carry out a management plan will result in poor and inadequate performance, and can in some cases cause offensive odours to be generated by the biofilter itself. Other modes of failure for poorly designed or maintained biofilters include:

- Channelling (fissure flow which bypasses most of the biofilter)
- Compaction / blockage (resulting in high resistance to flow)
- Drying out (ineffective and in extreme cases may catch fire)

Management of a biofilter would include: moisture and temperature management, performance monitoring (including back-pressure), establishment of a maintenance schedule and the use of standard operating procedures (SOPs).

8.2.3 Moisture

The micro-organisms within the bio-filter, like those in composting, require a supply of moisture. Due to the high volumes of air passing through the biofilter the medium can dry out quickly, particularly in warm summer conditions. Areas of the biofilter that dry out faster than others will allow air to pass through them more readily as air will follow the path of least resistance, which will have a negative impact on the biofilter efficiency.

It is therefore necessary to install a sprinkler system above the filter bed to maintain adequate moisture levels within the medium. The optimal moisture content of a biofilter media should be in the range of 55–60% (w/w). Routine sampling of the medium should be carried out to ensure that the optimal moisture is achieved. Sampling should be carried out at least 30 centimetres below the surface to ensure a representative sample is taken.

8.2.4 Temperature

The temperature of the biofilter medium is another parameter that should also be managed to ensure that the correct temperature is maintained. In order to promote the growth of mesophilic microbes, a temperature of 35-40°C is ideal.

Controlling this temperature can be best achieved through mixing ambient air with the exhaust air to create the correct temperature. The use of water sprays on the in-coming air will assist through evaporative cooling to reduce the air

temperature and prevent the filter medium drying out. More sophisticated systems employ a heat exchange/condenser, in order to lower the temperature of the inlet air and condense much of the water-soluble odorous compounds (many of which have a high nuisance potential) prior to passing it through the filter.

A combination of excessive temperature, low moisture levels and large quantities of pine wood in biofilters have been known to cause this bed to catch fire, possibly through spontaneous combustion of naturally occurring terpenes.

8.2.5 Size

The size of biofilter required is proportionate to the volume of air that will be moving through it. A rule of thumb, which can be adopted, is that for every 100 cubic metres of air treated per hour; one cubic metre of substrate is required within the biofilter to treat it. The design should ensure that air retention within the biofilter is greater than 45 seconds. The size and design should be such that it allows for areas of the biofilter material to be taken out of action for replacement without preventing the use of the biofilter as a whole. For this reason there needs to an oversize allowance built in at the design stage to cope with maintenance disruption, including peak periods of odour production.

8.2.6 Back pressure

> Backpressure usually refers to the pressure exerted on a moving fluid or gas by obstructions or tight bends in the confinement vessel along which it is moving, such as piping or air vents, against its direction of flow.

The last criterion, which needs proactive management, is that of back pressure. This measure will indicate to the operator at what stage the biofilter material will require changing. It will be necessary to decide on a predetermined pressure at which time the contents of the biofilter will require replacement.

The frequency of replacement will depend on the medium selected. This may in some cases be as often as every eighteen months. Some sites, which have selected a more durable, less degradable substrate such as hardwood, are still operating effectively after five years with the initial biofilter medium.

It is essential that porosity is maintained within the medium to allow for effective gas exchange. As the medium settles over time and moisture is added, the finer particulates can find their way to the base of the biofilter reducing the airflow. This is not desirable and at this stage renewal of the filter matrix should be considered.

8.3 Chemical scrubbing

Biofilters, in a wide range of configurations, are by far the most popular and common method of odour scrubbing at composting sites. They are generally quite successful in this role because of their potential for high removal efficiencies and low cost. However, biofilters are not particularly effective with highly variable odour streams, and will require a relatively large area and need to be actively maintained by competent personnel. Because of these limitations, there may be circumstances where wet chemical scrubbing is a suitable supplement or replacement for biofiltration in the removal of composting odours.

Wet chemical scrubbers provide intimate and prolonged contact between the treated air stream and an aqueous absorbing solution. A wide range of variations are possible including:

- Re-circulating and single-pass scrubbing solutions
- Acidic or alkaline scrubbing solutions
- Oxidising scrubbing solutions
- Packed column, plate or spray towers

The removal of dust can help to reduce the overall odour burden but de-dusting units on their own are not generally effective for the removal of odorous volatile chemicals.

Capital costs for these systems can be relatively high, particularly when equipped with systems to re-circulate and chemically dose the scrubbing solutions. However, their compact size, high potential removal efficiency and ability to handle highly variable air streams can make them cost effective in some cases, particularly where high volumes of air require treatment (e.g. building ventilation).

Careful design and knowledge of the odorous chemicals present is also critical for their effective application. For example, acidic scrubbing solutions may effectively remove

Case study describing the installation and operation of a biofilter at an in-vessel composting facility.

The in-vessel system at a site in Dorset is constructed of two retractable-roofed composting tunnels. These in-vessel tunnels were used initially for the treatment of animal by-product waste with a processing protocol of 60°C for two days in each tunnel prior to outdoor maturation and stabilisation. This provided compost suitable for use in agriculture.

This method of treatment was felt to be too restrictive to the types of waste that could be processed. In addition the system was limited in its ability to control and contain odours generated when feedstock was moved in or out of the tunnels.

The site was reconfigured to allow processing to be carried out through a single, lagged clamp at the EU processing standard of 70°C for one hour. This higher temperature process allowed a greater range of wastes to be processed including both catering waste and Category 3 animal by-products.

During the construction phase, the composting tunnels were configured so that they were sealed into the side of the reception/processing building. This allowed a biofilter to be installed on the end of the reception building that was capable of filtering all the air from this building (Figure 5). This ensured that no odours could escape the confines of this building without being first treated.

The biofilter draws air continuously from the reception building, providing four air changes per hour. Whenever the tunnels are opened for either loading or unloading, the airflow within the tunnels is drawn into the reception building and then through the biofilter, thus providing odour control for the whole loading/unloading operation, which was previously an odour sensitive operation.

The biofilter is powered by an axial fan. This draws air from the reception building through 900 mm square ductwork which finally passes the air to 120 mm diameter flexible drainage pipe that lies under the bed of the biofilter (Figure 5). This bed is made up of 150 mm of gravel (to provide drainage) overlaid by one metre of shredded, seasoned wood. Air is blown through this medium on a continuous basis, and effectively captures any odorous compounds. Residence time within the biofilter is approximately 30–40 seconds.

Maintenance of the filter comprises periodic weeding of the filter surface and irrigating the filter regularly. This has proved essential to preventing the matrix drying out and reducing its efficacy.

ammonia but have no effect on other odorous chemicals such as volatile fatty acids (e.g. acetic and propanoic acids). Effective scrubbing may therefore require two or more stages. Flow rates must also be designed to allow sufficient residence time and to prevent excessive carry-over of scrubbing solution into the treated air stream.

A more detailed discussion of a wider range of chemical scrubbing systems can be found in the Environment Agency's IPPC H4 Draft Horizontal Guidance for Odour Part 2 – Assessment and Control.

8.4 Ozone treatment

Ozone gas can be used to treat malodorous air at composting sites and wastewater treatment facilities. The ozone molecule is composed of three oxygen atoms combined as a single molecule of O_3, whereas the normal state for oxygen is to exist as a molecule of two oxygen atoms (O_2). This makes ozone very unstable. When it comes into contact with a volatile compound, it loses an oxygen atom, oxidising the volatile compound into a less odorous form and itself becoming O_2.

Figure 5 Illustration showing ductwork configuration at a biofilter in Dorset

Ozone is produced by passing air or oxygen through a reaction cell where it is subjected to a high voltage discharge between two electrodes. This high voltage causes a reaction between oxygen atoms to form the ozone molecule, which is then fed into the foul air stream in a contact chamber in which it has time to mix with the foul air and react with the odorous compounds.

8.5 Effective microbes (EM)

An alternative strategy to reducing the production of odorous compounds is through the addition of effective microbes (EM). The principles behind the use of EM are to increase the number of beneficial micro-organisms within the composting mass.

Effective micro-organisms are a mixture of different natural microbes and mainly made up of lactic acid bacteria, yeast, actinomycetes and some phototrophic microbes. Their role is to support the activities of other microbes that are working within the compost. A reduction in the mechanical turning of compost with this regime ensures less 'spiking' of temperatures, lower temperatures throughput the composting process and a more consistent level of temperature and degradation within the feedstock.

This additive will normally come in a liquid state. It is most effectively applied at the shredding stage of the composting operation (however, in some instances an additional application may be made when the feedstock is turned). A storage tank will normally be located on the shredder with spray nozzles located on the output conveyor of the machine. Accurate application to the feedstock is essential to ensure product works properly. Adding water to EM on application only serves to act as a carrier for the product.

Case study – use of ozone treatment in an in-vessel composting system

A Cambridgeshire site employs ozone treatment at their in-vessel composting facilities. It is a self-contained ozone production system housed in a stainless steel cabinet on the concrete roof of the composting tunnel. It usually consists of a compressor, oxygen producer, ozone generator, power distribution panel and control panel.

When fresh air is pumped into the composting tunnel the used air needs to be removed. The exhaust gases pass, via sealed pipes, into a sealed contact chamber. A programmable logic controller switches on the production of ozone, which is carried to the contact chamber via 5 mm pipes where it is mixed with the exhaust air. Production of ozone is automatic but an emergency stop button is also installed.

When sufficient air has been replaced in the composting tunnel the programmable logic controller stops removing waste air and ceases the production of ozone. Air recirculation then recommences. Ozone is therefore only produced when required.

To prevent the emission of ozone from the air treatment system, the discharge gasses are passed over a cartridge of carbon filter material, usually charcoal. By passing the gases over this material, any ozone remaining in the air is reduced to oxygen and carbon dioxide by reacting with the carbon in the filter.

The addition of EM to compost is primarily to reduce odour emissions. One of the other ways in which this is achieved is by negating the need for the compost to be turned as frequently during the sanitisation and maturation phase. Turning compost is recognised as dispersing odorous compounds when they have already formed. EM reduces the need to turn the compost to aerate the substrate.

This is an inexpensive system to install and has been extensively trialled in the UK. Operators will need one litre of activated EM in a maximum of 1,000 litres of water. From this mix use 10 litres per tonne of organic material. This equates to a cost of approximately 0.15 pence per tonne of organic material. An activation kit for the application of 1,000 litres will cost in the region of £1,000.

Case study evaluating the use of EM on a composting site

A composting site situated in the Home Counties, has effectively used an EM product, developed from a blend of organic herbs, plants and selected living micro-organisms. This product was sprayed on to newly shredded organic material at the rate of 0.8 litres per tonne, to help combat odours emanating from the composting process.

Here, problems first arose during the spring, following a period when significant volumes of dense, wet grass clippings were accepted onto the site. Whilst prepared for seasonal change, the facility rapidly experienced a problem accommodating larger than normal quantities of high nitrogen-containing material. This material very soon became anaerobic, producing 'silage' like odour.

When sprayed with an EM product, the facility identified that the decomposing material not only retained oxygen levels more efficiently, but also required turning less than it did previously, speeding production time by up to 25%. The net outcome was that odour production was reduced significantly on the site with a dramatic reduction in the level of complaints received.

As in the use of forced aeration equipment, there will be a significant reduction in the costs associated with turning the compost in the windrow.

8.6 Masking/neutralising agents

Another tool, which may be used to reduce odour detection off site, is the use of deodorisers. These agents come in a variety of aromas including peppermint, strawberry and eucalyptus. The science behind this technology is that odour compounds adhere to the neutralising compounds prevalent in the agent. The neutralising agent then dissolves the volatile organic compounds and combines with them to form a non-odorous compound. The selected agent is misted into the atmosphere along the periphery of the composting site through a series of fine misting nozzles (Figure 6).

The equipment required to operate these misting systems uses compressed air. Due to the significant air volume to be treated in proximity to the odour emissions and the diversity of dispersion routes that the air can take on leaving the site, the efficacy of this technology will vary according to the prevailing weather conditions. It should be noted here that the use of deodorisers can, in themselves, be considered offensive to some people if used over an extended period.

Figure 6 Misting points at the boundary of a composting site

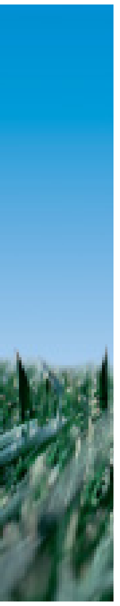
Case study examining the use of odour masking

Site x had applied for planning permission to extend an open windrow composting site. The Environment Agency asked the site manager to prepare an odour management plan. Complaints had been received from neighbours in the past, so a remedial plan of action was required to show that a solution would be both imminent and effective.

Several options were considered by the site operators to prevent this potentially serious situation from escalating. The demonstration of a deodorising system on the site had an immediate positive impact on the reduction of odours off-site. As a result of this, the site manager was successful in demonstrating to the authorities that he was able to offer an effective means of controlling the odour emissions from the site. His subsequent application for a site extension was duly granted.

This method of treatment should only be used as part of a more comprehensive odour abatement treatment plan. The good practice objective of preventing the formation of odorous chemicals must override the principle of treating them once they have arisen.

Treatment costs for the use of odorising chemicals is extremely variable. However companies that have used this technique successfully say that volumes of up to 25 litres/day of chemical diluted with water are not unusual (site size dependant). The cost of the concentrated deodoriser is in the region of £1.50–£1.80/litre. On the above application rates, this works out at a daily cost of £37.50–£45.00. The capital cost for the treatment equipment dependant on the number of injection dispersal nozzles will be £3,000–£4,000. This would include the cost of a compressor unit that is required to generate the compressed air to disperse the deodoriser through the misting nozzles.



8.7 Topical barrier treatments

As volatile odorous chemicals migrate to the surface of a pile they can be dissolved in, or released from, available water in the form of surface moisture. In order to take full advantage of this phenomenon, several conditions must be met:

- There must be sufficient water available to dissolve the chemicals
- The solubility of chemicals should be optimised for the odours present. Volatile fatty acids will dissolve more freely in alkaline solutions while ammonia will dissolve more freely under acidic conditions. Buffered neutral solutions (neither acidic nor alkaline) can provide an effective compromise
- An active aerobic biological community (e.g. bacteria, fungi, etc) can help to break down odorous chemicals once they are dissolved

Careful observation and judicious application of water, perhaps with the addition of an inexpensive neutral phosphate buffer, can help to optimise all of the above conditions. Too much water will reduce the availability of oxygen in the surface layer for aerobic microbes, while too little will not trap the odorous chemicals. Proprietary 'odour neutralisation' blends of essential oils, acidity buffers and microbial nutrients are available which may help. However, there is little evidence that these mixtures are any more effective than cheap food grade phosphate buffer solutions. Side-by-side testing of a number of proprietary topical treatments has demonstrated a wide range of effectiveness.

In some cases, odorous emissions from the surface of a pile may be reduced by changing the conditions on the surface. For example, if dissolved odorous chemicals are being released through the evaporation of moisture from the surface, then reducing this evaporation can reduce the rate of release. Water sprays to the surface will dilute any surface solutions of odorous chemicals and help to reduce the temperature. Similarly, providing shade or restricting air flow over the surface may also help reduce evaporation.

Topical barrier treatments represent a useful opportunity for controlling odorous emissions where moisture levels are carefully monitored. However, it would be unwise to expect consistently high levels of odour control from this approach on its own.

8.8 Containment

8.8.1 Introduction

The use of containment technologies at biowaste processing facilities provides the last good opportunity for preventing fugitive emissions from leaving the site. The complexity and associated costs for this option vary tremendously according to the selected options chosen.

Containment structures and systems can be very expensive, but the results will often justify the cost. One consideration to make when choosing a totally enclosed solution is occupational health. Working within an enclosed environment poses specific health and safety issues for workers that will require a risk assessment to be carried out. Ammonia emissions from biowaste processing can, in particular, be highly toxic within an enclosed building.[12]

Enclosure of the composting process within a building means that nuisance factors such as noise, dust and odours can be better captured and treated by one or more of the methods discussed in this section. Management of biowastes covered by the Animal By-Products Regulations must, by law, be undertaken within an enclosed reactor until the completion of the sanitisation phase. This means that before and during the high temperature phase of the process when odorous emissions are at their highest, capture and treatment of these emissions is much easier to achieve.

8.8.2 Reception building

It is normal for the reception area into which feedstock is delivered to be fully enclosed. This prevents the entry of vermin and assists in containing any emissions from this stage of the process. As delivery vehicles enter and exit the building, this entrance, should be closed automatically to prevent emissions escaping. However, in practice, this is not always a workable solution due to the number of vehicle movements using the facility. High-speed roller shutter doors are often used for this particular application to ensure an immediate airlock solution which prevents emissions leaving the building.

A typical solution that can be adopted for this part of the process is for air from the reception building to be treated through either a biofilter or an air scrubber. In most cases, feedstock will spend less than 24 hours within this building prior to in-vessel filling. Any feedstock blending or mixing with amendment material will usually be carried out within the reception building prior to in-vessel filling.

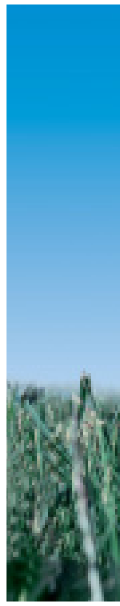
There are a number of different in-vessel technologies available for treating animal by-products and catering waste feedstocks. These include batch tunnels, vertical composting units, rotating drums and enclosed halls. All these technologies have the ability to capture and treat emissions during the sanitisation phase prior to their release to atmosphere. Some of these systems will require the feedstock to undergo the maturation and stabilisation phases outdoors. Although the material will be less biologically active at this stage of the process, there is still the potential for the release of odorous chemicals. The extent to which odours are formed will depend upon the residence time of the material in vessel and the type of feedstocks. Each site should assess this potential following its HACCP plan and make appropriate contingency measures in the event of equipment failure.

8.8.3 Containment for open air activities

To assist in the containment of emissions from open-air windrow facilities, the option of covering windrows using a fabric or membrane cover, such as Gore-Tex, is a possible solution. It enables fugitive emissions to be contained within a textile membrane cover that encapsulates the compost windrow.

Air can be positively injected into these membranes or drawn out and taken through a biofilter. This option will lessen the release of emissions to atmosphere at a cost that is significantly less than that of erecting a permanent structure. There is however a significant risk of odour release when the windrows are being formed and dismantled at the completion of the composting period.

The ultimate aim of any containment strategy should be to reduce the risk of pollution in the environment and annoyance to the local community.



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[12] *Health and Safety is described in further detail in the Composting Association's **Health and Safety at Composting Sites: A Guide for site managers** (2004) ISBN 0-9532546-9-0 (2nd Edition)*

9 PREVENTING ANNOYANCE

9.1 Introduction

Adequate odour reduction and containment should be proportionate to the risk of exposure and annoyance generated to the local community. The selection of the most appropriate solution will require careful thought and planning. No two sites have identical problems relative to their layout and design. For this reason, most solutions will be customised to the needs of each individual site and will need to be included at the planning and design stage.

Some of the most effective solutions to controlling odours can in many cases be the cheapest to implement as they will focus more on managing the process (microbe husbandry) which is responsible for producing the odorous chemicals and less on technology solutions.

Odour management represents a major commitment for most composting site operators in terms of capital investment, operating expenses and constant attention to detail. However, the ultimate objective is to minimise odour annoyance in the local community, not just to minimise odour exposure.

Even where all practical measures have been taken it may not be practical, or even possible to operate a composting site to a standard where people never notice that it is there. Sites operating to a good standard of odour control may still release enough odours to be noticed by more sensitive individuals within the community from time to time. While it may not be possible to control odours to the point where they go completely unnoticed, their impact on the community can still be minimised.

In addition, despite best efforts, things can still go wrong. Operators will be expected to plan for incident prevention and recovery but this may still not be enough to prevent significant exposure within the community if something unexpected goes wrong.

This section explores what can be done to minimise annoyance within the community once all practical measures have been taken to minimise routine emissions and reduce the risk of odour related incidents.

The composting of organic materials can provide significant environmental benefits to the local community and the wider environment. The effect that biowaste processing activities have on the local community should be considered as a prime concern for the operator. Engagement with the wider community should be established from an early stage of any site development, whether it is the expansion of an existing facility or the establishment of a new site. The sooner links can be made with local residences and a dialogue established, trust and confidence can be inspired between the two parties.

The processing of biowaste can be carried out effectively without causing harm to the local community or to the environment. These two factors are paramount to the successful operation of a sustainable processing facility and the wider industry.

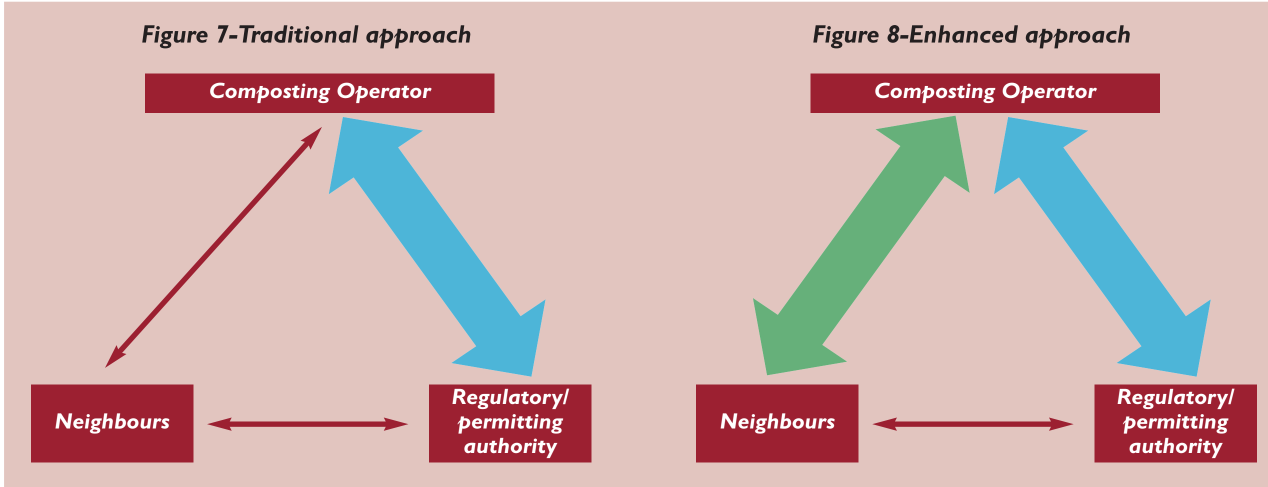
The subject of this industry guide is odour, but annoyance is typically the cumulative result of a range of factors. Annoyance factors may include odour, dust, noise, litter, traffic, etc. Furthermore, each of these factors will be understood as posing some sort of threat to individuals within the community. People may feel physically threatened by fast moving heavy lorries or be concerned of the health impact of dust. In some cases they may even feel threatened by a site operator personally. In cases where individuals believe an odour is coming from somewhere such as a hazardous waste site they may feel more threatened, and therefore more annoyed, than if they think it is coming from a farmyard or oil production site.

Reducing annoyance from other environmental factors is beyond the scope of this guide. Therefore, this section of the guide will focus on reducing the perception of threat from residual odours or significant short-term odours from any emergency situations or incidents.

9.2 Working with neighbours

By engaging with the local community at an early stage, relationships can be established which will help to reduce the perceived level of threat from the site. The perception of threat is a personal thing and operators should not underestimate the importance of establishing their position as an active and positive member of the community. If they are thought of as an accessible, accountable member of the community, the level of threat posed by any odours will be

Traditional and enhanced stakeholder relationship triangle[13]



reduced. Conversely, if they are perceived as uncaring, unaccountable and operating in secrecy, the perception of threat will be exaggerated.

It will help if operators can take a more inclusive approach to the local community and encourage them to come on site at an 'open day' events. In this way active engagement will improve the understanding of their neighbours and allow them to make informed decisions. Figures 7 and 8 illustrate this. They show that increased direct interaction is required with neighbours. Improving their understanding of what an operator is doing is fundamental to improving relations with these key stakeholders. Site operators should feel free to share with them how seriously they take their concerns about odour control and to illustrate this with the measures they are taking.

Biowaste processing sites may find it helpful to nominate a senior manager or member of staff to be responsible for and promote matters relating to odour. Besides ensuring that this person is technically competent to speak with authority on the subject of odours and their control, they should also understand the emotive nature of odour and be able to empathise with the concerns of people in the community. Their duties would include monitoring and recording odours as well as communicating with other site employees and also the wider community. This single point of contact will assist in ensuring that mixed messages are not given to other stakeholders including neighbours, and will ensure more clarity and consistency in communications.

[13] *Goldstein N.* **Neighbor Friendly Odor Management**, *BioCycle, JG Press ® March 2006)*

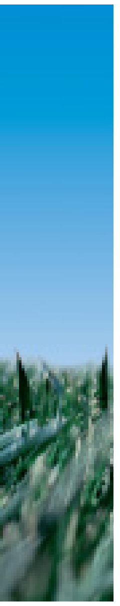
9.3 Complaints

In order to inspire confidence with the local community, operators need to be wholly transparent in all their actions. Odour complaints are a valuable source of information which should be taken seriously. Efficient and effective management of complaints can maximise the value of this information and help to minimise any secondary annoyance due to poor handling of their call. This can at times be difficult as the effects of odour on the wider community can give rise to strong feelings.

The descriptions of odours given by individuals within the community can sometimes be the only evidence available of community exposure. This will help clarify the nature and pattern of releases off site. The number of complaints received will often under -estimate annoyance within the community. Therefore a lack of complaints should not be understood as confirmation that there is no odour problem. This under-representation is mainly due to people:

- Not knowing where to complain
- Considering that the effort required to complain is too great
- Believing that their complaints will not affect any change
- Being concerned that they may be the subject of ridicule, retribution or simply that the value of their property will be diminished

Conversely, many site operators believe that complaints are often not justified or may be based on other annoyance factors mentioned earlier.



In some communities, there may be one or two individuals who make the most complaints. In addition, people who complain may not be able to recognise the actual source of the offensive odour but assume that a composting facility is likely to be the source. The history of the site in relation to malodours attributed to them and detected by neighbours will affect the manner in which the local community react.

The receipt of a complaint should act as a prompt for the site operator to improve the situation to reduce the generation of odours off site. Other sources of information, such as community odour observers, meteorological data and observations of the composting process should be used to help interpret and understand the significance of any complaints received.

Feedback from the local community and staff employed on site can provide valuable information about the impact of odorous emissions. If used correctly, this information can be used to provide a better understanding of how activities on-site, and other conditions such as weather, are associated with unacceptable exposure within the community. There may also be times on a composting site when unforeseen odour producing events can occur. A well-managed site needs to be prepared for this possibility and have a communications and troubleshooting plan to deal with such eventualities.

9.4 Communications plan

In the event of malodours being generated on a composting site, there should be a communications plan in place that will effectively communicate to all key stakeholders (including neighbours) the following messages:

1. The reason for the odour
2. The likely duration persisted the odour
3. What plan is in place to end the current problem
4. What preventative plan will be implemented to prevent a re-occurrence of the problem
5. What grievance procedure the aggrieved party can take
6. Who is the responsible person on site to contact

A suggested format, which operators can use to record complaints and build up a picture of which key site activities generate the most complaints, is shown on the next page. This will ensure that the higher risk activities can be managed in a more proactive manner. By actively involving the wider community in the monitoring of odours, there is an opportunity for this kind of programme to show the local community that their opinions are valued and taken into account on an ongoing basis.

ODOUR RECORDING AND COMMUNICATION TEMPLATE

SITE NAME

Operator's Name:

Unique Incident Code:

DATE OF OCCURRENCE

Time of Complaint:

Name of Complainant:

Address:

Telephone No.:

Email:

Respondent to Call:

SITE ACTIVITY TAKING PLACE:

Shredding:

Loading Vehicles:

Screening:

Turning:

Filling Tunnels:

Emptying Tunnels:

Deliveries of feedstock to site:

METREOLOGICAL CONDITIONS

Wind Direction: N NW NE S SW SE

Wind Strength: None Light Strong

Precipitation: Heavy: Light:

Temperature: Celsius:

VERBAL RESPONSE FROM SITE:

ACTION TAKEN ON SITE:

FOLLOW UP ACTIONS

INCIDENT LOGGED IN SITE DIARY:

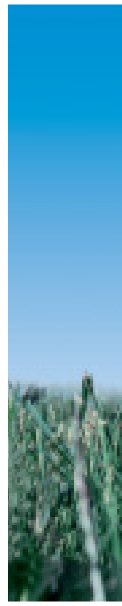
10 MINIMISING AND TROUBLESHOOTING ODOURS

10.1 Introduction

Most odour problems arising at composting sites are due to biological, mechanical or environmental problems. The majority can be controlled in some way by the site manager. Even when there are adverse weather conditions, operators need to be prepared to minimise the impacts.

Solutions to mechanical problems will necessitate the replacement or repair of a broken down machine or the purchase of a new item of equipment that will provide a more efficient means of carrying out a particular task. Problematic environmental factors tend on the whole to be weather related and can be rectified within the daily management of the composting process, e.g. if the compost is too dry, water can be added during the process.

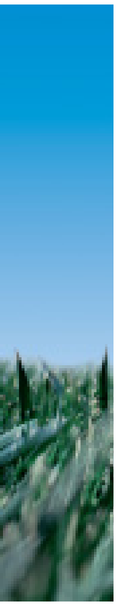
Biological difficulties can be harder to identify and will require a more holistic approach to finding a suitable solution. Managing the biological process effectively will be the most efficient way to prevent the formation of odours. For this reason the highest level of effort should be instigated on compost formulation, blending and microbe management. Table 6 provides guidance on preventing, minimising and troubleshooting odours should they occur.



10.2 Table 6 - Activities to prevent and troubleshoot odours

Key activity	Feedstock delivery
Odour issue event	Delivery of wet and compacted odorous feedstock comprising mainly grass collections
Corrective actions	As soon as material is discharged from the refuse collection vehicle, this material needs to be isolated from other feedstocks. Amendment material such as wood chips or oversize compost should then be mixed thoroughly to open up and add structure to the grass. On completion the blended material can be covered with wood chip or screened compost (preferably moistened), which will aid in reducing any odorous emissions to air.
Preventative actions	Liaise with the feedstock supplier and agree as to what feedstock will not be accepted due to odour potential. Train on-site operatives as to the acceptability criteria for in-coming loads.

Key activity	Feedstock delivery
Odour issue event	Delivery of bagged green waste feedstock
Corrective actions	Bagged material may be highly anaerobic and odorous. The bags require splitting open as soon as possible and the contents mixing with amendment material in order that structure and oxygen are readmitted.
Preventative actions	Decide on suitability of this material prior to signing contract with supplier. Discuss frequency of collection by local authority.



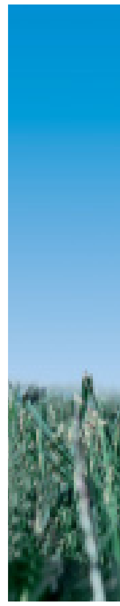
Key activity	Feedstock formulation
Odour issue event	Inappropriate feedstock composition. This may be as a result of excessive volumes of wet grass being delivered, or at the other extreme an influx of very dry 'woody' material.
Corrective actions	Blend materials to provide optimal C:N ratio.
Preventative actions	C:N ratio of feed needs to be >30, but this depends on available C and N and not just totals

Key activity	Feedstock storage
Odour issue event	During peak arising episodes (normally during spring), there can be a significant uplift in volumes delivered onto site. This may mean that feedstock is stored prior to shredding for a longer period of time.
Corrective actions	In order to reduce the possible incidence of odour emissions from stored material, covering this material with an amendment such as screened oversize material can act as a biofilter. In addition laying down an open 'bed' of a similar product, onto which the feedstock can be stored, will assist in maintaining a passive aeration 'chimney effect' throughout the stored material (storage time constraints stated within the site working plan will need to be adhered to).
Preventative actions	Place a maximum allowable volume on feedstock suppliers to reduce risk of 'overload' occurring.

Key activity	Shredding
Odour issue event	The movement, shredding and mixing of stored feedstock
Corrective actions	It is important that the day and time selection of this event are conducive to minimum impact on the surrounding environment and its inhabitants. Weather conditions will also require consideration for this activity. The use of water at shredding can assist in the containment of the release of odours. When selecting feedstock to shred from the storage pile, a diverse range of materials should be selected to ensure an even and homogenous final blend. This will greatly improve the microbial biodiversity within the composting feedstock.
Preventative actions	Adequate planning through the use of a HACCP plan

Key activity	Windrow formation
Odour issue event	Over sized windrows
Corrective actions	The dimensions of the stack are critical to ensuring that the pile 'breathes' effectively. Prevailing ambient weather conditions and available space need consideration when forming windrows. If material is considered to have a density exceeding 800 kg/m^3, air penetration within the batch core zone will be harder to achieve. Laying down of a porous 'bed' will prove to be beneficial (woodchip or coarse oversize compost is suitable for this purpose). This technique is particularly favoured with aerated static systems where the windrow is not likely to be disturbed for some time. If the compost is struggling to remain aerobic, make the windrows narrower and increase the surface area: volume ratio (by as much as 20%). This will enable the rows to draw in more air through the 'chimney affect'. Do not be tempted to make larger windrows than can be effectively managed. Larger windrows will have the potential to generate a greater level of malodours.
Preventative actions	Have sufficient space available to deal with peak input volumes and maintain windrows of manageable dimensions.

Key activity	Windrow management
Odour issue event	Unsuitable temperatures slowing the process of breaking down odours.
Corrective actions	Optimising the microbial activity within the windrow is essential to reducing odour generation. Active temperature control and management is a key part of achieving these desired temperatures. Compost that is too hot (over 75 °C) will dry out too fast and move outside the ideal temperature for encouraging thermophilic bacteria. Conversely cool temperatures (<40 °C) will slow the composting process down to a less than ideal rate.
Preventative actions	Ensure windrows are of suitable dimensions, are adequately aerated and moisture is actively managed.



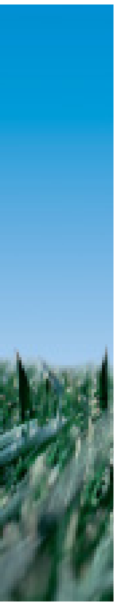
Key activity	Windrow turning
Odour issue event	Odour release during windrow turning
Corrective actions	Wind direction and strength need to be considered in relation to sensitive receptors in order that this activity can be undertaken with minimal impact to the environment and the local community (this will not always be possible but should be given due consideration prior to turning taking place). One indicator which can often be used as a guide to decide on the most appropriate time to turn is that of stack temperature. As this starts to reduce, turning should be initiated prior to the windrow becoming too anaerobic.
Preventative actions	Implement a regular turning schedule which ensures that anaerobic conditions and hence malodour generation is minimised prior to turning. Correct feedstock formulation will assist in maintaining an open aerobic state within the composting mass. Reduce the need to turn through the use of a forced aeration systems or EMs.

Key activity	Moisture amendment
Odour issue event	Compost which is too dry will break down odorous chemicals slowly, while overly wet compost will become anaerobic.
Corrective actions	Any water additions to compost should be done on 'a little and often' basis. Too much liquid applied at once will result in 'run-off' from the compost and subsequent ponding on the compost pad. It is advisable that any moisture additions to compost should be made with a fine misting applicator; this will improve its absorption into the compost. Where leachate is the main source of wetting agent to be used, there needs to be minimal atomisation. This is best done by adding water close to the surface of the compost and not from a distance. This will minimise the opportunity for volatile organic compounds to be atomised and released off site.
Preventative actions	Monitor moisture levels and temperatures on a continuous basis.

Key activity	Screening
Odour issue event	Screening
Corrective actions	This activity still carries some risk of producing malodours. The negative environmental impact factor will be significantly less when compared with shredding or turning activities. The wind direction relative to sensitive receptors needs to be considered prior to this operation taking place.
Preventative actions	Use of dust suppression equipment in the form of water misters will assist in entraining any odour emissions at this time. Material that is due to be screened should be of a sufficient age and stability to ensure that odorous emissions are minimal.

Key activity	Good housekeeping
Odour issue event	Leachate ponding and storage of 'old' feedstock or compost.
Corrective actions	Keeping drainage ditches and sumps cleared of any sediment is important. Compost falling outside retaining walls unless cleared away periodically will soon accumulate and produce undesirable odours. The use of a road sweeper for clearing spillages and surface ponding is a useful tool. Less expensive options such as a front-end loader bucket with brush attachment will carry out the same function.
Preventative actions	Carrying out regular 'good housekeeping' audits.

Key activity	Machinery breakdown
Odour issue event	Unplanned failure or breakdown of machinery.
Corrective actions	This is not an uncommon occurrence at composting facilities so a suitable plan of action should be in place to ensure that the failure of any machine does not have a significant effect on the potential to increase the generation of odours.
Preventative actions	It is recommended that machines such as shredders should be covered by a 24 hour breakdown cover by the supplier/contractor. It may also be worthwhile contacting other processing facilities in close proximity to set up a reciprocal loan agreement in place to cover such eventualities. Ensure a routine maintenance plan is adhered to.



SUMMARY

The prevention, control and treatment of odorous compounds from biowaste processing facilities require proactive management of the process and active microbe husbandry. There is no single factor that will prevent the generation and release of odours on its own. Prevention is best achieved through a collection of actions starting with feedstock preparation and blending, continuing through effectivement management of the active composting phase.

As has been discussed, there is more than one method of achieving the desired conditions within the compost to promote a diverse, active microbiological condition. The ability to achieve the optimal conditions on a continuous basis and minimise the risk of odour generation, require skill, experience and attention to detail from feedstock reception through to dispatch.

Biowaste processing can be carried out in such a way that the environment and the local community are not adversely affected and that the appropriate regulatory authority is satisfied. The challenge to the composting site operator is to achieve this outcome all year round regardless of the delivered feedstock inputs and prevailing weather conditions.

FURTHER READING

Gilbert E.J, Riggle D.S and Holland F.D. **Large Scale Composting: A practical manual for the UK**, The Composting Association (2001), ISBN 0-95325464-X

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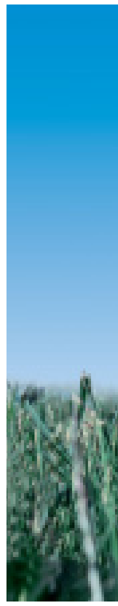
Defra. **Code of Practice on Odour Nuisance from Sewage Treatment Works** (2006) Defra website: www.defra.gov.uk ~ Product code PB 11833

Duckworth G. **The Composting Industry Code of Practice**. Researched and edited by the Composting Association (2006). ISBN 0-9547797-2-X

The Environment Agency. **Environment Agency Odour Guidance**, Internal guidance for the regulation of odour at waste management facilities, Version 3.0, (July 2002).



APPENDIX I

12 PASQUIL ATMOSPHERIC STABILITY CLASSES

Classification	Pasquill Stability Category
Extremely Unstable	A
Moderately Unstable	B
Slightly Unstable	C
Neutral	D
Slightly Stable	E
Moderately Stable	F
Extremely Stable	G

I. Pasquill Stability Classes General Descriptions and Definitions:

Extremely unstable 'A' – Weather conditions are very unpredictable. Wind speed average one metre/second but is 'gusty'. The temperature rapidly decreases with altitude. This condition is called superadiabatic. It is common on a hot sunny day. Due to these conditions, a contamination plume would loop and be unpredictable.

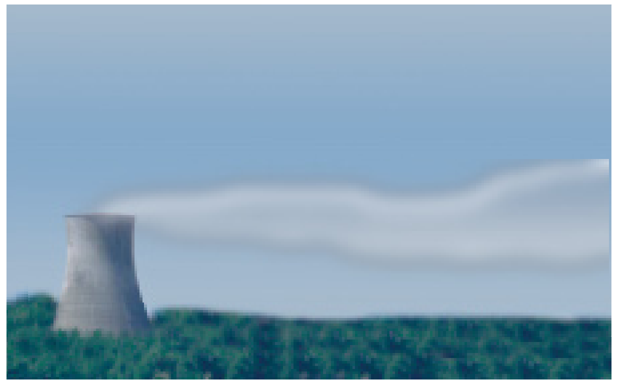
Extremely Unstable 'A'

Moderately unstable 'B' – Weather conditions are still unpredictable, but less so than 'A'. Wind speeds average two metres/second, and is not gusty. The temperature still decreases, but not as rapidly, with altitude. Looping of a plume would still occur, but is not as severe. This condition is common on a warm sunny day.

Slightly unstable 'C' – Weather conditions are somewhat unpredictable. Wind speeds average five metres/second. A little gustiness may be expected. The temperature still decreases and looping of a contamination plume may occur, but progressively less pronounced than 'A' or 'B' categories. This is an average day, slightly cloudy.

Neutral 'D' – Weather conditions are more predictable. Wind speeds average five metres/second, with no expected gustiness. The temperature still decreases with altitude, but the change is less pronounced. At this point, the condition name changes from 'superadiabatic' to 'adiabatic'. A contamination plume is more predictable, with minor looping. This condition is common on an overcast day or night (heavy overcast)

Neutral 'D'



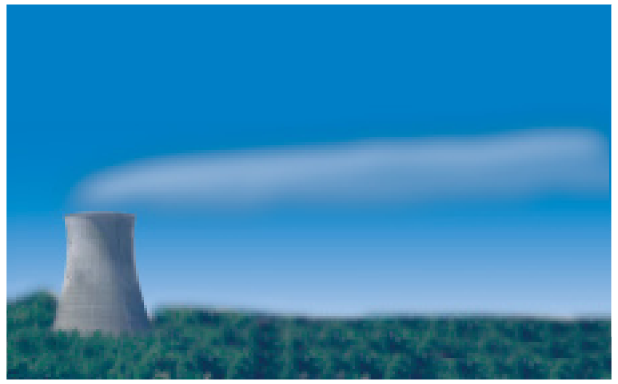
Slightly stable 'E' – Weather conditions turn more predictable than with 'D'. Wind speeds average three

Slightly Stable 'E'

metres/second. The temperature does not change with altitude. This condition is called 'isothermic'. A contamination plume is easy to predict with this condition. 'Coning' of the plume occurs. This condition generally occurs at night, and is considered an average night (partly cloudy).

Moderately stable 'F' – Weather conditions become very predictable. Wind speeds average two metres/second. This is an inversion. Temperatures increase with altitude. This condition is opposite of a Category 'A'. With this condition, little vertical dispersion occurs, i.e. it doesn't reach the ground rapidly.

Moderately Stable 'F'



Extremely stable 'G' – This condition is very predictable, but rarely occurs. No winds blow and the temperature increases rapidly with altitude. This condition may occur over a city, which is even less pronounced than an 'F' condition.

NOTES:

A. It should be noted that the above conditions are generalities. Stability classes change several times per day as wind speeds change and as sun and cloud cover change. 'A', 'B', and 'C' are most common during the day.

'D', 'E', and 'F' are most common at night.

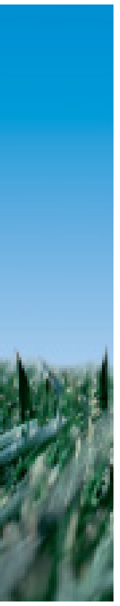
'G' is at night, but very rare.

B. Stability classes also change with altitude, with day and night changes. 1. Inversions (stable) can occur at low altitudes, and can be topped by an unstable class. When this occurs 'lofting' of a plume occurs, i.e., the contamination is carried higher into the atmosphere.

Stable topped by an unstable

2. Or the opposite can occur. Closer to the ground it can be unstable, while an inversion can exist at higher altitudes. When this occurs, fumigation occurs, i.e., plume rapidly disperses to the ground.

Unstable at ground with inversion above



APPENDIX 2

13 – GLOSSARY OF TERMS

Active composting phase
A loosely defined term often used synonymously to mean the high rate composting phase.

Aerated static pile systems
Un-turned (i.e. static) piles through which air is forced during composting via pipes laid beneath the composting mass. The air may either be blown (positive aeration or sucked (negative aeration).

Amendment material
Organic material which is used to improve the porosity or balance the C:N ratio within the feedstock. This may include shredded wood waste or oversize compost from screening. This material may be added at any stage of the process; typically it will be incorporated after shredding has taken place as the windrow is being formed.

Aerobic
Occurring in the presence of oxygen. Composting micro-organisms (aerobes) require oxygen to break down feedstocks, forming new microbes, creating humic and fulvic acids, and releasing carbon dioxide, water and heat energy as by-products.

Anaerobic
Occurring in the absence of oxygen. Some micro-organisms (anaerobes) only function and break down substances in environments without oxygen. In the process, they release by-products such as methane (a potent greenhouse gas) and volatile fatty acids (frequently odorous), which can be problematic in aerobic composting.

Animal by-products
These include animal carcases, parts of animal carcases (including blood) or products of animal origin not intended for human consumption, with the exception of animal excreta and catering waste.

Bacteria
A group of micro-organisms with a primitive cellular structure, in which the hereditary genetic material is not retained within an internal membrane (nucleus). (Singular = bacterium).

Bag tunnel systems
A type of in-vessel composting system that uses high tensile polythene to create a tunnel. Shredded waste is packed into the bag, which gradually unfurls as the loading equipment moves forward. Aeration is supplied by tubing laid inside the tunnel and venting pipes are attached to valves in the tunnel walls.

Batch processing
A processing method for in-vessel composting systems in which a composting mass is loaded, processed and unloaded from the container as a discreet batch without the introduction of new material during the composting process. It differs from continuous processing.

Bed
A term used to describe any active composting floor area utilised for in-vessel composting.(The term 'bed' may also refer to the entire mass of biofilter material within an enclosure).

Bioaerosol
Very small biological particles suspended in the air. These particles may be viable spores or cells, or non-viable fragments.

Biochemical oxygen demand (BOD)
A measure of the amount of organic matter in water that can be oxidised by micro-organisms. It is sometimes also called the 'biological' oxygen demand.

Biofilter
Organic, microbially active substrates (the medium) that filter odorous air through the action of micro-organisms that grow on the medium.

Bulk density
The mass per unit volume of a material.

Carbon dioxide
Substance formed during the composting process from the oxidation of organic chemicals in the presence of oxygen. It is a gas at room temperature and has the chemical formula CO_2.

Carbon to nitrogen ratio (C : N)
The ratio of total organic carbon to total nitrogen.

Catering waste
All waste food originating in restaurants, catering facilities and kitchens, including central kitchens and household kitchens.

Chemical oxygen demand (COD)
A measure of the amount of organic matter in water that can be oxidised by a cocktail of oxidising chemicals (usually potassium dichromate and concentrated sulphuric acid in the presence of a silver catalyst). The COD value for any given sample is greater than the BOD.

Compost
This has been defined as:
Biodegradable waste which has been aerobically processed to form a stable, granular material containing valuable organic matter and plant nutrients which, when applied to land, can improve the soil structure, enrich the nutrient content of soil and enhance its biological activity.

Compostable
A generic term used to describe feedstocks that are suitable for composting.

Composter
A colloquial term used to describe an operator of a composting facility, or person who composts.

Composting
This can be defined as:
The controlled biological decomposition and stabilisation of organic substrates, under conditions that are predominantly aerobic and that allow the development of thermophilic temperatures as a result of biologically produced heat. It results in a final product that has been sanitised and stabilised, is high in humic substances and can be beneficially applied to land.

Composting pad
The area where feedstocks are formed into windrows (in open-air turned-windrow systems) and actively composted.

Compost storage area
The section of a composting facility where mature compost is kept until sale or use.

Containers
In-vessel composting systems that are generally made out of metal or concrete boxes. Air is often forced through perforated floors into the composting material.

Development
In planning, the carrying out of building, engineering, mining or other operations in, on, over or under land or the making of any material change in the use of any buildings or other land.

Dust
Small particles of matter, which may include fragments of composting vegetation and clumps of micro-organisms that have been thrown up into the air.

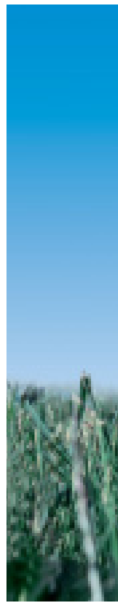
Duty of care
A requirement to anyone who produces, imports, keeps, stores, transports, treats or disposes of waste to ensure that it is stored safely and securely, that a waste transfer note be completed, and that wastes are only given to authorised persons or organisations.

Enclosed halls
A type of in-vessel composting system in which material is composted on the floor of an enclosed building (hall), usually contained in one long bed. The whole composting process tends to occur in the same hall, where large bucket wheels are used to turn and move the material through the system.

Environmental impact assessment (EIA)
A process that assesses the potential environmental impacts of any proposed development. It requires consultation with relevant stakeholders and the preparation of an environmental statement.

Environmental risk assessment
Methods used for determining environmental risk that use a 'source - pathway - receptor' approach to identify potential hazards, their consequences, the significance of the risk and how the risks can be managed to prevent and control.

Exposure
A concentration of odorant at a receptor with additional parameters of duration and frequency.Feedstock
The general name for any material that is composted. See also 'compostable' and 'organic waste'.



Forced aeration
A method to provide air (and hence oxygen) to a composting mass, usually via pipes laid beneath the pile. It can be done either with positive pressure, which blows air into the compost, or through negative pressure, which draws air down through the pile by suction.

Front-end loader (FEL)
A wheeled self propelled vehicle with the capacity to lift materials by means of a front bucket. These machines have a variety of applications for materials handling within a composting site.

Fugitive releases
Unintentional emissions from (e.g. windrows, open tunnels)-, points which are not designated or intended as release points

Green waste
Organic garden waste such as grass clippings, tree prunings, leaves, etc. which can be used as composting feedstocks. Synonymous with 'garden wastes', 'yard trimmings', 'botanical wastes' or 'garden trimmings'. They can arise from domestic gardens, public areas, private parks or gardens, or landscaping activities.

Growing medium
Material used to grow plants in containers, such as pots and growing bags, where the plants are confined and depend on the growing medium for most of their requirements.

HACCP
HACCP planning is is a system of product safety assurance based on the prevention of problems.

Hazard
Anything that has the potential to cause harm.

Hedonic tone
A judgement of the relative pleasantness or unpleasantness of an odour made by assessors on an odour panel. Odours which are more offensive will have a negative hedonic score whilst less offensive odours will tend towards a more positive score. The scores are intended to reflect the average responses of a large number of people. Individual responses may vary greatly.

High rate composting phase
The first stage in the composting process characterised by high rates of biological activity, oxygen demand and of heat generation.

Household waste
Waste collected from households at the kerbside, civic amenity sites, other bring or drop-off schemes. It also includes street sweepings, litter, plus bulky and hazardous household waste collections.

Humus
Brown or black complex material formed by micro-organisms during the decomposition of organic matter. It consists principally of humic and fulvic acids and forms the organic portion of soil.

Immature compost
Compost that has the potential to harm the germination of seeds or growth of plants. Immature composts usually contain phytotoxic substances, such as acids, and may not be stable. (See also 'mature compost' and 'stable' compost)

In-vessel composting system
A term adopted to cover a wide range of composting systems in which the material being composted is contained and, usually, enclosed.

Kerbside collection scheme
A collection method where organic wastes (or other recyclables) are regularly collected from commercial and industrial premises and households, normally at the end of curtilage of the property. Compare with 'bring collection schemes'.

Local planning authority
The local authority that has jurisdiction for determining planning applications. In England were there is a two-tier local authority system, applications for composting facilities are usually considered at the county level, whereas in Northern Ireland it is the Planning Service.

Leachate
Water that has percolated through the contents of a composting pile. It can be produced by moisture from composting materials or by rain or other water that has seeped through the pile.

Licence
See 'waste management licence'.

Liquor
A mixture of leachate and run-off. In an open-air turned-windrow system, leachate and run-off will flow together, and so cannot be separated.

Mass
The quantity of a substance. Usually measured in: milligrams (mg), grams (g), kilograms (kg) or tonnes (Mg). Where a percentage is expressed as % (m/m), this means that the relative proportions refer to ratios on a mass basis, rather than volume, which would be expressed as % (v/v). For example, 10% (m/m), could mean 10 kg in every 100 kg, or 10 g in every 100 g.

Maturation or 'curing'
The process whereby phytotoxic compounds in composts formed during the active composting phase are metabolised by micro-organisms into compounds that do not harm plants. It is generally characterised by a gradual drop in pH (from alkaline towards neutral), the conversion of ammonium compounds into nitrates, and the re-colonisation of the compost by beneficial soil micro-organisms destroyed during the active composting phase.

Maturation area
The area of a composting facility where compost is allowed to mature (or 'cure') until ready for use or sale. Mature compost Compost where intermediate breakdown products, many of which are phytotoxic, have been largely consumed so that it does not have a negative effect on seed germination or plant growth.(see also stable compost).

Maturity
The degree to which a compost has matured.(see also stability)

Medium
Term used to describe biofilter active materials.

Mesophilic
Organisms for which the optimum temperature for growth is within the range of 20 to 45 °C.

Micro-organisms
Microscopic organisms that are capable of living on their own. Often simply called 'microbes'.

Moisture content
The mass of water in a sample, usually expressed as a percentage on a mass for mass basis (m/m).

Negative pressure aeration
A method of compost aeration where air is sucked through composting materials from the atmosphere.

Noise
This can most simply be defined as 'unwanted sound', however, the perception of what is or is not a noise remains highly subjective.

Odour/odorant
A chemical or mixture which stimulates a human olfactory system so than an odour is perceived. In the context of this guide, odours are generally presumed to be unwanted, unpleasant or malodorous, unless otherwise indicated.

Odour unit
Mixtures of compounds require dynamic olfactometry for assessment of odour level. This involves exposing a selected and controlled panel of observers to precise variations in the concentrations in a controlled sequence, to determine the point at which only half the panel can detect the odour. This point is called the **odour threshold** or **one odour unit**. The number of odour units is the concentration of a sample divided by the odour threshold.

Offensiveness
An expression of the degree of unpleasantness of one odour relative to another. The perceived offensiveness of an odour will vary between individuals as a result of both physical and psychosocial differences. A population response of offensiveness can generally be described by a combination of hedonic tone and intensity.

Olfactometry (dynamic dilution olfactometry)
A test method to determine the extent to which substances are odorous using human subjects as a sniff panel.

Open-air turned-windrow system
Composting method where windrows are formed outdoors and mechanically turned.

Organic carbon content
See 'total organic carbon'.

Organic matter
A collection of complex humic substances and other organic compounds, generally of animal or vegetable origin.

Organic waste
A general, loosely defined term used to describe materials derived from living organisms that can be composted.

Pathogen
A micro-organism with the potential to cause disease through infection.

pH (Potential hydrogen)
The measure of acidity/alkalinity (as in soils, composts, solutions, etc.). It is a logarithmic scale. pH 7 is neutral. Not to be confused with total acidity or alkalinity.

Planning permission
Consent by a local planning authority for the development of any land.

Positive pressure aeration
A method of compost aeration where air is blown through composting materials.

Potentially toxic elements
Chemical elements that have the potential to cause toxicity to humans, animals or plants, although many are required for normal healthy growth in trace amounts. In the context of compost, it usually refers to heavy metals.

Reception area
The section of a composting facility where new feedstocks are delivered and stored before being actively composted (e.g. formed into windrows or loaded into an in-vessel system).

Regulator
Body that has a statutory duty to regulate waste management activities. In England and Wales it is the Environment Agency, in Scotland it is the Scottish Environment Protection Agency, and in Northern Ireland it is district councils (however this will be transferred to the Department of the Environment and Heritage Service at a future date).

Respiratory protective equipment (RPE)
Equipment to protect the airways of workers to vapours, dusts or bioaerosols. They comprise either respirators, which filter the air, or equipment with an independent air supply. Specialist equipment is required for atmospheres which are imminently dangerous to life or health because of the presence of hazardous substances or a lack of oxygen.

Responsible person
Designated person within the workforce who is trained appropriately to carry out on site monitoring.

Risk
The chance or likelihood of someone or something being harmed by a hazard under a certain set of circumstances.

Rotary composting vessel
A category of in-vessel composting system that consists of an enclosed rotating drum. Feedstock is fed into one end of the drum and exits from the other end in a sanitised condition.

Run-off
Water that has fallen onto a composting pile (for example, rainwater) but has not percolated through it, or that has fallen onto the site surface without touching the pile. Run-off may contain lower concentrations of pollutants than leachate.

Sampling
The practice of taking representative samples of composts according to agreed protocols for testing.

Sanitisation
The destruction of pathogenic micro-organisms, weed seeds and weed propagules by exposure to high temperatures (above 55°C) over an extended period of time.

Sanitised compost
Compost that has been subject to the sanitisation process.(For example 60 °C for 24 hours as required under the Animal by-products regulation 2002)

Screening
The process of separating particles according to their size.

Shredding
The process of breaking up large pieces of feedstock into smaller fragments, so that the structural properties are more conducive for composting.

Source-pathway-receptor
The approach employed in environmental risk assessment techniques. The 'source' is defined by the hazardous properties of the waste types and operations to which it will be subjected. The 'pathway' is the way in which the hazards are transferred into the environment, and the 'receptor' is the target or entities that may be affected by the identified hazards transferred from the source by the identified pathways.

Source separation
The principle of engaging waste producers to keep materials, such as organic wastes, separate from other residual wastes that would otherwise cause contamination.

Stable compost (stabilised compost)
Composts that do not have much oxidisable carbon and therefore have low residual microbial activity, which is characterised by low oxygen uptake rates, and low carbon dioxide and heat evolution rates.(For compost to comply with PAS 100 2005, the rate of respiration must be less than 16 mg CO_2 /g organic matter/day)

Stabilisation
The bio-oxidative process of degrading feedstocks into stable humic substances following the high rate-composting phase.

Stability
The degree of biological decomposition that composting feedstocks have achieved.

'Thatching effect'
This is the condition whereby compost forms a natural barrier to the ingress of additional water to its surface layer. This often occurs after a significant volume of water has already fallen on the surface of the compost and caused a natural barrier or 'thatch'

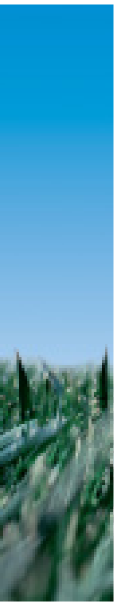
Thermophilic
Organisms for which the optimum temperature for growth is within the range of 45° to 80 °C. The respiration rate of thermophilic bacteria and fungi are much lower than for mesophilic oraganisms.

Threshold level
The level at which an odorous gas is diluted with odour free air until the odour is only detectable by 50% of the population.

Tunnel
A category of in-vessel composting system that consists of long enclosed chambers. The material is completely enclosed and usually aerated through floor perforations, although mechanical agitation has been incorporated into the more expensive versions.

Turning
The process whereby composting feedstocks are lifted up into the air and allowed to drop back down in order to introduce fresh air, release trapped heat, moisture and stale air, and homogenise the mix.

Vertical Composting Unit (VCU)
This is a category of in-vessel composting used for the processing of a wide range of biowastes. As the name suggests, the unit comprises of a vertical insulated container which is fed from the top with waste. Feedstock falls with the assistance of gravity to the outlet point at the base of the unit. This unit is modular in design, and may be housed either in the open air or within the confines of a building.



Volatile organic compounds (VOCs)
Molecules that contains carbon-to-carbon covalent bonds and are a gas at ambient air temperatures. Organic substance which will readily evaporate and transfer from a liquid to a gas state.

Volatile substances
A chemical that will be a gas under normal, ambient, conditions.

Waste
Any substance or object which the holder discards or intends to or is required to discard.

Waste Management Licence
Consent by the regulator for a licensee to carry out specified waste management activities at a particular site. Conditions will be imposed within the licence, with reference made to the working plan.

Waste panning authority (WPA)
Local authority with responsibility for land-use planning control over waste management activities. In Northern Ireland it is the Planning Service.

Windrow
A long pile of composting materials, usually shaped as an elongated triangular prism, although the exact shape will vary according to the material and equipment used. The term originates from the farming practice of piling hay in rows so that it will dry out in the wind. An essential feature of a windrow is that it will reach ground level between the individual rows. Failure to maintain this gap will defeat the object of facilitating the flow of air through the pile.

Working plan
A comprehensive document describing how a composting site will be prepared, developed and operated. It should include plans and drawings to appropriate scales, technical descriptions and specifications, documented procedures and recording systems. It should also include or make reference to supporting information, including risk assessments and detailed method statements. The working plan will also need to describe the engineering and/or operational controls (risk management provisions) to prevent or reduce the identified risks.