Institute of
Air Quality
Management

Guidance on the assessment of odour for planning

Version 1.1 - July 2018

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Contents

	Acknowledgements	3
	Record of substantive amendments	4
1.	Foreword	6
2.	Introduction	7
3.	Assessment of odour	11
4.	Using odour assessment tools	14
5.	Odour benchmark/odour assessment criteria	17
6.	Drawing conclusions from assessment results	23
7.	Odour Management Plans	24
	Appendix 1 - Predictive assessment tools	28
	Appendix 2 - Sniff testing	37
	Appendix 3 - Case law and appeals	43
	Appendix 4 - Comparison of OMP requirements in guidance	44
	Glossary	46
	Abbreviations and acronyms	49

Table 1: Description of the FIDOL factors	8
Table 2: Receptor sensitivity to odours	12
Table 3: IAQM suggested descriptors for magnitudes of odour effects	13
Table 4: Summary of odour assessment	15
Table 5: H4 benchmark odour criteria	19
Table 6: Proposed odour effect descriptors for impacts predicted by modelling – "Most Offensive" odours	21
Table 7: Proposed odour effect descriptors for impacts predicted by modelling – "Moderately Offensive" odours	21
Table 8: Recommended content of an OMP for planning purposes	26
Table 9: Examples of risk factors for odour source, pathway and receptor sensitivity	29
Table 10: Risk of odour exposure (impact) at the specific receptor location	31
Table 11: Likely magnitude of odour effect at the specific receptor location	32
Table 12: Example summary of the likely odour effects at existing sensitive receptors	32
Table 13: Some approaches for addressing uncertainty in odour modelling	36
Table 14: VDI 3940 odour intensity scale	37
Table 15: Matrix to assess the odour exposure neutral and unpleasant odours) at time and place of sampling	39
Table 16: Matrix to assess the odour effect at individual receptors	41

Figure 1: From odour formation to complaint	9
Figure 2: Plan, do, check, act framework	25

Box 1: Definitions of impacts and effects used in this guidance	11
Box 2: Example of multi-tool odour assessment of site suitability	14
Box 3: What is an Odour Management Plan?	24
Box 4: Example of sniff test sampling procedure	39
Box 5: Checking the sensitivity of odour assessors	41

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Chair of the working group
Michael Bull, Arup

Members
Alun McIntyre, SKM
Darren Hall, Amec
Gordon Allison, CH2M Hill
Jethro Redmore, REC
Jon Pullen, RPS Planning & Development
Laurence Caird, Air Quality Consultants
Matthew Stoaling, SLR Consulting
Ruth Fain, Golder Associates

Graphic Design: Darren Walker (darrengraphidesign.com)

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About the Institute of Air Quality Management (IAQM): The IAQM aims to be the authoritative voice for air quality by maintaining, enhancing and promoting the highest standards of working practices in the field and for the professional development of those who undertake this work. Membership of IAQM is mainly drawn from practising air quality professionals working within the fields of air quality science, air quality assessment and air quality management.

Internal photos: Jon Pullen **Cover photo:** Michael Bull

Contact: IAQM
c/o Institution of Environmental Sciences
3rd Floor
140 London Wall
London
EC2Y 5DN
T: +44 (0)20 7601 1920
E: info@the-ies.org

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Original location	Revised location	Amendment made
General		Name change: Version 1.1 - 2018 update
General		Changes to shading of tables
Page 4		Deletion: "national Government"
Page 4		Addition: "The evidence presented to justify a decision should be examined carefully and the base science presented should be the main consideration when reviewing the outcome of an appeal."
2.1 paragraph 1		Deletion: "addresses that need"
2.1 paragraph 1		Addition: "produced various guidance documents on odour but these were withdrawn in September 2017"
2.2.3 paragraph 1		Change: "emissions" to "odour exposure"
Table 3		Addition: "relative" to "Odour Exposure (Impact)"
4.1 paragraph 7		Addition: "former" before "Defra Code of Practise"
Table 4		Deletion: "Draft method pred264086 is currently going through the CEN voting process"
Table 4		Change: Final column title to "Notes"
4.3 paragraph 1		Addition: "and other statutory consultees"
4.3 paragraph 1		Addition: "on their own guidance"
5.5 paragraph 2		Addition: "The CIWEM Position Statement was produced in 2012 by a group of odour assessment practitioners. The statement is based on their interpretation of the available evidence at the time and the experience of members of the group. No new research was used to produce this statement."
5.6	Page 43	Move entire segment to new position as Appendix 3
5.6		Addition: "Taking into account the available scientific evidence and the collective experience of IAQM members involved in drafting this guidance, the odour concentration change descriptors together with impact descriptors in Table 6 are proposed for an odour at the offensive end of the spectrum. These adopt the C98 as the appropriate frequency metric, encompasses the 1 to 10 ouE/m3 concentration range referred to above and also considers also the potential sensitivity of different receptors. It is also consistent in format and concept with other guidance in the air quality field. Examples of receptors that fall into the above sensitivity categories are contained in Table 2. For odours that are less unpleasant, the level of odour exposure required to elicit the same effect may be somewhat higher, requiring professional judgement to be applied. For example, odours from sewage treatment works plant operating normally, i.e. non-septic conditions, would not be expected to be at the 'most offensive' end of the spectrum (Table 5) and can be considered on par with 'moderately offensive' odours such as intensive livestock rearing. Table 7 below shows the impact descriptors proposed for a 'moderately offensive' odour."

Original location	Revised location	Amendment made
Page 21		Addition: Moderately offensive odours table (Table 7)
Page 22		Deletion: Remove reference 21
Table 7	Table 10	Deletion: "if possible" from rows 2 and 3
Table 7	Table 10	Change: If the measures are not sufficient, they need to be tightened further or else possibly ceasing/reducing odorous operations" to "It should be stated that if all the measures are shown not to be sufficient, then they will need to be tightened further or else, possibly ceasing/reducing odourous operations."
A1.3 paragraph 3 and figure 3		Deletion: "In a recent survey in preparation for this guidance, IAQM members were asked which model they would select for an odour assessment, the results are shown in figure 3 which shows there is no general preference and, in any event, the results may simply reflect which models a particular company has access to" + Deletion Figure 3
A1.3.1		Addition: "Meteorological data should be obtained from a representative monitoring station or from the Met Office NWP model."
A1.3.1	Page 35	Addition: "provided the data are representative having been obtained from a suitable number of survey. To allow for external verification the full library of emission data should be publically available."
A2.1		Addition: "Sniff testing needs to be carried out on sufficient occassions to represent the full range of likely odour emissions and in meteorological conditions favourable to odour detection (i.e. light wind and state of atmosphere)."
A2.1.1	Page 40	Addition: "As noted earlier, a suitable number of sampling visits depends on the variations in source activity and differences due to time of day, season and weather conditions. As an absolute miniumum, the IAQM recomments sampling on three seperate days, provided the observed Pasquill stability categories (based on obersved sunshine, cloud cover and wind) account for at least 70% of conditions typically experienced over the course of a year."

1. Foreword

The Institute of Air Quality Management (IAQM) is committed to enhancing the understanding and development of the science behind air quality by promoting knowledge and understanding of best working practices. Membership of IAQM is mainly drawn from practicing air quality professionals working within the fields of air quality science, air quality assessment and air quality management. Most, if not all, the assessment approaches described here require some degree of professional judgement from a competent and suitably experienced air quality professional in order to reach a conclusion on the overall significance of the odour impact. Full membership of the IAQM – the only professional body specifically for air quality practitioners in the UK - can be evidence of such competence and experience. Membership of some other professional bodies having relevance to the practice of air quality assessment may also provide a degree of reassurance.

Odour is an issue that air quality professionals are frequently required to assess, particularly in respect to planning. Odour impacts may be assessed when considering a planning application for an activity that may release odours or when a sensitive use is being proposed near to an existing odorous process (known as 'encroachment'). Typical examples of potentially odorous activities are sewage works, intensive animal rearing, processing of animal remains, solid waste management (for example composting) and some industrial processes.

Some guidance on odour assessment is already available from national Government, the Scottish Environmental Protection Agency (SEPA) and the Environment Agency (EA). However, none of this specifically provides guidance applicable for planning purposes. This IAQM document has been prepared to assist practitioners involved in odour assessment for planning. It is not intended to replace existing guidance produced by the environment agencies for environmental permitting (EP) purposes or where a specific assessment method is already provided within existing guidance.

The field of odour impact assessment is a developing one. It should be noted that Inspectors` decisions on past planning appeals, though useful and often setting precedents, will have been based solely on the evidence that was presented to them, which may have been incomplete or of a different standard to current best practice: caution should therefore be exercised. The evidence presented to justify a decision should be examined carefully and the base science presented should be the main consideration when reviewing the outcome of an appeal. This guidance describes what the IAQM considers to be current best practice; it is hoped it will assist with and inform current and future planning appeals and decisions.

This Guidance is aimed primarily for use in the UK, where the vast majority of IAQM members work. However, it is recognised that the membership of IAQM is international and that the guidance may be applied elsewhere. Where this occurs careful consideration needs to be given to its applicability where local approaches to odour assessment may be significantly different.

As experience of using the Guidance develops, and as further research relating to odour become available, it is anticipated that revisions of this document will become necessary.

The use of some odour assessment tools in the UK suffers from sparseness of published evaluation of the relationship of effects/annoyance to exposure and what level of exposure can be considered to be acceptable. The IAQM is particularly keen to hear of examples of the use of these tools so they can further evaluated and the presentation of such data to the air quality community will itself improve the practice of odour impact assessment.

All comments and further information in relation to this guidance should be sent to odour@iaqm.co.uk.

2. Introduction

2.1 Scope and purpose of this guidance

This guidance is for assessing odour impacts for planning purposes. This document is not intended to provide guidance on odour for environmental protection regulatory purposes (e.g. Environmental Permitting, statutory nuisance investigations, etc.) and specific odour guidance from the EA[1] and SEPA[2]. Defra[3,4,5] produced various guidance documents on odour but these were withdrawn in September 2017. Guidance from those organisations also provides some background information on odours, details of how odours are measured, and options for controlling odour emissions; these subject areas are not repeated in detail in this guidance document.

Odour can be an important issue for waste-handling and treatment developments, wastewater treatment works (WWTWs), some industrial processes, and rural activities (e.g. farming and biosolids application to fields). The relevant Planning Authority must consider whether a proposed development (an odour source itself or nearby new receptors such as residential dwellings) will be a suitable use of the land.

The planning system has the task of guiding development to the most appropriate locations: ideally, significant sources of odour should be separated from odour-sensitive users of the surrounding land (sensitive receptors); failing this, it may be possible to employ control and mitigation measures to make a proposed development acceptable from a land-use perspective. New proposals for such developments may require an odour impact assessment to be submitted, either as a stand-alone assessment or as part of an Environmental Statement, to accompany the planning application.

Following the granting of planning consent, some industrial or waste activities will operate under an Environmental Permit, whereby on-going pollution control of many (though not always all) of the operations will be regulated by the Environment Agency or other agencies. National planning guidance requires that the Planning Authority works on the assumption that such pollution control regimes will operate effectively; however, even with effective operational pollution regulation in place there can remain some residual odour and there may be some situations where such residual effects would make a development an unsuitable use of land at its proposed location. For sites that will be subject to an Environmental Permit it is still necessary, therefore, for the Planning Authority to consider at the planning stage whether the proposed development at the site will be a suitable use of the land - in particular, with regard to the likely residual effects of odour on nearby sensitive users.

Finally, this guidance is limited to assessing the effects of odour on amenity, not on health. Strictly speaking, what we term odour is not really an air pollutant at all; rather, it is the human olfactory response (perception followed by psychological appraisal) to one, or more often a complex mixture of, chemical species in the air. These chemicals are the actual pollutants and they may, or may not, have health effects at the concentrations that trigger an odour response; however, that is a separate matter and this document does not provide guidance on the health effects of odours.

2.2 A basic understanding of odour

2.2.1 The subjective nature of odour

Most odours are mixtures of many chemicals that interact to produce what we detect as a smell. A distinction should be made between: odour-free air, containing no odorous chemicals; and fresh air, usually perceived as being air that contains no chemicals or contaminants that are unpleasant (i.e. air that smells 'clean'). Fresh air may contain odorous chemicals, but these odours will usually be pleasant in character, such as freshly-mown grass or sea spray. Perceptions of an odour - whether it is found to be acceptable, objectionable or offensive - are partly innate and hard-wired, and partly determined through life experiences and hence can be subjective to the individual.

2.2.2 Odour exposure

Before an adverse effect (such as disamenity, annoyance, nuisance or complaints) can occur, there must be odour exposure. For odour exposure to occur all three links in the source-pathway-receptor chain must be present:

a) an emission **source** - a means for the odour to get into the atmosphere.

b) a **pathway** - for the odour to travel through the air to locations off site, noting that:

- anything that increases dilution and dispersion of an odorous pollutant plume as it travels from source to receptor will reduce the concentration at the receptor, and hence reduce exposure.
- increasing the length of the pathway (e.g. by releasing the emissions from a high stack) will – all other things being equal – increase the dilution and dispersion.

c) The presence of **receptors** (people) that could experience an adverse effect, noting that people vary in their sensitivities to odour.

The scale of exposure (the impact) is determined by the parameters collectively known as the FIDO factors (Frequency, Intensity, Duration and Offensiveness; these are described in **Table 1**. The magnitude of the effect experienced is determined by the scale of exposure (FIDO) and the sensitivity of the receptor (L, denoting the location, which is often taken to be a surrogate for the sensitivity and incorporates the social and psychological factors that can be expected for a given community.) **Figure 1** depicts how the human appraisal of the FIDOL factors and social and psychological factors determines whether an odour has an adverse odour impact and an objectionable effect.

Different combinations of the FIDO factors can result in different exposures at a location. For example, odours may occur as a one-off, as frequent short bursts, or for longer, less-frequent periods, and may be said to give 'acute' or 'chronic' exposures respectively.

2.2.3 Adverse effects of odour

The odour effect we need to be concerned with is the negative appraisal by a human receptor of the odour exposure. This appraisal, occurring over a matter of seconds or minutes, involves many complex psychological and socio-economic factors. Once exposure to odour has occurred, the process can lead to adverse effects such as disamenity, annoyance, nuisance and possibly complaints (see **Glossary** for definitions). It is important to emphasise the technical differences* between annoyance and nuisance[6]:

- annoyance – the adverse effect occurring from an immediate exposure; and
- nuisance - the adverse effect caused cumulatively, by repeated events of annoyance.

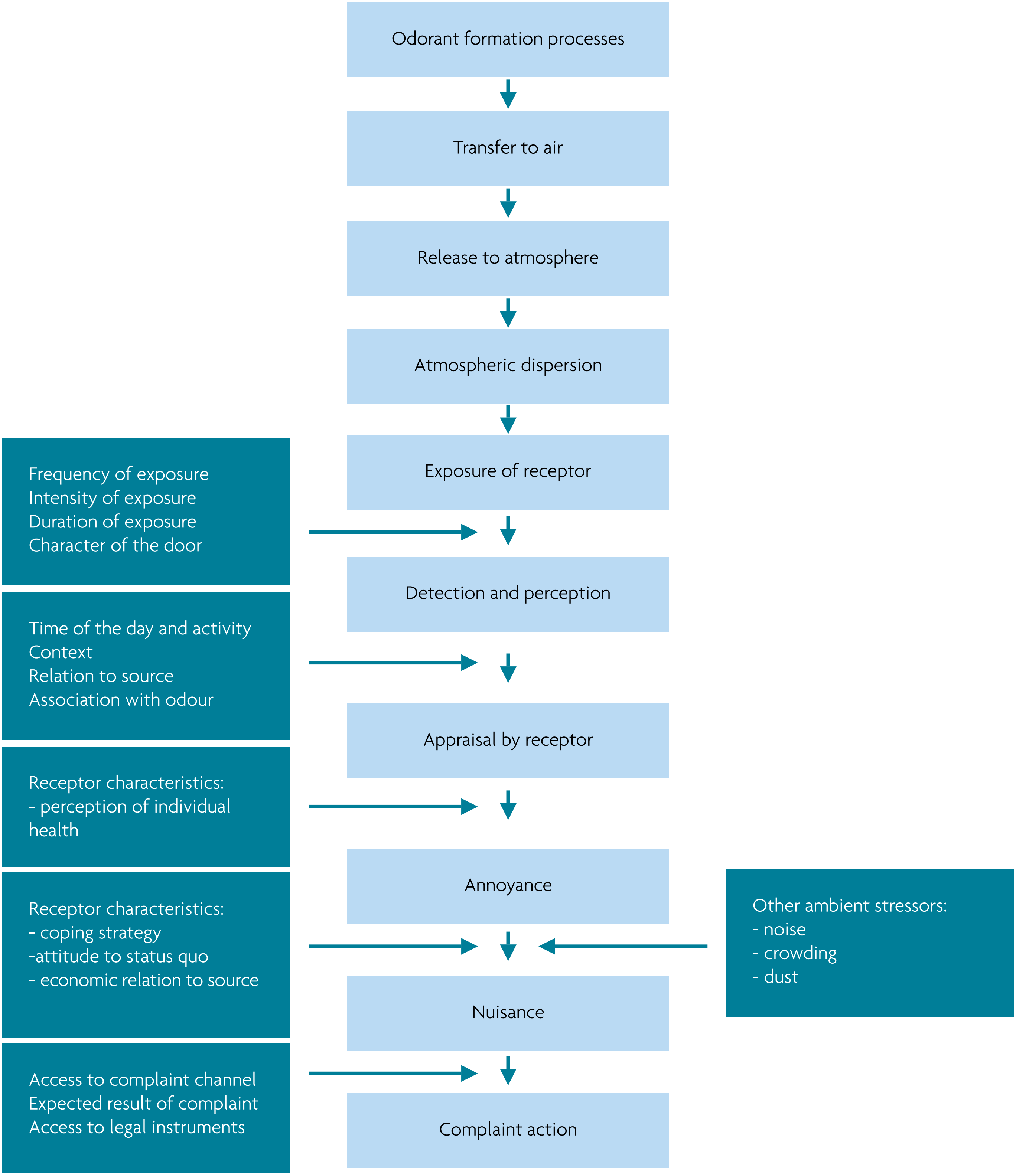
Planning policy[7] requires that the effects of pollution on health, the natural environment or general **amenity** should be taken into account.

* A complicating factor is that as well as the technical definition, nuisance is also a term in law (e.g. Statutory Nuisance). The legal use of Nuisance has preceded the technical definition of nuisance described here, which has only relatively recently been put forward and generally accepted. The definition of Statutory Nuisance covers seven areas, and that which relates to odour is (s.79(1) EPA 1990): "any dust, steam, smell or other effluvia arising on industrial, trade or business premises and being prejudicial to health or a nuisance;" The EPA 1990 contains no technical definitions of nuisance, such as maximum concentrations, frequencies or durations of odour in air and only the Court can decide whether a legal Nuisance is being caused. It should be noted that unless stated otherwise this Guidance uses the phrase odour nuisance in a general sense.

Table 1: Description of the FIDOL factors

Frequency	How often an individual is exposed to odour
Intensity	The individual's perception of the strength of the odour
Duration	The overall duration that individuals are exposed to an odour over time.
Odour unpleasantness	Odour unpleasantness describes the character of an odour as it relates to the 'hedonic tone' (which may be pleasant, neutral or unpleasant) at a given odour concentration/ intensity. This can be measured in the laboratory as the hedonic tone, and when measured by the standard method and expressed on a standard nine-point scale it is termed the hedonic score.
Location	The type of land use and nature of human activities in the vicinity of an odour source. Tolerance and expectation of the receptor. The 'Location' factor can be considered to encompass the receptor characteristics, receptor sensitivity, and socio-economic factors.

Figure 1: From odour formation to complaint (Van Harrevelt, 2001)[6]



Loss of amenity or disamenity does not equate directly to nuisance and significant loss of amenity will often occur at directly lower levels of odour exposure than would constitute a statutory nuisance.

Both, or either, annoyance and nuisance can lead to complaint action. However, a lack of complaints does not necessarily prove there is no annoyance or nuisance, or loss of amenity. On the other hand, there needs to be an underlying level of annoyance before complaints are generated. Furthermore, people`s annoyance and nuisance responses can change over time. The appraisal is influenced by a wide range of factors including history of exposure. This is important to bear in mind when interpreting odour complaints. The complaints can, in rare circumstances, represent a reaction to a single odour exposure event. However, complaints are generally a public expression of concern over odour exposure that has been experienced over a much longer period of time, leading to the incremental development of annoyance. Once someone reaches the point of annoyance, they may then start to complain about odours that would not normally bother other members of the population. The lesson is, complaints in the present are likely to be strongly associated with events in the past.

REFERENCES

[1] Environment Agency, H4 *Odour Management* (March 2011).
[2] SEPA, *Odour Guidance* (January 2010).
[3] Defra, *Good Practice and Regulatory Guidance on Composting and Odour Control for Local Authorities* (March 2009).
[4] Defra, Odour Guidance for Local Authorities (March 2010).
[5] Defra, Guidance on the Control of odour and Noise from Commercial Kitchen Exhaust Systems
[6] Van Harreveld A.P., *From Odorant Formation to Odour Nuisance: New Definitions for Discussing a Complex Process*, Water Science and Technology, Vol.44, No.9, pp9-15 (2001)
[7] National Planning Policy Framework, DCLG, March 2012.

3. Assessment of odour

3.1 Content of an odour assessment for planning

An assessment of the impact and resulting effects of an odour source on surrounding users of the land will usually contain the following major elements:

1. A description of existing baseline odour conditions (including complaints history) where relevant*.

2. A description of the location of receptors and their relative sensitivities to odour effects.

3. Details of potential odour sources (whether existing or proposed), including the activities and materials involved (including a brief outline of quantities, durations, methods of handling and storage, etc) and the resulting potential for generating odours, covering fugitive sources, diffuse sources and point sources as applicable.

4. A description of control/mitigation measures incorporated into the scheme (including management controls and, where appropriate, engineering controls).

5. A prediction or observation (or combination of both), using appropriate assessment tools, of the likely odour impact and resulting effects at relevant sensitive receptors, and taking into account:

   a. the likely magnitude of odour emissions (after control by measures incorporated into the scheme, if applicable);

   b. the likely meteorological characteristics at the site;

   c. the dispersion and dilution afforded by the pathway to the receptors and the resulting magnitude of odour that could result;

   d. the sensitivity of the receptors (See **Table 2**); and

   e. the potential cumulative odour effects with any odours of a similar character, (e.g. if odours from kitchen waste are in addition to an existing municipal solid waste throughput.)

6. Where odour modelling has been used the reports should contain full details of the input data and modelling options used to allow a third party to reproduce the results.

7. Where odour effects are assessed as significant, details of appropriate further mitigation and control measures that could allow the proposal to proceed without causing significant loss of amenity.

8. The residual odour impacts and their effects (see **Box 1**).

9. A conclusion on the significance of the residual effect, i.e. whether "significant" or "not significant".

To make the predictions or observations in Point 5 above, Air Quality Practitioners need to use at least one odour assessment tool that takes the FIDOL factors into account. A number of odour assessment tools exist and will be considered later in this guidance. Atmospheric dispersion modelling has a very important role to play because it can (in appropriate situations) forecast odour exposure over a wide study area and over a long timeframe; however, other assessment tools exist that can complement modelling, or can in certain circumstances be more appropriate than modelling. Because the various assessment tools have different applications, strengths and limitations, they are often used in combination (see next section).

In the Methodology section of the report or ES chapter, the Air Quality Practitioner should justify the following:

- why the chosen odour assessment tools have been used and why they are suitable for the assessment in question; and
- that the approach used is of a depth and rigour consistent with the likely risk of adverse effects.

*Noting that odours are not usually additive in their impacts unless they are of a similar character.

Box 1: Definitions of impacts and effects used in this guidance

IEMA Guidelines for Environmental Impact Assessment (2004) recommend a clear progression from the characterisation of "impact" to the assessment of the significance of the "effect" taking into account the evaluation of the sensitivity and value of the receptors. The guidelines emphasise the need to clearly define at the outset how the two terms will be used and then to apply them in a consistent fashion. In this IAQM guidance, the following definitions are used:

- **Impacts** – these are changes to the environment attributable to the development proposal.
- **Effects** – these are the results of the changes on specific receptors.
- **Receptors** - are the users of the adjacent land, which may vary in their sensitivity to odour.

An increase in odour levels (the impact) would therefore cause a particular effect (e.g. loss of amenity) if the adjacent land use was residential, and perhaps a lesser effect if the adjacent land use was an industrial facility.

Table 2: Receptor sensitivity to odours

For the sensitivity of people to odour, the IAQM recommends that the Air Quality Practitioner uses professional judgement to identify where on the spectrum between high and low sensitivity a receptor lies, taking into account the following general principles:

High sensitivity receptor	Surrounding land where: • users can reasonably expect enjoyment of a high level of amenity; and • people would reasonably be expected to be present here continuously, or at least regularly for extended periods, as part of the normal pattern of use of the land. Examples may include residential dwellings, hospitals, schools/education and tourist/cultural.
Medium sensitivity receptor	Surrounding land where: • users would expect to enjoy a reasonable level of amenity, but wouldn't reasonably expect to enjoy the same level of amenity as in their home; or • people wouldn't reasonably be expected to be present here continuously or regularly for extended periods as part of the normal pattern of use of the land. Examples may include places of work, commercial/retail premises and playing/recreation fields.
Low sensitivity receptor	Surrounding land where: • the enjoyment of amenity would not reasonably be expected; or • there is transient exposure, where the people would reasonably be expected to be present only for limited periods of time as part of the normal pattern of use of the land. Examples may include industrial use, farms, footpaths and roads.

3.2 General approach to assessing odour effects for planning

Being able to use the assessment tools and understanding the meaning of the results are two distinct skills. Most of the odour assessment tools measure odour exposure (i.e. impact), or some other parameter; very few of the tools measure the resulting *effect* (e.g. annoyance or nuisance) directly - and none measures disamenity specifically. Nevertheless, planning policy (NPPF, Para 120), requires that it is the *effects* of pollution on health, the natural environment or general amenity thasshould be taken into account. Furthermore, the EIA regulations require that an assessment reaches a conclusion on the likely *significance* of the effect. Therefore an assessment has to to go further than simply estimating the odour exposure/impact and attempt to gauge the *magnitude of the effect* resulting from that impact on a receptor of a particular sensitivity. This is a matter of judgement that cannot easily be defined by scientific methods alone and ideally requires a wider societal or stakeholder consensus to be arrived at. It is generally agreed that a high sensitivity receptor subject to a large odour exposure will experience a substantial-adverse effect, and a low sensitivity receptor subject to a small odour exposure will experience a negligible effect; however, between these extremes the various combinations will give rise to a gradation of effects for which no descriptor terms have been universally agreed. **Table 3** shows the IAQM's proposed general framework of descriptors for the magnitude of effects for receptors of different sensitivities receiving different odour exposures. This framework will be kept under review to benefit from the feedback of affected or interested parties.

Table 3 describes a general relationship between the level of odour exposure (impact) experienced by a receptor of a given sensitivity and the magnitude of adverse effect that is likely to result. This general relationship for an odour* will hold irrespective of the particular tool or method (e.g. modelling, qualitative assessment, or monitoring) that has been used. It is necessary to ensure that the result from whichever assessment tool is used, is properly matched up to the correct descriptor term (i.e. very large, large, medium, small or negligible exposure) on the exposure/impact scale#. This is covered in detail in the later sections and appendices of this guidance.

* A different relationship may hold for other pollutants, e.g. dusts or chemical species. For example, exposure to very toxic chemicals may cause a highly significant effect at even small levels of exposure.
# The effects matrices for different tools, although based on Table 3, will not necessarily be identical because different tools may cover different parts of the odour exposure scale.

Table 3: IAQM suggested descriptors for magnitudes of odour effects

		Receptor Sensitivity		
		Low	**Medium**	**High**
Relative Odour Exposure (Impact)	**Very Large**	Moderate adverse	Substantial adverse	Substantial adverse
	Large	Slight adverse	Moderate adverse	Substantial adverse
	Medium	Negligible	Slight adverse	Moderate adverse
	Small	Negligible	Negligible	Slight adverse
	Negligible	Negligible	Negligible	Negligible

Applicable to odours at the "most offensive" end of the relative-unpleasantness spectrum

The EIA regulations require an assessment to reach a conclusion on the likely significance of the predicted effect. Where the overall effect is greater than "slight adverse", the effect is likely to be considered significant. Note that this is a binary judgement: either it is "significant" or it is "not significant". Concluding that an effect is significant should not mean, of itself, that a development proposal is unacceptable and the planning application should be refused; rather, it should mean that careful consideration needs to be given to the consequences, scope for securing further mitigation, and the balance with any wider environmental, social and economic benefits that the proposal would bring.

4. Using odour assessment tools

4.1 The need to combine odour assessment tools

The preference towards combining a number of assessment tools within the study is a feature that often distinguishes odour assessments from conventional air quality assessments.

Some odour assessment tools are empirical - observing the current odour impacts or effects, by monitoring or by using community assessment techniques. In contrast, other tools make use of a "model" – a simplified version of the real situation – to predict what the impact might be. All odour assessment tools, whether models or empirical observations, have a degree of uncertainty associated with their estimates of impact.

Models can range from a simple qualitative representation of the Source-Pathway-Receptor (S-P-R) concept, through semi-quantitative look-up tables or screening nomographs, to quantitative atmospheric dispersion models; from this point the term 'modelling' refers solely to the use of an advanced atmospheric dispersion model.

Modelling is a valuable tool and plays a major role in odour assessment; however, it is important to remember that models, even though quantitative, are a simplification of the real situation. If the model is a good representation of the system in operation (the odour release and its dispersion in the atmosphere) and the assumptions and input data are reasonable, then we can use models to make predictions of what might happen. On the other hand, if these criteria are not met (because for example odour impacts are dominated by unpredictable, unplanned or accidental releases), then we simply end up predicting the wrong answer very precisely! Even when the model is a good representation of the real situation and the assumptions and input data are reasonable, the uncertainty for predictions from dispersion modelling can be considerable. It therefore useful to use empirical, observational tools where they are available and applicable, and combine these with modelling where appropriate. In some instances empirical results from observational tools can be used to corroborate or check the reasonableness of the predictions. For example, some water companies plot modelling contours of odour concentration together with complaint locations in order to identify a site-specific concentration associated with complaints, based on the benchmark principle given in the UKWIR guide[8]. However, it should be borne in mind that many of the empirical tools themselves also have considerable uncertainty associated with them.

Further drivers for using multiple assessment tools within a study are:

- the partly subjective nature of odour and the wide differences that exist in population response; and
- the fact that there is no "silver bullet" assessment tool that on its own provides an unequivocal answer - results from each of the different techniques tend to give information only on some limited aspect of the odour impact or effect.

Fortunately, these different assessment tools are not mutually exclusive and using them in combination can minimise individual limitations and increase confidence in the overall conclusion. Best practice is to use a multi-tool approach where practicable. This is consistent with the former Defra Code of Practice on Odour Nuisance from Sewage Treatment Works[9].

4.2 Overview of the odour assessment tools available

In this guidance, the assessment tools have been grouped into either predictive or observational/empirical (**Table 4**). This grouping matches the two main scenarios practitioners will be called on to consider (i.e. a new odour source, or an existing odour source).

Appendix 1 provides further details on predictive tools; and

Box 2: Example of multi-tool odour assessment of site suitability

The benefits of the multi-tool assessment approach are illustrated by the following example - assessing the impact on proposed development land around an existing odour source:

- Monitoring (e.g. sniff tests) can give a measure of odour at specific locations under the conditions prevailing at the times and days of the sampling, but cannot cover all receptor locations under every meteorological condition over a typical year.
- Complementing monitoring with dispersion modelling provides greater spatial and temporal coverage and the reasonableness of the estimates from the model can be compared with the observed (i.e. monitored) levels.
- Modelling (and probably monitoring) is only likely to characterise normal operations of the odour source, whereas it is known that unexpected events (e.g. breakdowns) and abnormal operations at some facilities can account for a significant proportion of high odour episodes. If there are already receptors in the locality, analysis of historical complaints data can provide an alternative perspective on the impact that is inclusive of such unexpected events and abnormal operations.

Appendix 2 on sniff testing, a key observational tool.

Each has its own strengths, limitations, and preferred applications. Using tools from both of these categories will usually improve confidence in the conclusions reached.

The observational/empirical tools, by definition, require some form of measurement of ambient odour levels at sensitive receptors local to the source. This is challenging due to:

- the nature of odour exposure – it is perceived over very short time periods (as short as a few seconds), making most conventional sampling periods (where the sample is averaged over hours to weeks) inappropriate; and
- the difficulty of measuring odour at ambient levels – no analytical techniques can currently match the sensitivity, speed of response and breadth of application of the human nose.

These difficulties influence strongly the choice of tools available to us to directly measure/observe odour levels at receptors. The observational/empirical measurement tools tend to fall into two categories:

a) **conventional monitoring approach**, where the Air Quality Practitioner makes the odour measurements in the field, (e.g. using sniff tests, field olfactometry or chemical compound analysis); and

b) **community assessment approach**, which uses public responses as raw data (e.g. odour diaries, attitude surveys, or complaints monitoring).

It should be noted that it is not possible to monitor ambient odour at receptors as the 98th percentile of 1-hour mean concentrations: concentration benchmarks expressed in this form are designed for use with predictive dispersion modelling, not monitoring.

Table 4: Summary of odour assessment tools

Type	Approach	Tool		Notes
Predictive	Qualitative	Risk-based assessments using Source-Pathway-Receptor concept		A relative risk score or descriptor (e.g. negligible, low, medium or high-risk impact)
	Semi-quantitative	Screening models, look-up tables and nomographs		Estimated concentration
	Modelling	Atmospheric dispersion modelling with ADMS, AERMOD, etc using source terms that have been measured by Dynamic Dilution Olfactometry (DDO) or using literature values.		Predicted concentrations (ou/m^3), usually as 98th percentiles of 1-hour means
		CFD tools		Image representation of flow patterns
Observational /Empirical	Monitoring of odour in ambient air	Sensory	Sniff Tests	Odour exposure inferred from measurements of intensity, frequency, duration, offensiveness.
			Field Olfactometry	Odour exposure inferred from measured concentration (Dilutions-to-Threshold, similar to (ou/m^3), together with frequency, duration, offensiveness.
		Compound analysis	H_2S by gold-film analyser	Odour exposure inferred from measured concentration (μg/m^3) and odour detection threshold, together with frequency, duration,
			VOCs, etc analysis	
	Actively using the community as the "sensor"	Odour diaries		Days (%) on which odour detected above a given intensity
		Community surveys		% annoyed or % experiencing nuisance
	Passively using the community as the "sensor"	Complaints analysis		Frequency of complaints

4.3 Selecting the appropriate odour assessment tools

In designing the odour assessment strategy, the Air Quality Practitioner needs to select odour assessment tools that suit the study situation. It is therefore normal practice for practitioners to consult with the Local Planning Authority (and/or its air quality specialists) and other statutory consultees to gain agreement on the approach and methodology that will be used. The air quality section of the National Planning Practice Guidance (NPPG) notes that "The scope and content of supporting information is therefore best discussed and agreed between the local planning authority and applicant before it is commissioned."[10] For assessments of development site suitability around existing odorous activities, the process operator (e.g. a water company operating an existing wastewater treatment works) may also have an opinion on their own guidance on what should go into the assessment if they are not to dispute the results and potentially object to the application at planning. Ultimately though, it is up to the Planning Applicant to decide on how much weight they wish to give to the views of third-party organisations on the approach they will be using, informed by the professional judgement of their Air Quality Practitioner.

The following step-wise approach may be used as a guide:

Step 1 – Predictive tools alone, or predictive tools with empirical observations?
Some tools can only be used for certain scenarios, so the first point to consider is whether the assessment is of the impact of a proposed (i.e. future) odorous development on surrounding receptors, or whether the assessment is of the suitability of proposed development land (e.g. for residential dwellings) around an existing odour source:

- *For assessing the impact of a future odorous development* No empirical observations will be available (unless from a similar "surrogate" site that is currently operating) and odour effects will need to be forecast using predictive tools (e.g. qualitative risk based assessments, dispersion modelling).

- *For assessing site suitability of proposed development land (e.g. residential) around an existing odour source* Where there is an existing odour source, the odour effect would normally be assessed using predictive methods (which may be qualitative or modelling) to complement observational methods. Ideally, where we could make many measurements spatially and temporally, empirical observations alone would suffice and would likely be preferred to a prediction; however, that is rarely practicable within the constraints of a planning application timetable and budget. The compromise is to use predictive methods (e.g. modelling) to improve the spatial and temporal coverage of limited empirical observations. Nevertheless, in most circumstances at least some observations (such as complaints analysis and sniff tests) can usually be accommodated even with the most time-constrained application timetable.

Step 2 – Select which assessment tools are suited
Having narrowed the choice to either predictive assessment tools alone, or predictive plus empirical tools, the next step is to select which of the tools are well suited and to exclude any that are not suited or practically available. More detail on this is given in **Appendix 1** and **Appendix 2**.

Step 3 – Decide how many assessment tools are needed
Next, the practitioner must decide how many of these tools it is necessary to use in the assessment in order to provide a robust body of evidence on which to base the conclusion of impact. This should be based on the potential of the proposed development to cause, or experience, adverse odour effects:

- if there is a low likelihood (risk) of adverse odour effects, then a single assessment tool may suffice and/or they may be more qualitative than quantitative.

- on the other hand, if there is a high potential for adverse odour effects (e.g. there are sensitive receptors relatively close to a source of significant magnitude), then a combination of assessment tools may be required to provide an adequate body of evidence and/or the tools are likely to include quantitative techniques.

This meets the requirements in the air quality section of the NPPG for assessments to "be proportionate to the nature and scale of development proposed and the level of concern"[10]

Deciding on the potential for adverse odour effects itself requires some initial assessment or professional judgement. Often, the best approach is to carry out a screening assessment before deciding whether a more detailed assessment is necessary based on whether there is likely to be a significant risk of an odour impact.

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5. Odour benchmark/odour assessment criteria

5.1 Introduction

Benchmark criteria exist for a number of odour assessment tools; however, this section focuses on numerical (concentration) limits set as assessment criteria specifcally for dispersion modelling studies and examines:

- Criteria that have been applied in the UK and Europe to date;
- Differences between amenity, annoyance and nuisance;
- Efficacy of absolute odour concentration limits and limits based upon concentration exceedence thresholds (the percentile approach);
- The underlying body of available technical evidence from the UK and Europe;
- Criteria established in other countries; and
- Recommendations for the use and application of criteria in odour assessments.

5.2 Criteria developed in the UK & Europe

In 1993, during a Public Inquiry into a planning application an odour criterion of 5 ou/m^3, as a 98th percentile of hourly means over a calendar year* was proposed by the applicant and accepted by the Inquiry Inspector[11], as follows: "*There are no guidelines against which to assess odour emissions. However, the technique (olfactometry) defines a "faint odour" as one lying within the range of 5-10 ou/m*$^{-3}$. *While a particularly sensitive person could detect an emission level as low as 2 ou/m*$^{-3}$*, it seems to me that adoption of a level of 5 ou/m*$^{-3}$ *for the appeal site proposals is both reasonable and cautious*".

This criterion was proposed based upon data from 200 sites in the Netherlands and it is not clear what is the original source reference for this.

The wording of the Inspector's endorsement is perhaps indicative of the relative novelty of odour assessment at that time, in that it would appear that the concept of the 98th percentile metric has not been appreciated. While it is acknowledged that 5 ou/m^3 is designated as a faint odour, it can be the 2% of hourly average odour concentrations above that level that largely determine a population response.

Results of studies and criteria published prior to the publication and wider application of the current CEN Standard method (BSEN13725:2003) on olfactometry should be interpreted cautiously . There is an important difference between the panel olfactory results obtained by using the Dutch "pre-standard" and results obtained using current day olfactometric procedures based upon the CEN Standard.

In practical terms, the scientific method of determining a relationship between odour concentration, frequency of occurrence and annoyance or nuisance is to carry out exposure-response studies, where the odour emissions from a facility can be quantified, the local population is interviewed and their reactions to the odour are characterised (such as those described in **Appendix 2**). It is then possible to postulate a relationship between odour exposure (the concentration of odour experienced by a member of the population) and their response to it, in terms of annoyance.

Miedema & Ham[12] carried out an initial exposure-response study, where odours arising from three different types of source (rapeseed oil production, electrical wire insulation plant and a pig farm) were considered. In this study, exposure was determined by measurement of emissions and use of a dispersion model, calculating the 98th percentile (C_{98}) value of hourly average odour concentrations. This was combined with a questionnaire survey of the affected populations in the vicinity of the three odour sources, which classified the degree of annoyance felt by the respondent into five categories:

- Not annoying;
- Just not annoying;
- Just annoying;
- Annoying; and
- Very annoying.

A mathematical relationship was then established between the level of odour exposure calculated by the dispersion modelling and the percentage of the interviewed population. A good relationship between the C_{98} odour concentration and percentage of the population annoyed was established, with a correlation coefficient of 0.9.

The key points arising out of this analysis were as follows:

- At a C_{98} of 5 ou/m^3, approximately 10% of the interviewed population was annoyed or very annoyed;
- It appeared that differences in the nature of the odours from the three sources had no effect upon the level of annoyance;
- Different responses to the quality of odours under previous laboratory test conditions were not replicated in this study, indicating that in the real world, differences between odours may not be important;
- It was concluded that, from the results of the questionnaire survey, every industrial odour was considered by respondents to be out of place in residential areas; and

* What this means in simple terms is that an odour concentration of 5 ou/m3 should not be exceeded for more than 2% of the hours in a year at any sensitive receptor outside the site boundary, equivalent to approximately 175 hours per annum.

To set an odour standard, it was necessary to decide what level of odour is just acceptable.

Subsequent work in this area by Miedema *et al*[13] set out to determine the relationship between odour "pleasantness" and odour annoyance response, using 12 different odour sources. This study identified, using two separate pleasantness scoring techniques, that there were definite differences in response, in terms of the levels of annoyance felt by respondents between the odours.

Taking all 12 odours into account, a relationship between the percentage of the population "highly annoyed" and the C_{98} value was determined by various mathematical models, with regression coefficients (r^2) of between 0.838 and 0.897 (where 1 is a perfect match).

When the pleasantness scores were incorporated into a model, the regression coefficients increased to between 0.921 to 0.945, at C_{98} odour concentrations from 10 to 59 ou/m^3.

The key conclusions were:

- The percentage of the population highly annoyed (%HA) by odours increases as a quadratic function of the log of C_{98} and the rate of increase in %HA was higher for the less pleasant odours; and
- It was therefore concluded that further work was required to more closely define the relationship between odour annoyance and odour pleasantness.

A study of 2,300 residents exposed to odours from pig farms in the Netherlands was reported by Bongers *et al*[14], in which residents were subdivided into three categories in order to incorporate contextual factors into the odour dose-response relationship. The subdivisions were thosing living in:

- "non-concentration areas", where the number of pig farms was small;
- "concentration areas", with no connection with the pig production industry, where the number of long-established pig farms was high and; and
- "concentration areas" with a direct connection with the pig production industry.

In summary, the study found that, perhaps unsurprisingly, the population in non-concentration areas were the most sensitive to odours, whilst those for whom pig odours were a familiar aspect of their lives were least sensitive.

The findings of this research were subsequently used in the formulation of policy for the control of odours from pig farming in Ireland[15], where the following odour criteria were proposed, having previously been developed and reported in a 2002 document[16]:

- Target value: C_{98}, 1-hour ≤ 1.5 ou_E/m^3. The target value provides a general level of protection against odour annoyance for the general public, aiming to limit the percentage of people experiencing some form of odour-induced annoyance to 10% or less;
- C_{98}, 1-hour ≤ 3.0 ou_E/m^3 - Limit value for new pig production units; and
- C_{98}, 1-hour ≤ 6.0 ou_E/m^3 - Limit value for existing pig production units.

5.3 Pollution control regulation and guidance

The original study outputs were also used to inform the odour guidance for the EPR permitting regime in England & Wales. However, in this case, the above differential criteria were extended to apply as benchmarks for a wide range of odours other than those from pig farming. The means by which this transformation was achieved is reported in an Environment Agency R&D report[17] and involved the categorisation of the hedonic tones of a range of odours and then relating these back to pig farm odours.

The guidance also contained advice to the effect that the indicative criteria could be tightened, depending upon local conditions, by reducing the criteria by 0.5 ou_E/m^3 in each case, although the technical basis for this is not clear. Whilst not explicitly mentioned in the document, it would appear that criteria could also be relaxed, depending on local conditions. These criteria were then carried forward into the final version of the H4 guidance[18], as shown in **Table 5**. It is useful to note that in the Environment Agency`s original draft H4 the C_{98}, 1-hour benchmark concentrations were described as Indicative Odour Exposure Standards, to be used as defaults where no sector- or site-specific dose response relationships had been carried out to provide more specific benchmarks. In the final version (2011) of H4, however, the "indicative" label was not used and the criteria are simply referred to as Benchmark Levels to help inform a judgement of unacceptable pollution.

Research published in 2004[19] determined that there was very little difference between the annoyance impact of unpleasant or neutral odours. In addition, it was found that for pleasant odours hedonic tone has a clear effect on the dose-response relationship and pleasant odours have a significantly lower annoyance potential (at the same frequency) than unpleasant ones.

5.4 Water industry guidance

In 2007, Defra published *Code of Practice on Odour Nuisance from Sewage Treatment Works (STW)*, which provides both general and specific advice to local authorities and STW operators for the avoidance of odour nuisance. It does not, however, provide guidance on what are acceptable odour annoyance criteria, in terms of odour concentrations. In Section 3.3 "Planning Controls and Amenity", it is stated:

"The occupiers of any new development are likely to expect and demand high amenity standards and this could result in complaints."

No guidance is offered as to where, on the scale of concentrations, a standard should be set.

5.5 CIWEM position policy statement

Guidance was produced in 2012 by the Chartered Institution of Water and Environmental management (CIWEM) for application to waste water treatment sites[20]. CIWEM's position on odour impact criteria is summarised in the document as follows: *"CIWEM considers that the following framework is the most reliable that can be defined on the basis of the limited research undertaken in the UK at the time of writing:*

- *C_{98}, 1-hour >10ou$_E$/m^3 - complaints are highly likely and odour exposure at these levels represents an actionable nuisance;*
- *C_{98}, 1-hour >5ou$_E$/m^3 - complaints may occur and depending on the sensitivity of the locality and nature of the odour this level may constitute a nuisance; and*
- *C_{98}, 1-hour <3ou$_E$/m^3 - complaints are unlikely to occur and exposure below this level are unlikely to constitute significant pollution or significant detriment to amenity unless the locality is highly sensitive or the odour highly unpleasant in nature."*

The CIWEM Position Statement was produced in 2012 by a group of odour assessment practitioners. The statement is based on their interpretation of the available evidence at the time and the experience of members of the group. No new research was used to produce this statement.

5.6 Recommended odour assessment criteria for planning

Odour assessment methodology, as it has developed in Europe and UK over the last 35 years, has become well-established. The predictive, quantitative approach involves obtaining estimates of the odour source emission rate, use of the emissions in a dispersion model to predict 98th percentile concentration at sensitive receptors and comparison of these with criteria that have evolved from research and survey work. At the present time, this remains an accepted technique and the IAQM supports this.

Table 5: H4 Benchmark odour criteria

Criterion, C_{98} ou$_E$/m^3	Offensiveness	Odour Emission Sources
1.5	Most Offensive	Processes involving decaying animal or fish remains Processes involving septic effluent or sludge Biological landfill odours
3.0	Moderately Offensive	Intensive livestock rearing Fat frying (food processing) Sugar beet processing Well aerated green waste composting
6.0	Less Offensive	Brewery Confectionery Coffee

What is not entirely clear from the scientific data, is the level at which the odour concentration should be set and whether different concentrations should be set for different odours and in different settings. In addition, it appears that the C_{98} metric is predicated on the basis of a constant odour emission, whereas many odour emissions are intermittent or only occur for certain periods within a calendar year. In this case, the situation can arise where, over the year, a C_{98} concentration of, say, 3 ou$_E$/m^3 may be complied with but, over the period for which the odour is emitted, it may be exceeded.

The body of research that supports the adoption of numerical odour assessment criteria is incomplete, in that appropriate and reliable dose-response survey work has not been carried out in the UK and the criteria that have been used by practitioners have been derived from source-specific work carried out on a limited range of odour-emitting processes, notably in the Netherlands, using older-generation dispersion models.

In the absence of comprehensive dose-response information to allow the derivation of exact C_{98} concentration metrics for different types of odour, IAQM is of the opinion that the practitioner should observe, from the various scientific studies, case law and practical examples of the investigation of odour annoyance cases, that in any specific case, an appropriate criterion could lie somewhere in the range of 1 to 10 ou_E/m^3 as a 98th percentile of hourly mean odour concentrations.

In deciding upon what constitutes an appropriate criterion, account should be taken of the underlying exposure-response studies that have led to the H4 recommended indicative criteria and more recent research work from Germany.

Taking into account the available scientific evidence and the collective experience of IAQM members involved in drafting this guidance, the odour concentration change descriptors together with impact descriptors in **Table 6** are proposed for an odour at the offensive end of the spectrum. These adopt the C_{98} as the appropriate frequency metric, encompasses the 1 to 10 ou_E/m^3 concentration range referred to above and also considers also the potential sensitivity of different receptors. It is also consistent in format and concept with other guidance in the air quality field. Examples of receptors that fall into the above sensitivity categories are contained in **Table 2**.

For odours that are less unpleasant, the level of odour exposure required to elicit the same effect may be somewhat higher, requiring professional judgement to be applied. For example, odours from sewage treatment works plant operating normally, i.e. non-septic conditions, would not be expected to be at the 'most offensive' end of the spectrum (**Table 5**) and can be considered on par with 'moderately offensive' odours such as intensive livestock rearing. **Table 7** below shows the impact descriptors proposed for a 'moderately offensive' odour."

It is incumbent on the responsible practitioner to exercise good professional judgement in selecting an appropriate odour assessment criterion for any particular case and providing justification for that selection. Practitioners are also recommended to exercise such judgement in appreciating other factors which govern human responses to odour. It is not simply the presence of odours that govern the responses of individual population members to malodour, but many other socio-psychological factors[21], including the existence of health conditions, beliefs regarding the alleged harmfulness of the odorants, individual coping behaviours and other demographic and social factors, and the variation in the sensitivity of sense of smell in the general population.

This could result in the application of odour exposure criteria that may appear, on the basis of the studies carried out to date, to be erroneous. Such a case has occurred recently, as reported in a Defra publication[22], where a concerted and comprehensive odour emission sampling and modelling campaign revealed C_{98} concentrations well below the most stringent 1.5 ou_E/m^3 criterion, but where up to 50 complaints about odour per day arose. Similarly, another recent study found numerical odour criteria did not predict complaints around sewage works.[23]

The practitioner needs to take into account the uncertainty of the prediction and/or the degree to which conservative assumptions have been used.

Table 6: Proposed odour effect descriptors for impacts predicted by modelling – "Most Offensive" odours

Odour Exposure Level C_{98}, ou_E/m^3	Receptor Sensitivity		
	Low	Medium	High
≥10	Moderate	Substantial	Substantial
5-<10	Moderate	Moderate	Substantial
3-<5	Slight	Moderate	Moderate
1.5-<3	Negligible	Slight	Moderate
0.5-<1.5	Negligible	Negligible	Slight
<0.5	Negligible	Negligible	Negligible

It should be noted that the Table applies equally to cases where there are increases and decreases in odour exposure as a result of this development, in which case the appropriate terms "adverse" or "beneficial "should be added to the descriptors.

Table 7: Proposed odour effect descriptors for impacts predicted by modelling – "Moderately Offensive" odours

Odour Exposure Level C_{98}, ou_E/m^3	Receptor Sensitivity		
	Low	Medium	High
≥10	Moderate	Substantial	Substantial
5-<10	Slight	Moderate	Moderate
3-<5	Negligible	Slight	Moderate
1.5-<3	Negligible	Negligible	Slight
0.5-<1.5	Negligible	Negligible	Negligible
<0.5	Negligible	Negligible	Negligible

It should be noted that the Table applies equally to cases where there are increases and decreases in odour exposure as a result of this development, in which case the appropriate terms "adverse" or "beneficial "should be added to the descriptors.

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6. Drawing conclusions from assessment results

The conclusion on the overall significance of likely odour effects will usually involve the practitioner drawing together the findings of several odour assessment tools, each of which have their own inherent strength and weakness and uncertainties*. This "weight-of-evidence" approach differs from conventional air quality assessments, where the conclusion is usually based on the results of one (or a couple at most) assessment tool to which considerable precision and accuracy (i.e. certainty) is ascribed.

When coming to a conclusion on odour impact, the practitioner also needs to give the right amount of weight to the results provided by each tool according to how well-suited it is to the study scenario in question.

For instance, where the assessment is of an existing activity or process, empirical observations will usually be possible of what is happening on the ground: considerable weight should normally be given to the observational findings of community-based tools (complaints analysis, community surveys and odour diaries) and sensory assessments (such as sniff tests). These may be supported by the results of any dispersion modelling (or perhaps ambient air monitoring for specific compounds) if these add tangible value to the study, e.g. they provide wider spatial or temporal coverage than observations alone.

However, it should be emphasised that the results from a model should not be used to try to "prove" the absence of an existing adverse odour effect (e.g. nuisance) when strong empirical evidence from complaints analysis, community response data, and sensory tests (by appropriately trained persons) show otherwise. To do so would be to mistake the model for the reality of the situation, rather than a simplified version of it.

* This is assessment uncertainty in a wider sense than just the modelling or monitoring uncertainty. For example, a monitoring method may have excellent precision and accuracy, but if only a few measurements are carried out then the temporal and spatial uncertainties will probably be considerable. This may be good enough for what is required, but it needs to be recognised when using professional judgement to arrive at the conclusion on effects.

7. Odour management plans

7.1 The Odour Management Plan as a control measure

The preceding sections have concentrated on assessing the odour impact. For many new developments that are themselves a source of odour, there will be a need to re-visit the scheme design and incorporate control measures in some way. Some control measures are best suited to point sources and others best suited to fugitive sources. Odour Management Plans (OMPs) can be relevant to both: they are an essential tool for controlling odour at sites dominated by fugitive emissions; but also, OMPs complement engineering control measures (e.g. abatement systems)* on sites with controlled point-source odour emissions, where there is a significant risk of odour nuisance associated with plant or process failure and external factors outside of the control of the operator (a quantitative approach to this type of odour incident being extremely difficult)[24].

OMPs are recommended in a number of official guidance documents (see **Section 7.3**), but these share no common definition of an OMP and they show some differences on what it should contain. Notwithstanding these difference, there is some general agreement on what it an OMP is and its main purpose, as summarised in **Box 3**.

Box 3: What is an Odour Management Plan?

- An OMP is a live working document that formalises and describes how odour issues will be managed on site. An OMP forms part of the operational management system (indeed it may form part of a site`s wider Environmental Management System or Integrated Management System).
- An OMP should show how odours will be managed and controlled so as to prevent or minimise impact. As well as covering normal operations, it should anticipate and plan for abnormal events and foreseeable accidents and incidents.
- It is *not* an impact assessment; it's a mitigation/control measure.
- It should not be complex; simple plans are needed, that can be easily actioned by the site operatives.

7.2 OMPs and planning

Following the granting of planning consent, some potentially odorous new developments may be required to operate under an Environmental Permit, whereby on-going pollution control of many (though not always all) of the operations will be regulated by the Environment Agency. In such cases, planning authorities should work on the assumption that such pollution control regimes will operate effectively; nevertheless, it should be recognised that some residual odour is likely to remain and there may be some situations where such residual effects would make a development an unsuitable use of land at its proposed location. For sites that will be subject to an Environmental Permit it is necessary for the planning authority to consider at the planning stage whether the proposed development at the site will be a suitable use of the land - in particular, with regard to the likely effects of odour on nearby sensitive users. If an OMP is being proposed as the means of control to make the residual impact acceptable for users of the surrounding land, then the planning authority will expect the submitted OMP to meet the standards of current good practice. We summarise these standards in the following sections.

7.3 Guidance on OMPs

OMPs are described in several existing guidance documents:

- The Defra *Odour Guidance for Local Authorities* (2010) and the Defra G*ood Practice and Regulatory Guidance on Composting and Odour Control for Local Authorities* (2009) ;
- The EA technical guidance note H4 *Odour Management* (2011) ;
- The SEPA *Odour Guidance 2010*; and
- *Odour Monitoring and Control on Landfill Sites*[25] (2013) .

It should be noted the above documents vary in what they require from an OMP, i.e. no single guidance document covers all the aspects that the other documents consider good practice. (A comparison of the above guidance documents is included for information in **Appendix 3**). Furthermore, none of the documents is aimed at planners needing to decide whether the proposed means of control is likely to make the residual impact acceptable for users of the surrounding land. The IAQM has therefore brought together the good practice requirements from the different guidance documents to help planning authorities have confidence that OMPs submitted for planning purposes meet the standards of current good practice.

* This guidance document does not provide advice on engineering control measures and abatement systems and the reader should refer to other guidance on that subject.

7.4 Recommended content of OMPs for planning purposes

An OMP should follow basic management system principles:

Plan – identify releases (normal and abnormal conditions) and document the specific control measures for each
Do – apply the specific control measures (routine and additional)
Check – verify if the measures are working well enough
Act – review and revise to keep effective

This is an iterative process which, if followed properly, should be effectively self-regulating and should require little detail intervention from outside: it requires the operator to take the appropriate action to bring any problems under control or else suspend operations; so if there's an odour problem, this should be picked up by checks (through monitoring, complaints system, etc) and the control processes reviewed and tightened to deliver the objective - no significant odour impact off-site.

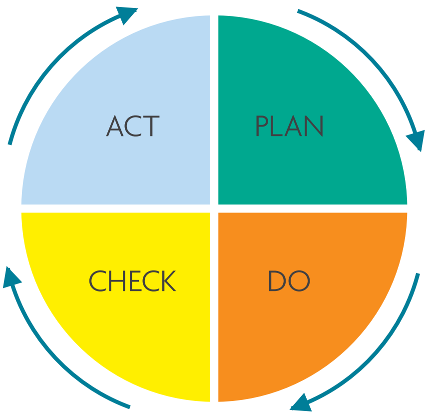

Figure 2: Plan, do, check, act framework

Table 8 summarises the recommended content of an OMP for planning purposes. As this has been consolidated from the requirements of existing guidance documents from Defra and the environment agencies, an OMP covering the areas described in this table should also meet the basic requirements of the various operational pollution regulatory control regimes as they stand at the time of writing. Further detailed advice on how to address each of these points in the OMP can be found in the aforementioned guidance documents.

When developing OMPs, it is often appropriate to give considerable attention on inventory (including feedstock) and process controls. This approach is particularly important for waste sites where loss of these controls. This approach is particularly important for waste sites where the loss of these controls is common and can result in pollution which cannot be effectively mitigated by dispersion or abatement.

It is also good practice for commitments rather than expressions of intent to be made. For example. 'we will clear waste from the reception area at the end of each day' is a commitment, whereas "we will aim to minimise the holding time of waste in the reception area' is an unenforceable and non specific expression of intent.

7.5 Recommended level of OMP Detail for planning

For OMPs for planning purposes, the IAQM fully supports the stance that an OMP should be risk-based with the level of depth, complexity and sophistication being dependent on the complexity of the activity to be carried out on the proposed development and the potential impact of the odour on neighbouring premises. Where a proposed development may produce particularly offensive odours, then the OMP will necessarily be detailed and thorough; conversely, for a process with a lower potential odour impact, a simpler OMP will suffice. It should be stressed that an OMP is merely a wrapper document for the management procedures and specific mitigation/control measures it contains; the OMP will only be of benefit if the underlying mitigation and control measures are robust and effective.

It is recognised that at the planning application stage, some of the detailed design features of the proposed development scheme may not yet be available. This could mean that not all of the areas recommended in **Table 8** can be described in the OMP as the level of detail likely to be eventually required. This should not be a significant problem for developments that, once operational, will be subject to on-going pollution regulatory control (e.g. under the Environmental Permitting Regulations), as planning authorities should work on the assumption that such pollution control regimes will operate effectively. For proposed developments that will not be subject to such on-going pollution regulatory control, the planning authority may decide to make a pre-commencement planning condition requiring the fully-detailed OMP to be submitted for approval before operations begin.

REFERENCES

[24] Environment Agency Technical Guidance Note IPPC H4, *Horizontal Guidance for Odour*, DRAFT, October 2002.
[25] *Odour Monitoring and Control on Landfill Sites*, Scotland & Northern Ireland Forum for Environmental Research (Sniffer), March 2013.

Table 8: Recommended content of an OMP for planning purposes

ESSENTIAL SITE DETAILS
A process description, particularly describing odorous, or potentially odorous, activities or materials used (inventory)
Identification of all the release points for each of the activities (plan/map)
Identification of the sensitive receptors within the area of influence that could be impacted (plan/map)
A description of the meteorological conditions prevailing at the site, especially wind direction. A wind rose (from a nearby representative meteorological station or from site sensors if installed) is an ideal format.
ROUTINE CONTROLS UNDER NORMAL CONDITIONS
A description of the *routine* mitigation/control measures that would be used day-to-day under normal operating conditions in the absence of any unusual risk factors. Examples of routine control measures include receipt, inspection, acceptance/rejection of materials, storage, containment, handling, treatment and timing of activities.
A list of the actions in detail and who is responsible for carrying them out.
REASONABLY FORESEEABLE ABNORMAL CONDITIONS AND ADDITIONAL CONTROLS
Identification of possible risk factors (e.g. adverse weather conditions) and anticipation of resonably foreseeable odour-related incidents and accidents (e.g., abnormal situations, spillages, power failure, breakdown of doors, equipment or abatement) and a listing of the consequences for odours of these risk factors.
A description of the *additional* measures (e.g. additional control measures and modifications to site operations, such as diverting odorous waste loads to facilities with less sensitive surroundings during adverse weather conditions) that will be applied during these periods to deal with these risks and any reasonably foreseeable incidents and accidents. It should be stated that if all the measures are shown not to be sufficient, then they will need to be tightened further or else, possibly ceasing/reducing odourous operations.
A list of the actions in detail and who is responsible for carrying them out
TRIGGERS FOR ADDITIONAL CONTROLS AND CHECKS ON EFFECTIVENESS
A description of what would trigger this further action/additional measures, such as: – the results of planned routine checks/inspections/surveys on site; – the results of on-site measurements of process parameters and surrogate measurements for odour (e.g. pH, temperature, oxygen, etc) exceeding defined trigger levels; – other metrics, such as particular meteorological conditions (e.g. temperature above a certain value, wind blowing in a particular direction, or calms); and – odour monitoring on- and/or off-site, including: • odour complaints monitoring (which should be carried out for all sites); • monitoring carried out on-site, showing non-compliance with any emission limit values (ELVs) set for controlled point source releases; and • monitoring carried out off-site (e.g. by sniff testing, odour diary surveys, etc), showing non-compliance with any action levels for ambient odour levels.
MANANGEMENT GOOD PRACTICE
A description of: - the roles and responsibilities of personnel on site (e.g. organisational chart); and - the training and competence of staff in odour-critical roles
Details of how the following will be carried out, and who has been assigned managerial and operational responsibilities for them: – implementing and maintaining the OMP; – responding to odour-related incidents and any elevated odour levels from the aforementioned checks/inspections/surveys, monitoring, or on receipt of complaints of odour nuisance; including carrying out investigations and taking appropriate remedial action to prevent recurrence; – planned maintenance and repair and the keeping of essential odour-critical spares; – regular review (at least once per year) of the effectiveness of odour controls - including the OMP itself – taking account of complaints, monitoring results, inspections, surveys and other information and feedback received. This interval may be shorter if there have been complaints or relevant changes to your operations or infrastructure; – engaging with your neighbours and communicating with relevant interested parties (e.g. local community and local authority) to provide necessary information and minimise their concerns and complaints, including methods used, content and frequency of communication; and – keeping records of all activities and actions relating to odour and the OMP.

Appendices

Appendix 1 - Predictive assessment tools

A1. Overview of predictive odour assessment tools

Defra`s *Green Leaves III* guidance[26] provides generic guidelines for the assessment and management of environmental risks. The Source-Pathway-Receptor (S-P-R) concept presents the hypothetical relationship between the source (S) of the odour, the pathway (P) by which exposure might occur, and the receptor (R) that could be adversely affected.

We can predict, using the S-P-R concept, the ambient odour exposure at ground-level local receptors. We need estimates (measurements or approximations) of emissions of odour from the source (e.g. heap, stockpile, tank, vent, chimney, etc) and a technique to forecast how the odour will disperse and dilute in the air and what the resultant ambient odour exposure is likely to be at ground level at the local receptors. These predictive techniques vary in their sophistication, cost and in how quantitative the predictions will be; they include:

- Qualitative, risk-based odour assessments;
- Simplified modelling, such as screening models, look-up tables and nomographs; and
- Fully quantitative atmospheric dispersion modelling.

None of these assessment tools forecast disamenity, annoyance or nuisance effects directly: they allow odour impact (the exposure) to be estimated, but the magnitude of the odour *effect* experienced by the receptors needs to be gauged as described in **Section 3.2**.

A1.2 Qualitative risk-based assessments

A1.2.1 Basis of qualitative risk-based odour assessments

Some qualitative assessments of effects rely solely on subjective judgement, or comparison with a consensus view for a particular scenario; these are not covered by this guidance and here we are concerned with qualitative assessments that make a prediction informed by risk.

The basic concept of risk assessment is that the overall risk depends on the probability* of the event together with the likely consequence if that event were to transpire. For odour assessments (and indeed environmental assessments in general) the probability can be considered to be the likelihood of exposure (impact), and the consequence can be considered to be the effect on the receptor if that exposure (impact) took place. These two facets are neatly pulled together by the S-P-R concept.

Behind the S-P-R concept, is the fundamental relationship:

Effect ≈ Dose x Response

In the specific case of odour assessments, the dose can be considered equivalent# to the odour exposure, in other words the impact. (Another way of thinking about the exposure, is that it is the amount, pattern and character of odour that is available for perception by an individual.) The impact will be determined by FIDO of the FIDOL factors. The effect is the result of the changes on specific receptors (people in the case of odour) taking into account their sensitivities (i.e. responsiveness to odour); the L (location) in FIDOL is to categorise the sensitivity.

A1.2.2 Main applications of qualitative odour assessments

A qualitative risk-based approach is appropriate for:

a. Screening of odour impacts;

b. Development proposals likely to have a low risk of adverse effects;

c. Situations where there is insufficient information to carry out detailed predictive dispersion modelling;

d. Situations where the information has wide uncertainties and its use as input to a detailed predictive dispersion model would be at best a waste of time, money and effort or, worse, would lead to an illusory and false impression of accuracy and precision in the numbers generated;

e. When the model is not able to properly represent the reality of the situation being assessed, e.g. if the odour effects are likely to be significantly influenced by accidental, unexpected, or unknown releases. In such instances a qualitative estimate may be more appropriate, on the basis that it is better to be broadly correct than precisely wrong.

Many (though not all) fugitive/diffuse sources fall into the last three categories and it may not be practicable to model these because reliable quantitative emissions data are often not available.

* Qualitative risk-based odour assessments look at the probability (i.e. the likelihood or chance) of an impact occurring at a location and the likely magnitude of the effect resulting from the exposure; they do not predict with certainty that any given impact/exposure will occur at a particular time (this feature they share with quantitative modelling assessments).

\# This simplification is valid for odour; but does not apply to toxic chemicals, where exposure and dose are different (with dose being the amount of substance actually absorbed into the body).

There is a wide need, therefore, to carry out qualitative odour assessments. There are some existing, published methods for certain specific applications:

- **Odour impacts of wastewater treatment works** - the SEPA 2010 guidance[27] summarises a method for ranking the impact of odours from waste water treatment plants to determine whether they are likely to be causing nuisance. As well as considering the source (odour intensity, frequency, nature and persistence), pathway (distance) and receptor sensitivity, it also takes into account complaints levels. The SEPA guidance states that it can be used as a confirmation or supplemental to other odour impact assessments for other industrial sources, although it cautions that this method must not be used in isolation of other assessment methods. The methodology is drawn from the Statutory Code of Practice on Odour Control of Odour from Waste Water Treatment Plants (2006)[28], where full details on how to use the matrix can be found. Other risk assessment approaches have been published by the water industry[29, 30].

- **Anglian Water Odour Risk Assessment**. Anglian Water has adopted a risk based assessment to screen the risks of odour from its works affected planning applications proposed near to their operational sites. This uses the capacity of the works expressed as the population equivalent to determine zones of potential risks (low, medium and high), the distance of each zone based on the size of the works[31].

- **Odour impacts of commercial kitchens, restaurants and food premises** - non-statutory guidance is provided by Defra[32] for estimating the odour risk taking into account the stack/exhaust height, the size of the kitchen (i.e. number of covers), the type of kitchen and proximity to sensitive receptors.

For other, general, applications there is no standard method for qualitative risk-based odour assessment; the IAQM recommends that such assessments are based clearly on the S-P-R concept, taking into account the odour potential of the emission source, the prevailing wind direction relative to the locations and distances of the proposed residential receptors, and their sensitivity to the type of odour in question. The IAQM considers the following example approach, which explicitly demonstrates the source-pathway-receptor relationship, provides a suitable framework for assessments for planning purposes.

A1.2.3 Example framework for qualitative odour assessment

How well a qualitative assessment predicts the impact of a given scenario depends largely on how well the magnitude of the source release, the effectiveness of the pathway, and the sensitivity of the receptor can be ranked or scored. **Table 9** provides examples of low, medium and high risk factors for the odour source, the pathway and receptor sensitivity that will be appropriate in many cases; however, it is difficult to provide a detailed method that will be universally-suitable for application to all odorous developments (or sites around them); therefore, professional judgement will need to be used to check the risk-classification of factors is suitable to the scenario in question[#].

[*] This qualitative odour assessment framework follows the same principles as the method used for fugitive dust in other guidance published by the IAQM, *Assessment of dust from demolition and construction*, 2014.

[#] The underlying Source-Pathway-Receptor conceptual approach to a qualitative odour assessment will be applicable to virtually all scenarios, but the "calibration" of the effect predicted from the factors may require modification for some scenarios.

Table 9: Examples of risk factors for odour source, pathway and receptor sensitivity

Source Odour Potential	Pathway Effectiveness	Receptor
Factors affecting the source odour potential include: • the magnitude of the odour release (taking into account odour-control measures) • how inherently odorous the compounds are • the unpleasantness of the odour	Factors affecting the odour flux to the receptor are: • distance from source to receptor • the frequency (%) of winds from the source to receptor (or, qualitatively, the direction of receptors from source with respect to prevailing wind) • the effectiveness of any mitigation/control in reducing flux to the receptor • the effectiveness of dispersion/dilution in reducing the odour flux to the receptor • topography and terrain	For the sensitivity of people to odour, the IAQM recommends that the air quality practitioner uses professional judgement to identify where on the spectrum between high and low sensitivity a receptor lies, taking into account the following general principles: ▶

Large Source Odour Potential Magnitude – Larger Permitted processes of odorous nature or large STWs; materials usage hundreds of thousands of tonnes/m^3 per year; area sources of thousands of m^2. The compounds involved are very odorous (e.g. mercaptans), having very low Odour Detection Thresholds (ODTs) where known. Unpleasantness – processes classed as "Most offensive" in Table 5; or (where known) compounds/odours having unpleasant (-2) to very unpleasant (-4) hedonic score. Mitigation/control – open air operation with no containment, reliance solely on good management techniques and best practice.	**Highly Effective Pathway for Odour Flux to Receptor** Distance – receptor is adjacent to the source/site; distance well below any official set-back distances[a]. Direction – high frequency (%) of winds from source to receptor (or, qualitatively, receptors downwind of source with respect to prevailing wind). Effectiveness of dispersion/dilution – open processes with low-level releases, e.g. lagoons, uncovered effluent treatment plant, landfilling of putrescible wastes.	**High sensitivity receptor** - surrounding land where: • users` can reasonably expect enjoyment of a high level of amenity; and • the people would reasonably be expected to be present here continuously, or at least regularly for extended periods, as part of the normal pattern of use of the land. Examples may include residential dwellings, hospitals, schools/education and tourist/cultural.
Medium Source Odour Potential Magnitude – smaller Permitted processes or small Sewage Treatment Works (STWs); materials usage thousands of tonnes/m^3 per year; area sources of hundreds of m^2. The compounds involved are moderately odorous. Unpleasantness – processes classed in H4 as "Moderately offensive"; or (where known) odours having neutral (0) to unpleasant (-2) hedonic score. Mitigation/control – some mitigation measures in place, but significant residual odour remains.	**Moderately Effective Pathway for Odour Flux to Receptor** Distance – receptor is local to the source. Where mitigation relies on dispersion/dilution – releases are elevated, but compromised by building effects.	**Medium sensitivity receptor** – surrounding land where: • users` would expect to enjoy a reasonable level of amenity, but wouldn't reasonably expect to enjoy the same level of amenity as in their home; or • people wouldn't reasonably be expected to be present here continuously or regularly for extended periods as part of the normal pattern of use of the land. Examples may include places of work, commercial/retail premises and playing/recreation fields..
Small Source Odour Potential Magnitude – falls below Part B threshold; materials usage hundreds of tonnes/m^3 per year; area sources of tens m^2. The compounds involved are only mildly odorous, having relatively high ODTs where known. Unpleasantness – processes classed as "Less offensive" in H4; or (where known) compounds/odours having neutral (0) to very pleasant (+4) hedonic score. Mitigation/control – effective, tangible mitigation measures in place (e.g. BAT, BPM) leading to little or no residual odour.	**Ineffective Pathway for Odour Flux to Receptor** Distance – receptor is remote from the source; distance exceeds any official set-back distances. Direction – low frequency (%) of winds from source to receptor (or, qualitatively, receptors upwind of source with respect to prevailing wind). Where mitigation relies on dispersion/dilution – releases are from high level (e.g. stacks, or roof vents >3m above ridge height) and are not compromised by surrounding buildings	**Low sensitivity receptor** – surrounding land where: • the enjoyment of amenity would not reasonably be expected; or • there is transient exposure, where the people would reasonably be expected to be present only for limited periods of time as part of the normal pattern of use of the land. Examples may include industrial, farms, footpaths and roads.

Notes: [a] Minimum "setback" distances may be defined for some odorous activities: for example, standard setback distances for livestock housing units are a popular tool for odour regulation in Australia and New Zealand, Europe and the United States.

The first step in the assessment is to estimate the odour-generating potential of the site activities, termed the "Source Odour Potential", which takes into account three factors:

i. The scale (magnitude) of the release from the odour source, taking into account the effectiveness of any odour control or mitigation measures that are already in place. This involves judging the relative size of the release rate* after mitigation and taking account of any pattern of release (e.g. intermittency).

ii. How inherently odorous the emission is. In some cases it may be known whether the release has a low, medium or high odour detection threshold (ODT); this is the concentration at which an odour becomes detectable to the human nose. In most instances the odours released by a source will be a complex mixture of compounds and the detectability will not be known. However, for some industrial processes the odour will be due to one or a small number of known compounds and the detection thresholds will be a good indication of whether the release is highly odorous or mildly odorous.

iii. The relative pleasantness/unpleasantness# of the odour. Lists of relative pleasantness of different substances are given in the Environment Agency guidance H4 *Odour Management* and in more detail in the SEPA document *Odour Guidance 2010* [2].

Using the example risk ranking in **Table 9**, the Source Odour Potential can be categorised as small, medium or large.

Next, the effectiveness of the pollutant pathway as the transport mechanism for odour through the air to the receptor, versus the dilution/dispersion in the atmosphere, needs to be estimated. Any factor that increases dilution and dispersion of the odorous pollutant plume as it travels from source (e.g. processes and plant) to receptor will reduce the concentration at the receptor, and hence reduce exposure. Important factors to consider here are:

i. The distance of sensitive receptors from the odour source.

ii. Whether these receptors are downwind (with respect to the predominant prevailing wind direction). Odour episodes often tend to occur during stable atmospheric conditions with low wind speed, which gives poor dispersion and dilution; receptors close to the source in *all* directions around it can be affected under these conditions. When conditions are not calm, it will be the downwind receptors that are affected. Overall therefore, receptors that are downwind with respect to the prevailing wind direction tend to be at higher risk of odour impact.

iii. The effectiveness of the point of release in promoting good dispersion, e.g. releasing the emissions from a high stack will - all other things being equal - increase the pathway, dilution and dispersion.

iv. The topography and terrain between the source and the receptor. The presence of topographical features such as hills and valleys, or urban terrain features such as buildings can affect air flow and therefore increase, or inhibit dispersion and dilution.

Using the example risk ranking in **Table 9,** the pollutant pathway from source to receptor can be categorised as ineffective, moderately effective, or highly effective.

The Air Quality Practitioner should document in the assessment report the justification for their assignment to the selected categories for Source Odour Potential and the Pathway Effectiveness.

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* It is unlikely that actual odour release rates (in units of ou_E/s), will be available if a qualitative assessment is being carried out.
# This can be measured in the laboratory as the hedonic tone, and when measured by the standard method and expressed on a standard nine-point scale it is termed the hedonic score.

Table 10: Risk of odour exposure (impact) at the specific receptor location

		Source Odour Potential		
		Small	**Medium**	**Large**
Pathway Effectiveness	**Highly effective pathway**	Low Risk	Medium Risk	High Risk
	Moderately effective pathway	Negligible Risk	Low Risk	Medium Risk
	Ineffective pathway	Negligible Risk	Negligible Risk	Low Risk

In the third step, the estimates of Source Odour Potential and the Pathway Effectiveness are considered together to predict the risk of odour exposure (impact) at the receptor location, as shown by the example matrix in **Table 10**.

The next step is to estimate the effect of that odour impact on the exposed receptor, taking into account its sensitivity, as shown by the example matrix in **Table 11**. The odour effects may range from negligible, through slight adverse and moderate adverse, up to substantial adverse.

Table 11: Likely magnitude of odour effect at the specific receptor location

Risk of Odour Exposure	Receptor Sensitivity		
	Low	Medium	High
High Risk of Odour Exposure	Slight Adverse Effect	Moderate Adverse Effect	Substantial Adverse Effect
Medium Risk of Odour Exposure	Negligible Effect	Slight Adverse Effect	Moderate Adverse Effect
Low Risk of Odour Exposure	Negligible Effect	Negligible Effect	Slight Adverse Effect
Negligible Risk of Odour Exposure	Negligible Effect	Negligible Effect	Negligible Effect

Table 12: Example summary of the likely odour effects at existing sensitive receptors

Receptor details and location	Source Odour Potential	Pathway (Transport Effectiveness)	Odour Exposure	Receptor Sensitivity	Likely Odour Effect
54 Church Street (Residential, 500 m upwind)	Medium	Ineffective Pathway	Negligible Risk	High Sensitivity	Negligible Effect
4 High Street (Residential, 300 m upwind)	Medium	Moderately Effective Pathway	Low Risk	High Sensitivity	Slight Adverse Effect
The Villas (Residential, 500m downwind)	Medium	Moderately Effective Pathway	Low Risk	High Sensitivity	Slight Adverse Effect
The Crescent (Residential, 250m downwind)	Medium	Moderately Effective Pathway	Low Risk	High Sensitivity	Slight Adverse Effect
County Savings Bank (Office/ Retail/ Commercial, 30m downwind)	Medium	Highly Effective Pathway	Medium Risk	Medium Sensitivity	Slight Adverse Effect
Flat above Bank (Residential, 30m downwind)	Medium	Highly Effective Pathway	Medium Risk	High Sensitivity	Moderate Adverse Effect
Lower Farm (working farm, 30m downwind)	Medium	Moderately Effective	Low Risk	Low Sensitivity	Negligible Effect

This procedure results in a prediction of the likely odour effect at each sensitive receptor. Often there will be numerous receptors around the odour source; **Table 12** shows an example of how the results of an odour assessment at multiple nearby sensitive receptors may be summarised. This example is for an odour source of medium odour potential, say, a modest sized waste transfer station dealing with 50 k tonnes per annum mixed waste. Having predicted the likely odour effect at individual, representative receptors, the next step for most assessments for planning purposes will be to estimate the overall odour effect on the surrounding area, taking into account the different magnitude of effects at different receptors, and the number of receptors that experience these different effects*. This requires the competent and suitably experienced Air Quality Practitioner to apply professional judgement.

As noted earlier in **Section 3.2**, the EIA regulations require that an assessment reaches a conclusion on the likely significance of the effects. Where the overall effect is greater than "slight adverse", the effect is likely to be considered significant. This is a binary judgement: either it is "significant" or "not significant".

A1.3 Dispersion modelling

Dispersion modelling is a widely applied tool in odour assessment and in combination with agreed numerical standards (see **Section 5**) they can be a useful tool. However, it should always be considered in an odour assessment that there are some types of odour source that may exist that are not easily modelled (e.g. diffuse sources, fugitive emissions or intermittent sources) and so model results may not give a complete picture of the odour risk on site. Current odour assessment cannot be applied to short-term events.

Where dispersion modelling is applicable?
Dispersion modelling can be applied when:

- The sources of odour are clearly identifiable;
- Where the source characteristics are clearly defined (i.e. physical size, emission characteristics such as temperature and efflux velocity are known);
- Odour emission rates can be reasonably determined;
- Odour emission rates are not subject to large variation;
- The area does not have other relevant odour sources that may be difficult to model; and
- The area is suitable for dispersion modelling, i.e. there are no extremes of terrain height, appropriate meteorological data is available, there are no local features that would mean dispersion modelling results are unreliable.

Some odour sources can be difficult to define, they may emit odour from a wide area or have large fluctuations in odour emissions, an example may be a composting site where the windrows are turned ocassionally, increasing odour emissions.

Which model to select?
Odour assessment uses standards that have been derived in a different manner compared with other environmental standards. Normally measurements are taken of the concentration of a pollutant and these are compared with standards based on a dose-response relationship. For instance, for some air quality pollutants, experiments have shown a threshold concentrations level where health effects can be observed and air quality standards have been set below this threshold level. The odour standards currently used have not been derived in this manner, rather they have been derived from community surveys of perceived annoyance that have been compared with modelled 98th percentile odour concentrations, and custom and practice. The models used to derive these relationships are not widely used in the UK and consequently alternatives have to be used. Odour assessments are almost exclusively undertaken in the UK using the AERMOD or ADMS models.

A1.4 Modelling the dispersion of odours

Whilst it is not within the remit of this Guidance to provide a prescriptive recommendation for how the dispersion of odours from sources should be modelled, it is considered useful to include some general guidance on the technical approach to modelling, arising from the practical experience of the Working Party members.

Dispersion modelling is an inherently uncertain process, in its attempt to simulate the complex atmospheric parameters that influence the behaviour of gaseous substances emitted into the atmosphere by means of a series of simplifying mathematical equations and formulae. It is, therefore, important for the practitioner to appreciate from the outset that the strength of modelling lies in its ability to identify the differences between emissions scenarios. That is, the facility to show the effect of applying odour abatement measures to a source or group of sources, in terms of reduced ambient odour concentrations at receptors. Modelling cannot be relied upon to generate or predict precise and accurate odour concentrations but it can be used to add to the body of evidence of odour annoyance.

General best practice guidance on dispersion modelling is provided by the Environment Agency , the Atmospheric Dispersion Modelling Liaison Committee (ADMLC) and Meteorological Society document . There is no specific guidance for odour modelling but some useful observations can be found in a recent Environment Agency Science Report . In addition, a recent ADMLC report has highlighted some differences in the outputs from different model codes when attempting to simulate dispersion from area and volume sources .

Unlike modelling of classical air pollutants such as SOx, NOx and particulates, for which there are a mixture of statutory air quality standards and objectives that are expressed over different averaging periods, there are no statutory limits for odours, merely “custom & practice” criteria that have evolved over the last 25 years or so. These are expressed as 98th percentile metrics of hourly average concentrations over a calendar year and are explained elsewhere in this document.

There are four main dispersion model codes that are extensively used within the UK, Europe and USA and Australia – ADMS, AERMOD, CALPUFF and AUSPLUME. The critical inputs to the models are, as for all modelling:

- The source term(s) – odour emission rates;
- Meteorological data – hourly sequential records from the nearest recording station or NWP data, produced from the UK Meteorological Office’s Unified Model;
- Location(s) and characteristics of sources (whether Point, Area, Volume or Line);
- Location(s) and sensitivity of receptor point(s);
- Topography (terrain) and land use;
- Influence of buildings/structures on dispersion; and
- Influence of emissions variation.

The IAQM does not endorse any particular model but we do recognise that for odour assessment there is the need to build up more information concerning the performance of models for odour assessment and that it will be useful that a similar approach is adopted for the model assessment. The model selected should be agreed with the relevant expert within the planning authority. a particular company has access to.

Model options
The location of receptors is also important, in many cases contour plots are produced to present the results of the odour assessment. It is important to ensure that sufficient data points are modelled so that the contours can be produced without significant extrapolation of the results. This can be tested by using different data gridding methods and ensuring that the results do not significantly change. Frequently a relatively small grid interval is required to obtain sufficient information for robust contoured results.

All current odour benchmarks are based on the 98th percentile of hourly means and the model should be configured to predict this value.

Selection of meteorological data
Meteorological data should be obtained from a representative monitoring station or from the Met Office NWP model.

It is well established when carrying out dispersion modelling that several years of meteorological data should be used to assess inter-year variations, the Environment Agency H4 guidance suggests that “To represent conditions for an *“average year” hourly meteorological data for a period of at least three, preferably five years should be used”*. The H4 guidance is not clear on how this data should be used, i.e. whether the data should be combined into a single model run or whether individual years should be modelled.

IAQM recommends that individual years be modelled and five years of data should be used. It may be useful to report each result to demonstrate the variation in predicted concentrations but the assessment conclusions should be based on the worse case results selected from each of the model runs. Some models and some users have specific approaches for treatment of calm hours. The treatment of calms can have a considerable influence on the predicted 98th percentile from a model and the approach selected should be justified within the assessment report.

Definition of odour sources
Common dispersion models can represent point, area, line and volume sources, these will usually be sufficient to represent the odour sources encountered in these types of study.

In most cases, the sources can be represented directly in the dispersion model based on their physical size and operating characteristics, for example, for point sources the height diameter, efflux velocity and temperature will be known.

Frequently sources are open areas in process such as a sedimentation or aeration tank. These should be represented as an area source with no or minimal efflux velocity.

Odour emission rates
Odour emission rates for modelling are obtained either from “standard” emission values for various process or measured values from on-site surveys of the odorous processes. Standard emission rates are a useful method for screening odour problems and determining whether there is the potential for a problem to exist. However, there is considerable variation in emission rates observed for the same processes which reflects local conditions and operational practices. For instance, fourteen measurements of the odour emission rates from primary settlement tanks

had a range from 0.4-24 $ou_E/m^2/s$, a mean value of 9.8 and a standard deviation of 9.5 indicating a wide spread in the measured values.

Where "standard" data are used, the source must be clearly noted and it should be demonstrated that the information is likely to be a reasonable representation of odour emission rates on the study site.

Experience from the IAQM working group suggests that use of "standard" or library data often provides a useful overall view of the impact of a site. Site specific information taken from measurements on site provides useful information to add certainty to the assessment, provided the data are representative having been obtained from a suitable number of survey. To allow for external verification the full library of emission data should be publically available.

Treatment of calm conditions

One particular issue that is relevant to modelling odour dispersion is that of calm periods in the hourly meteorological record. In simple terms "calm" means no wind. In practical terms, there are very few occasions upon which there is no air current or movement at all, merely very low wind speeds, which may or may not be registered and recorded by measuring equipment, depending upon its sensitivity.

In addition to this, some dispersion models routinely discount wind speeds below a certain value. In the case of ADMS, for example, there is a "default" wind speed value of 0.75 m s-1, below which the model does not calculate dispersion. This can be amended, however, by the user, such that wind speeds down to 0.5 m s-1 will be modelled using the Gaussian solution. For wind speeds less than this value (down to a minimum of 0.3 m s-1), a radial solution is applied, which means that emitted material is assumed to disperse in all directions simultaneously. Wind speeds below 0.3 m s-1 cannot be modelled.

Calm and low wind speeds tend to be worst-case conditions for dispersion of odour, particularly when there are large area sources, such as sewage treatment works, open windrow composting facilities and landfill sites. Whilst there are concerns about the validity of low wind speed dispersion algorithms and the radial solution itself, it is recommended that, in certain circumstances, the use of a calms routine in modelling would be appropriate as a sensitivity test.

Assessment of uncertainty

IAQM acknowledges that odour modelling inherently includes uncertainties, these arise from simplifications in the modelling process, data uncertainty and errors and user error. Where an odour assessment is being made to determine acceptability of land use then IAQM considers that it is very important to consider these uncertainties before reaching a conclusion. We therefore recommend that a section on uncertainty assessment is included that considers the factors shown in **Table 13**.

Table 13: Some approaches for addressing uncertainty in odour modelling

Source of Uncertainty	Possible Approach
Model uncertainty	Reference to published validation studies; Use of more than one model and comparison of results
Odour emission rates	Use of multiple years of data Examination of alternative sites for data
Meteorological data	Use of multiple years of data Examination of alternative sites for data Comparison of results with and without local wind field models
User error	Following IAQM guidance for • modelling inputs • analysis of results Clear reporting of modelling approach Inclusion of modelling input files in reporting.

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Appendix 2 - Sniff Testing

A2.1 Monitoring of ambient odours – sensory testing

An adverse effect of odour exposure, such as annoyance or loss of amenity, is subjective and is not something that can be wholly defined or assessed by scientific methods alone; an assessment can therefore be strengthened by including a subjective assessment of prevailing odour conditions by those directly affected or by experienced, trained, observers*.

Sensory testing techniques use the human nose as the analytical sensor to enable the odour magnitude (as either intensity or concentration), frequency, duration and offensiveness of the odour to be recorded at a particular location at a specific time. This is a sound approach considering that (currently) no analytical instrument can give a unified measure of a complex mixture of compounds that quantifies it as a whole in the same way that a human experiences odour. (Sensory testing also allows the character of the odour to be assessed, which is a great benefit when there are a number of different odour sources.)

Sensory testing can be carried out using the nose alone, by "sniff testing"; or with the assistance of an instrument – the field olfactometer. With the sniff test variant of sensory testing, the trained field operative measures the odour magnitude as odour intensity, whereas field olfactometry gives a measure of odour magnitude as the concentration.

Subjective sensory tests such as the Sniff Test should certainly not automatically be considered inferior to quantitative ambient monitoring; when carried out to a rigorous, well-designed methodology, the results of such sensory surveys can be expected to be robust and reproducible.

Although the argument may be put forward that sensory testing results can't be compared directly with the exposure benchmarks for modelling set as $C_{98,}$ 1-hour concentrations (ou_E/m^3), it should be borne in mind that the latter are just surrogate exposure indicators for the actual effect of annoyance#. Sniff tests also give an estimate of exposure; this is just expressed in a different way to modelling output. The main difference is that for modelling, a consensus has been reached on what levels correspond to annoyance effects; whereas for sensory tests this consensus has not yet been achieved.

Sniff testing needs to be carried out on sufficient occassions to represent the full range of likely odour emissions and in meteorological conditions favourable to odour detection (i.e. light wind and state of atmosphere).

* Although amongst a group of individuals, not all will agree, a consensus can emerge about what could reasonably be considered as an adverse odour effect.
# The Environment Agency's exposure benchmark levels were originally derived from the correlation between modelled exposure around a Dutch piggery and the resulting annoyance effects as measured by a community questionnaire survey. A level of 10% annoyed was chosen as the lowest level that would be statistically significant, based on the "background noise" for measurement of annoyance using questionnaires plus two times the standard deviation. The level of 10% annoyance to pig odours correlated with an exposure (C_{98}, 1-hour) of 1.3 ou_E/m^3 and this was used for the basis for setting an odour modelling guideline of 1.5 ou_E/m^3.

Table 14: VDI 3940[33] Odour intensity scale

Odour Strength	Intensity Level	Comments
No odour/not perceptible	0	No odour when compared to the clean site
The Odour Detection Threshold (ODT) of 1 $ou_E.m^{-3}$ is somewhere between 0 and 1		
Slight/very weak	1	There is probably some doubt as to whether the odour is actually present
Slight/weak	2	The odour is present but cannot be described using precise words or terms
Distinct	3	The odour character is barely recognisable
VDI 3940 says that the recognition threshold intensity is generally 3-10 times higher than the ODT (i.e. 3-10 $ou_E.m^{-3}$)		
Strong	4	The odour character is easily recognisable
Very strong	5	The odour is offensive. Exposure to this level would be considered undesirable
Extremely strong	6	The odour is offensive. An instinctive reaction would be to mitigate against further exposure

A2.1.1 Sensory Testing by the "Sniff Test"

There are two main methods of sniff test: a so-called "objective" method and a "subjective" method. The "objective" approach, popular in the US and documented in ASTM E544-99, involves the assessor gauging the magnitude of the environmental odour against a numerical scale based on a series of standard "sniffing sticks" containing different concentrations of 1-butanol.

In Europe, Australia and New Zealand the "subjective" sniff test is more widely used, where the assessor allocates the intensity of the environmental odour against a numerical scale linked to qualitative descriptions such as "not perceptible", "weak", strong", etc. There is currently no UK national standard method for subjective sniff tests; however, a German national standard exists: VDI 3940: 1993, *Determination of Odorants in Ambient Air by Field Inspection*. The VDI standard intensity (I) scale ranges from 0 (no odour), through 1 (slight/ very weak), to 6 (extremely strong).

The VDI 3940 method is very comprehensive but requires a full year's worth of measurements (unlikely to be compatible with a planning application timetable) and can require multi-person "sniffing squads". A CEN standard on assessing odour in ambient air has been prepared (EN 16841-1:2016)[34] which covers the German grid approach, a dynamic plume assessing approach is also available (EN 16841-2:2016)[35] that describes a plume method for determining the extent of the downwind odour plume of a source.

The Environment Agency outlines its own brief and straightforward sniff test procedure in an appendix to its H4 guidance, which has been updated to use the VDI intensity scale, but is designed more for checking compliance against Permit odour conditions (e.g. "no observable odour beyond the site boundary") than for estimating the odour impact or effect.

The challenge for practitioners, is how to design a sniff test survey and interpret the results in a way that allows the odour effects on the surrounding land-users to be gauged for planning purposes. In the absence of a definitive standard method for this application, the IAQM has provided an illustrative example of how the subjective sniff test can be used. The main principles of the sensory assessment are:

Step 1 – Conduct the Sniff Testing

The sniff test technique is used to gather information on odour intensity, character, unpleasantness, frequency and duration at the test locations of interest (usually at sensitive receptors or at an installation boundary) according to the procedure in **Box 4**. The number of test locations and their exact locations should be selected taking into account the number of sensitive receptors, their distance to the source and orientation in relation to the prevailing wind direction. Where available, other existing data (e.g. complaints records, any atmospheric dispersion modelling predictions, stack heights, etc.) should be taken into account.

The test locations should be clearly marked on the area map showing the site, key community features, and the extent of the odour survey. The odour assessor should start the survey at those test locations that are upwind of the site activities, starting with those furthest away and moving progressively to those closer to the site. Only then should tests be carried out at the downwind test locations, again starting with those furthest away and moving progressively to those closer to the site.

Step 2 – Estimate Odour Exposure at the Test Location

The results are then interpreted to assess the odour impact at the time and place of sampling. The Odour Exposure experienced at each location will be dependent on the frequency, intensity, duration and unpleasantness of the odour and different combinations of the FIDOL factors can result in different exposures: for example, odours may occur frequently in short bursts ('acute' exposures), or for longer periods ('chronic' exposures). **Table 15** is one example of how the intensity, frequency and duration can be considered together.

Box 4: Example of sniff test sampling procedure

The sensory test is carried out at each test location over a standard observation time, typically 5 minutes. Testing should start from locations affected by the least-intense odours, to avoid olfactory fatigue. For each test location, the start time of the observation period and the attributes of the odour over the observation period are recorded as follows:

i) The assessor breathes normally, inhaling ambient air samples through the nose at regular intervals (say, every 10 seconds, to give 30 samples over typically a 5 minute observation period). However, where the odour levels are either constant or intense then the odour assessor should avoid olfactory fatigue/desensitisation by alternating each sample sniff of ambient air with a sniff of odour-free air from an ori-nasal face mask fitted with carbon filters.

ii) For each sample, the odour intensity (VDI scale, 0-6) is recorded.

iii) At the end of the observation period at the test location, the odour unpleasantness is noted down by classifying it as unpleasant, neutral (neither pleasant nor unpleasant) or pleasant. This assumes that at least some of the 30 samples were of intensity 3 or more ("i.e. the odour is at least "barely recognisable").

iv) The odour descriptor should also noted: odours can be objectively described using standardised categories and reference vocabulary. It is useful to provide odour assessors with standard descriptor terms, which are organised with similar terms in categories and groups either as a list or as an "odour wheel".

v) Next the pervasiveness/extent of the odour at this test location is assessed. This can be calculated as the percentage odour time, $t_{I\geq4}$, which is the number of samples where odour was recognisable divided by the total number of samples (i.e. 30). Note that "recognisable odour" is where the odour strength exceeds the recognition threshold and is definitely recognisable by the assessor, i.e. the assessor is capable of definitely identifying its quality/character, which corresponds to VDI intensity of 4 or more.

vi) The average odour intensity, I_{mean}, over the test period is calculated and the maximum intensity observed is noted.

The above procedure is then repeated at the next test location, remembering that the character of an odour mixture can change over distance, as the particular components may become diluted below their individual detection thresholds at different distances.

A record should be kept of the meteorological conditions at the time of testing (including wind strength and direction, atmospheric stability category, barometric pressure, rainfall, temperature and humidity), together with information relating to the operations and activities being undertaken on site and in the surrounding area.

Table 15: Matrix to assess the odour exposure (neutral and unpleasant odours) at time and place of sampling

Average Intensity (I_{mean})	Percentage odour time ($t_{I\geq4}$) during the test				
	10%	11 to 20%	21 to 30%	31 to 40%	≥41%
6	Large	Very Large	Very Large	Very Large	Very Large
5	Medium	Large	Large	Very Large	Very Large
4	Small	Medium	Medium	Large	Large
3	Small	Medium	Medium	Medium	Medium
2	Small	Small	Medium	Medium	Medium
1	Small	Small	Small	N/A	N/A

Notes: I_{mean} should be rounded to the nearest whole number.
The following overriding considerations affect the scoring of the odour annoyance impact:
if I_{mean} = 0, then the odour effect can for practical purposes be considered negligible; and
if I_{mean} = 1 but $t_{I\geq4}$ = 0%, then the odour effect can for practical purposes be considered negligible.

The relative unpleasantness of an odour is probably its most subjective attribute. It is also complicated by the interdependence with intensity and frequency/duration: some odours may be pleasant when weak but unpleasant when strong, or when exposure is frequent. **Table 15** is for unpleasant and neutral odours: research[36,37] on the influence of hedonic tone on annoyance, suggests there is no significant difference between the annoyance potential of unpleasant odours and neutral odours. Pleasant odours do, however, have a significantly lower annoyance potential at the same intensity. Or put another way, the pleasant odours have to occur more frequently to elicit the same annoyance as unpleasant or neutral odours. However, it is also known that odours that are normally (i.e. at a low to moderate intensity) considered pleasant, can become unpleasant at high odour intensities. For pleasant odours, the matrix in **Table 15** would need to be adjusted to take these characteristics into account.

Step 3 – Bring Together the Results of Repeated Tests and Receptor Sensitivity to Judge the Odour Effect

Measuring the exposure at a particular place (receptor) and time using the Sniff Test technique, is (relatively) straightforward; however, the frequency that odour episodes occur is thought to be at least as important as the magnitude of the individual odours. The real challenge, therefore, is:

i. to decide how to expand this snapshot* into a sampling campaign that gives a longer term representative picture of the prevailing odour climate at those receptor locations (covering any variations in source activity, and differences due to time of day, season and weather conditions); and

ii. how to combine the resulting probability of impact with the sensitivity of the receptor to gauge the effect that is taking place.

This requires professional judgement and it is difficult to be prescriptive because different approaches may be suited to different situations. However, some general guidance is offered below:

If one had carried out many repeated Sniff Tests to cover the majority of meteorological (including wind direction) conditions and source variations that are likely to occur, then you will have multiple estimates of odour exposure (impact) at each receptor. It is relatively straightforward to then make a judgement on the overall odour exposure (impact) and then combine this with the sensitivity of the receptor to gauge the effect. **Table 16** has been included below to provide guidance on how these factors might be considered together; the matrix is not prescriptive but it is hoped that it may help a consensus emerge on how Air Quality Practitioners describe the magnitude of adverse odour effects. Despite the understandable perception that the subjective nature of the sniff test is somehow inaccurate or imprecise#, such extended surveys can arguably provide some of the best evidence on odour impact out of all the tools at our disposal.

If far fewer tests had been carried out, the Air Quality Practitioner would need to consider carefully how those snapshots of exposure/impact could be used to come to a conclusion on *overall* odour impact/exposure (and then onwards to estimate the effects). This would be likely to require consideration of the meteorological conditions at the time of the tests and how frequently these occur over the longer term. (If the source varies as well, then carrying out few tests is unlikely to be an acceptable approach unless the measurements are carried out during worst-case emissions).

As noted earlier, a suitable number of sampling visits depends on the variations in source activity and differences due to time of day, season and weather conditions. As an absolute miniumum, the IAQM recomments sampling on three seperate days, provided the observed Pasquill stability categories (based on obersved sunshine, cloud cover and wind) account for at least 70% of conditions typically experienced over the course of a year.

QA/QC for Sniff Testing

With a subjective approach such as the Sniff Test, general quality assurance/quality control (QA/QC) issues assume a huge importance. The main QA/QC factors are: having a robust protocol; the sensitivity of the assessor being "normal"; and adequate training. In the United States, where sensory field odour assessments are used by many state environmental regulators, a credible programme of sensory monitoring is considered to require four main components[38]:

1. Suitably qualified and trained odour assessors;
2. Objective methods of describing and measuring odours;
3. Standard monitoring practices, e.g. routine survey routes; and
4. Standard data collection and reporting forms.

* Although a snapshot might be good enough to confirm an adverse impact (if you`re lucky enough to catch it); numerous repeat surveys will usually be required to show with a reasonable degree of certainty that there is an absence of adverse impact. In general the geater the number of surveys carried out, the higher the confidence in the conclusion drawn.

The certainty and reliability of the conclusion is likely to be affected mainly by how well the monitoring campaign captures the spatial and temporal variability of the odour; this is likely to be driven more by the variation in the magnitude of odour sources, and the differences in dispersion and dilution that occur with different meteorological conditions (such as wind speed and direction, insolation, atmospheric stability and precipitation) than by the measurement uncertainty.

Table 16: Matrix to assess the odour effect at individual receptors

		Receptor Sensitivity (refer to Table A1.1)		
		Low	**Medium**	**High**
Overall Odour Exposure	**Very Large**	Substantial adverse	Substantial adverse	Substantial adverse
	Large	Moderate adverse	Moderate adverse	Substantial adverse
	Medium	Slight adverse	Slight adverse	Moderate adverse
	Small	Negligible	Negligible	Slight adverse

A further application of professional judgement then needs to be applied to conclude the significance of the odour effect on, or from, the development as a whole, taking into account the possibly different magnitudes of effects that occur at different receptors.

The following are additional factors to safeguard the quality of sensory assessments:

- The odour assessor should not carry out the assessment if they have a cold, sore throat, sinus trouble, etc.
- The odour assessor should not be hungry or thirsty.
- The odour assessor should not work within half an hour of the end of their last meal.
- The odour assessor should not smoke or consume strongly flavoured food or drink, including coffee, for at least half an hour before the field odour survey is carried out, or during the survey.
- The odour assessor should not consume confectionery or soft drinks for at least half an hour before the field odour survey is carried out, or during the survey.
- Scented toiletries, such as perfume/aftershave should not be used on the day of the field odour survey.
- The vehicle used during the field odour survey should not contain any deodorisers.
- If the odour assessor has had to travel a long distance, then a rest period should be taken before starting the survey.
- To reduce the likelihood of odour fatigue, assessors should always carry out the field odour survey *before* making any works site visit, inspection or walk-through survey.
- For sources with a diurnal odours release pattern there may be a need to conducting more than one set of sniff tests during each site visit day; the assessor should removes themself to a place well away from the odour source for the hours between sniff tests.

Box 5: Checking the sensitivity of odour assessors

A wide natural variation of olfactory sensitivities exists in the population. Air Quality Practitioners who carry out field odour assessments of ambient odour using sensory tests should have a normal sense of smell and may find it beneficial to check their odour sensitivities. It is not required that they are within the very tight sensitivity range (of between 20–80 ppb to n-butanol) that qualifies someone to act as a laboratory panellist for dynamic dilution olfactometry to method EN13725: just as the majority of the population would fail to come within this narrow band of sensitivity, so too would the majority of Air Quality Practitioners; the logic and practicability of excluding them (when they can be considered as surrogates for the majority of the population) and their opinions/observations from the assessment process cannot really be justified. Sensitivity testing therefore tends to be used in most countries simply to demonstrate the assessor is neither nose-dead nor highly sensitive, i.e. that the assessor has the ability to detect odours that is neither very poor, nor very good. This balance is important given the differing perspectives of the owners of an odour-emitting activity and the potentially impacted community. In the US, sensitivity is checked using standard n-butanol pens, the aim being to identify anyone who is very insensitive or hypersensitive (defined as by falling in the upper or lower 5% tails of the normal distribution curve).

A2.1.2 Sensory testing by portable field olfactometer

Field olfactometers are able to extend the value of the sniff test by allowing the strength of the ambient odour to be measured quantitatively, in concentration units of dilution-to-threshold* (D/T), rather than a subjective odour intensity based on a descriptive scale as with the sniff test.

The only type of instrumental olfactometry suitable for ambient measurements is portable field olfactometry#: this technique incorporates a dilution device within a portable device, allowing direct measurements of odour concentration to be carried out in real time in the field, without the need for separate sampling and laboratory dilution stages. A number of portable hand-held instruments are available, including the Scentometer, the NasalRanger® device (which has a lower detection limit of 2 dilutions-to-threshold (2 D/T)) and the Scentroid SM100.

This quantitative measurement of the odour strength is useful in situations where an added level of objectivity is required, or where there is disagreement between two sides who have assessed the odour intensity subjectively using the sniff test. It is important to remember that the odour strength, whether measured as concentration or intensity, is only one factor that determines the odour impact; the other FIDOL factors will still need to be assessed (and combined in a similar way to **Table 14** and **Table 15**) if a full assessment of odour impacts is the aim rather than simply for checking compliance with a maximum boundary odour concentration limit.

A limitation of some types of field olfactometers is the response time: it can take an experienced operator say 30 seconds to a minute to go through the sequential dilution stages (with an inhalation at each stage) to obtain a concentration estimate; whilst this is no problem for steady, constant odours, it is possible to miss intermittent wafts of odour that would be picked up by the straightforward (albeit subjective) sniff test.

There are no UK standard protocols for the use of field olfactometers, which have yet to find widespread use here. In the US, state regulations often require boundary odour concentrations to be measured using this technique and McGinley & McGinley[39] describe the protocols that can be adopted.

* The Dilution-to-Threshold ratio is a measure of the number of dilutions (with carbon-filtered air) needed to make the odorous ambient air non-detectable. D/T is similar to the units of ou m^{-3} used in DDO, although the two are not interchangeable or directly comparable because the former is based on the odour detection threshold of one individual and the latter on a panel of typically six people.

Laboratory-based dynamic dilution olfactometry (DDO) should not normally be used for ambient odour measurements. Although lung-sampling followed by laboratory-based dynamic dilution olfactometry (DDO) is the standard method (BS EN 13725: 2003, Air Quality - Determination of Odour Concentration by Dynamic Oflactometry) for measuring the odour concentration of source emissions, such as stacks, the lower detection limit of that method (about 50 ou_E m^{-3}) is not low enough for measuring typical odour concentration in the ambient environment.

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Appendix 3 – Case law and appeals

Support for the use of C_{98} concentration metrics in a High Court case and several planning appeal decisions can be found. A High Court Judgement relating to odour nuisance at Mogden STW in west London and recent Inspectors' reports and decisions from Public Inquiries into residential developments near to STW sites at Stanton near Bury St. Edmunds and Cockermouth in Cumbria provide some illuminating "Case Law" in relation to odour nuisance.

In the Mogden case, the Judge concluded at paragraph 992 of his Judgement:

"I have to consider whether the odour which has been caused by particular odours has amounted to a nuisance in law and, if so, to assess damages for that nuisance. It is clear that odour concentrations below 1.5 ou_E per m^3 would not be considered to be a nuisance but I must bear in mind the fact that, on the basis of my findings, there are a number of processes at Mogden STW which Thames Water carry out and which do not give rise to Allen negligence but clearly give rise to odour emissions. It is therefore the additional odour nuisance caused by matters for which Thames Water are liable under Allen which I must consider. Such an assessment has no precise mathematical correlation with odour concentration figures and the application of a particular figure is difficult in this case because there has been no modelling of the odour conditions for which I have held Thames Water liable. I would be reluctant to find nuisance if the odour concentration was only 1.5 ou_E per m^3 but as the odour concentration rises to 5 ou_E per m^3 I consider that this is the area where nuisance from Mogden STW would start and that by the time that 5 ou_E per m^3 or above is reached nuisance will certainly be established."*

* In this case, operation of the sewage treatment works is undertaken by a statutory authority, governed by legislation, and, therefore, in simple terms, it is permitted to emit some odour that may be detectable, as long as operations comply with best practice.

In his report on the Stanton Appeal, the Inspector concluded at paragraph 55:

"The parties accepted that annoyance levels producing complaints are subjective and can arise both at levels below 1.5 ou_E/m^3 and from events in the 2% frequency. The existence of complaints does not necessarily demonstrate an unacceptable loss of amenity, but a lack of any is important in terms of the CoP. It is material in this case. On balance, and taking the relevant advice, decisions and practice into account, it seems to me that the appropriate threshold for this type of small STW is more than the 1.5 ou_E/m^3 now promoted by Anglian Water and the Council. I consider that a more appropriate threshold in this case is 3-5 ou_E/m^3, the level of the Defra guidance's "faint odour". Note that again, the Inspector's report appears to have misinterpreted the evidence presented and is using data presented as a 98th percentile to compare with a faint level of odour.

In the report on the Appeal Inquiry in Cockermouth, the Inspector concluded:

"I am mindful that the assessment based on a 98th percentile 1-hour average odour concentration (C_{98}, 1hour) would not result in a totally odour free scenario, as there is a likelihood of some occasional odour issues with sites such as the WWTW. However, any period of exposure to unpleasant odour should be short lived at some 2% of a year. Moreover, there are varying degrees of odour from sewage treatment. At this WWTW, odour from the sludge holding tanks is abated by use of an odour control unit, which odour sampling has shown to have an odour removal efficiency of approximately 98%. Thus it seems that highly offensive odours are unlikely to arise during normal operation. Should odours fall within medium offensiveness, rather than low, the C_{98}, 1hour 3 ou_E/m^3 level modelled by the appellant indicates that it would not impinge on the appeal dwellings."

Sewage treatment works odours are a specific case, amongst approximately 20 other statutory authority examples, in that, as a result of the statutory duty incumbent upon water companies to accept and treat domestic sewage, there is a portion of the odour produced and emitted that cannot be actionable under a nuisance case. Therefore, if the operator can demonstrate that best practice is being carried out, in accordance, for example, with the Defra Guidance[21], it is highly likely that no further enforcement action would be taken.

Appendix 4 – Comparison of OMP requirements in guidance

Good-practice OMP requirement	EA final H4 (2011)	SEPA Odour Guidance 2010	Defra Odour Guidance for LAs (2010)	Defra Composting Good Practice for LAs (2009)	Defra CoP on Odour from STWs (2006)	Sniffer OMP report for landfill Sites (2013)
A process description, particularly describing odorous, or potentially odorous, activities or materials used (inventory)	•	•	•			•
Identification of all the release points for each of the activities (plan/map if possible)		•	•	•	•	•
A description of the routine methods and mitigation/control measures that would be used day-to-day under normal operating conditions in the absence of any unusual risk factors (including pre-acceptance, receipt, inspection, acceptance/rejection of materials, storage, containment, handling, treatment and timing of activities).	•	•	•	•	•	•
A list of the actions in detail and who is responsible for carrying them out.		•	•	•	•	•
Identification of possible risk factors (e.g. adverse weather conditions) and anticipation of odour-related incidents and accidents (e.g., abnormal situations, spillages, power failure, breakdown of doors, equipment or abatement) and a listing of the consequences for odours of these risk factors.	•	•	•	•	•	•
A description of the additional measures (e.g. additional control measures and modifications to site operations for example diverting odorous waste loads to facilities with less sensitive surroundings during adverse weather conditions) that will be applied during these periods to deal with these risks and any reasonably foreseeable incidents and accidents. If the measures are not sufficient, they need to be tighted further or else possibly ceasing / reducing odorous operations.	•	•	•	•	•	•
A list of the actions in detail and who is responsible for carrying them out		•	•	•	•	•
A description of what would trigger this further action/additional measures, such as:	•		•			•
– the results of planned routine checks/inspections/surveys on site;	•		•			
– the results of on-site measurements of process parameters and surrogate measurements for odour (e.g. pH, temperature, oxygen, etc) exceeding defined trigger levels;	•					
– other metrics, such as particular meteorological conditions (e.g. temperature above a certain value, wind blowing in a particular direction, or calms); and	•		•			
– odour monitoring on- and/or off-site, including:	•	•	•	•		
• odour complaints monitoring (which should be carried out for all sites);			•			
• monitoring on-site showing non-compliance with any emission limit values (ELVs) set for controlled point source releases; and	•		•			

Good-practice OMP requirement	EA final H4 (2010a)	SEPA Odour Guidance 2010	Defra Odour Guidance for LAs (2010)	Defra Composting Good Practice for LAs (2009)	Defra CoP on Odour from STWs (2006)	Sniffer OMP report for landfill Sites (2013)
• monitoring off-site showing non-compliance with any action levels for ambient odour levels (e.g. by sniff testing, odour diary surveys, etc).	•					
A description of: - the roles and responsibilities of personnel on site (e.g. organisational chart); and		•			•	•
- the training and competence of staff in odour-critical roles		•	•	•	•	•
Details of how the following will be carried out, and who has been assigned managerial and operational responsibilities for them:						
– implementing and maintaining the OMP;			•	•	•	•
– responding to odour-related incidents and any elevated odour levels from the aforementioned checks/inspections/surveys, monitoring, or on receipt of complaints of odour nuisance; including carrying out investigations and taking appropriate remedial action to prevent recurrence;	•	•	•	•	•	•
– planned maintenance and repair and the keeping of essential odour-critical spares;		•	•	•	•	•
– regular review (at least once per year) of the effectiveness of odour controls - including the OMP itself – taking account of complaints, monitoring results, inspections, surveys and other information and feedback received. This interval may be shorter if there have been complaints or relevant changes to your operations or infrastructure;	•	•	•	•	•	•
– community liaison - engaging with neighbours and communicating with relevant interested parties (e.g. local community and local authority) to provide necessary information and minimise their concerns and complaints, including methods used, content and frequency of communication; and	•		•	•	•	•
– keeping records of all activities and actions relating to odour and the OMP.		•	•	•	•	•

Glossary

Abatement: An end-of-pipe control measure to reduce odour levels in the exhaust gas of a source, usually a controlled point source.

Adaptation: The long-term process that can occur when communities become increasingly tolerant of a particular source of odour, which is primarily a psychological response to the situation. For example, where odours are associated with a local industry that is considered to be important for the well-being of the local community and the industry maintains a good relationship with community members, then adaptation to the odour effects can occur over time.

Amenity: *"A positive element or elements that contribute to the overall character or enjoyment of an area. For example, open land, trees, historic buildings and the inter-relationship between them, or less tangible factors such as tranquillity."* (Source: www.planningportal.gov.uk/general/glossaryandlinks glossary/a. Accessed November 2013)

Annoyance: Odour annoyance can be considered the expression of disturbed well-being induced by adverse olfactory perception in environmental settings. Odour annoyance occurs when a person exposed to an odour perceives the odour as unwanted. Annoyance is the complex of human reactions that occurs as a result of an immediate exposure to an ambient stressor (odour) that, once perceived, causes negative cognitive appraisal that requires a degree of coping. Annoyance may, or may not, lead to nuisance and to complaint action.

Annoyance potential: Annoyance potential is the attribute of a specific odour (or mixture of odorants) to cause a negative appraisal in humans that requires coping behaviour when perceived as an ambient odour in the living environment. It is an attribute of an odour that can cause annoyance and may lead to nuisance and complaint. Annoyance potential indicates the magnitude of the ability of a specific odorant (mixture), relative to other odorants (mixtures), to cause annoyance in humans when repeatedly exposed in the living environment to odours classified as 'weak' to 'distinct odour' on the scale of perceived intensity (VDI 3882:1997, part 1). Annoyance potential is likely to be function of both hedonic tone and odour character/quality. Whether annoyance potential of an odour does, or does not, cause annoyance depends on location and receptor factors

Character (of an odour): Odour character or quality is basically what the odour smells like. It is the property that identifies an odour and differentiates it from another odour of equal intensity. For example, ammonia gas has a pungent and irritating smell. The character of an odour may change with dilution.

Chemical analysis: A variety of instruments can be used as sensors to measure the concentration of one or more odorous chemical compounds. The compound concentration can then be compared to the odour threshold to see if an odour is likely to be detected (odour detection threshold) or recognised (odour recognition threshold). The mass concentration of the compound can be converted approximately into odour concentration units (ou_E/m^3) by expressing it in multiples of the compound's ODT.

Community surveys: Measuring directly the odour impact (e.g. annoyance) in the local population by survey methods (e.g. quality of life surveys).

Complaints: Odour complaints occur when individuals consider the odour to be unacceptable and are sufficiently annoyed by the odour to take action.

Concentration (of an odour): Concentration is the amount of odour present in a given volume of air. We measure and model odour concentration, not odour intensity. For a known, specific chemical species this can be expressed either as the volume of that compound per unit volume of air (e.g. ppm or ppb) or the mass of that compound per unit volume of air (e.g. mg/m^3 or $\mu g/m^3$). For odours that are mixtures of compounds, concentration is measured in ou_E/m^3.

Descriptor (of an odour): The odour character is assessed by either the degree of its similarity to a set of reference odours or the degree to which it matches a scale of various 'descriptor' terms. Numerous standard odour descriptors, in list form or as 'odour wheels' (with the general descriptors placed at the centre of the wheel and more specific characters towards the wheel rim) have been developed for use as a reference vocabulary by assessors.

Desensitisation (of individuals to odour): This can, like sensitisation, result from exposure to an odour. A person may become unable to detect the odour, or there is a reduction in the perceived odour intensity and/or effect, even though the odorous chemical is still present in the air.

Dilutions to threshold ratio: A measure of the number of dilutions (with carbon-filtered air) needed to make the odorous ambient air non-detectable. D/T is similar to the units of ou_E/m^3 used in dynamic dilution olfactometry, although the two are not interchangeable or directly comparable.

Disamenity: The government Planning Portal does not define disamenity, but its literal meaning would be "impaired amenity" and from its definition of amenity could be considered to be a negative element or elements that detract from the overall character or enjoyment of an area. The Oxford English Dictionary defines disamenity as "*the unpleasant quality or character of something*". In relation to the impacts of landfills, Defra has described disamenity as nuisance caused by an activity such as noise, odour, litter, vermin, visual intrusion and associated perceived discomfort (Source: Defra, A study to estimate the disamenity costs of landfill in Great Britain, Final report Cambridge Econometrics in association with EFTEC and WRc, February 2003).

Duration: The duration of the odour occurrence is how long an individual is exposed to odour in the ambient environment.

Dynamic dilution olfactometry: The measurement of odour concentration using human subjects as the 'sensor'. The CEN standard has been adopted by practitioners in most of the world and has become the de facto international standard for laboratory dynamic dilution olfactometry (DDO). The concentration of the odour sample is measured in ou_E/m^3, which is equivalent to the number of repeated dilutions with a fixed amount of odour-free air or nitrogen that are needed until the odour is just detectable to 50% of a panel of trained observers. DDO is a valuable objective measure of odour concentration. It is limited in application to air samples having odorant concentrations at many times above the detection threshold (usually at least 50 ou_E/m^3).

Empirical dose-response approach: The approach to obtaining an odour modelling guideline value from an empirical dose-response study relating modelled exposures to community responses (e.g. annoyance).

European odour units per cubic metre of air (ou_E m^3)

Equivalent to the number of repeated dilutions with a fixed amount of odour free air or nitrogen that are needed until the odour is just detectable to 50% of a panel of trained observers in a DDO determination to the CEN standard BS EN 13725.

Exposure: The result of an exposure chain, consisting of an odour source, a transport mechanism and a receptor. Magnitude of odour exposure is determined by the FIDOL factors. Once exposure to odour has occurred, the process can lead to annoyance, nuisance and possibly complaints.

FIDOL factors: The perception of the impact of odour involves not just the strength of the odour but also its frequency, intensity, duration and offensiveness (the unpleasantness at a particular intensity) and the location of the receptors. These attributes are known collectively as the FIDOL factors.

Frequency: The frequency of the odour occurrence is how often an individual is exposed to odour in the ambient environment.

Fresh air: Air perceived as being air that contains no chemicals or contaminants that could cause harm, or air that smells 'clean'. Fresh air may contain some odour, but these odours will usually be pleasant in character or below the human detection limit.

Hedonic scores: Quantitative values assigned to the unpleasantness of source emission samples, by measurement in the laboratory by a panel of trained assessors in an odour panel following the German method VDI 3882 Part 2. Hedonic tone is scored on a nine-point scale ranging from very pleasant (score of +4, e.g. bakery smell) through neutral to highly unpleasant (score of -4, e.g. rotting flesh).

Hedonic tone (of an odour): Hedonic tone is the degree to which an odour is perceived as pleasant or unpleasant. Such perceptions differ widely from person to person, and are strongly influenced by previous experience and emotions at the time of odour perception. Hedonic tone is related to (but not synonymous with) the relative pleasantness or unpleasantness of an odour.

Intensity (of an odour): How strong an odour is perceived to be. Odour intensity describes the relative magnitude of an odour sensation as experienced by a person.

Nuisance: Nuisance is the cumulative effect on humans, caused by repeated events of annoyance over an extended period of time, that leads to modified or altered behaviour. This behaviour can be active (e.g. registering complaints, closing windows, keeping 'odour diaries', avoiding use of the garden) or passive (only made visible by different behaviour in test situations, e.g. responding to questionnaires or different responses in interviews). Odour nuisance can have a detrimental effect on our sense of well-being, and hence a negative effect on health. Nuisance occurs when people are affected by an odour they can perceive in their living environment (home, work-environment, recreation environment) and:

i. the appraisal of the odour is negative;
ii. the perception occurs repeatedly;
iii. it is difficult to avoid perception of the odour; and
iv. the odour is considered a negative effect on their well being.

Nuisance is not caused by short-term exposure, and it is not alleviated by relatively short periods (months) of absence of the ambient stressor.

Numerical benchmark criteria: The collective term used for odour exposure limits from different sources and agencies, such as WHO guideline values, the Environment Agency's Indicative Odour Exposure Standards, and custom and practice benchmarks.

Odour annoyance threshold approach: Odour modelling guidelines derived from an essentially theory-based analysis of odour definitions from first principles. This approach was used as the basis for the interim criteria that were recommended as New Zealand's first national odour concentration guideline values for all types of odour sources.

Odour detection threshold: The ODT is the lowest concentration of any specific chemical or mixture at which it can be ascertained that an odour is present, i.e. the level that produces the first sensation of odour.

Odour-free air: Air containing no odorous chemicals at all.

Odour modelling guideline value: A numerical benchmark criteria used specifically for relating the occurrence of adverse effects, such as annoyance, with the concentrations of odour at various receptor sites as predicted by atmospheric dispersion modelling.

Offensiveness (of an odour): A lack of agreed terminology has resulted in there being two meanings in common use of the term offensiveness of an odour, which can be confusing. On the one hand, offensiveness is sometimes used to describe the character and unpleasantness of an odour at a particular intensity, so it is related to the hedonic tone – one of the FIDOL factors. When used in this context, the term relative offensiveness is sometimes used. However, offensiveness is also used in the context of overall impact in terms of 'offence to the senses'. Here it has a much broader meaning, encapsulating the combined effect of most or all the FIDOL factors.

To avoid this confusion of terms, this document has used the term odour unpleasantness to describe the character of an odour as it relates to the hedonic tone. The term offensiveness has been used solely to describe the combined effect of all the FIDOL factors in terms of 'offence to the senses

Olfaction: The human ability for the sensing of smell.

Olfactory fatigue: The term sometimes used to describe desensitisation that occurs on a short term basis.

Quality (of an odour): What an odour is perceived to be like. See Character (of an odour).

Recognition threshold: The concentration, at some point above the odour detection threshold, at which the odour is recognised as having a characteristic odour quality. The concentration at which the character and hedonic tone of the odorant is recognisable.

Relative unpleasantness (of an odour): The degree to which one odour is perceived as being more or less pleasant or unpleasant than another odour under similar conditions.

Sensitisation (of individuals to odours): This may occur after acute exposure events or as a result of repeated exposure to nuisance levels of odours. Sensitisation changes a person's threshold of acceptability for an odour. This can result in a high level of complaint over the long term and a general distrust within the community of those perceived as responsible for the odour.

Sensitivity (of individuals to odours): Different life experiences and natural variation in the population can result in different sensations and emotional responses by individuals to the same odorous compounds.

Sensitivity (of the receiving environment): The type of land use and nature of human activities in the vicinity of an odour source and also the tolerance and expectation of the receptor. The 'Location' factor in FIDOL can be considered to encompass the receptor characteristics, receptor sensitivity and socio-economic factors.

Sensory analysis: Using the human nose as the sensor in an analytical measurement, a technique termed olfactometry.

Sensory testing: Using the human nose as a detector in tests for odour. In this context the tests are usually field tests for the assessment of odour impact. These tests can be subjective (so-called 'sniff tests') or objective (quantitative) using field olfactometry.

Sniff test: This tool – also called a direct sensory test, subjective testing or simplified olfactometry – gives a subjective measure of odour impact based on the assessor's opinion on the FIDOL factors at the receptors which are compared with descriptive (or sometimes numerical) guidelines.

Strength (of an odour): The magnitude of an odour – the odour strength – can be described in two ways, by its intensity and its concentration.

Abbreviations and acronyms

ASTM – American Society for Testing and Materials (method)

BAT – Best Available Techniques

CEN – Comité Europeén de Normalisation/European Committee for Standardisation

DDO – dynamic dilution olfactometry

DCLG – Department for Communities and Local Government

Defra – Department for Environment, Food and Rural Affairs

D/T – dilutions to threshold

EA - Environment Agency

ELV – emission limit value (at source)

EPA – Environmental Protection Agency

EPR – The Environmental Permitting Regulations

EROM – European Reference Odour Mass

FIDOL – frequency, intensity, duration, offensiveness and location

GC-MS – gas chromatography separation stage combined with mass spectrometry detection stage

mg/m^3 – milligrams per cubic metre

µg/m^3 – micrograms per cubic metre

OCI – odour concentration–intensity (relationship)

ODT – odour detection threshold

ou_E/m^3 – European odour units per cubic metre of air

PIR – Process Industry Regulation

ppb – parts per billion

ppm – parts per million

SEPA - Scottish Environmental Protection Agency

UKAS – United Kingdom Accreditation Service

UKWIR – UK Water Industry Research (limited)

VDI – Verein Deutscher Ingenieure (standards)

WHO – World Health Organisation

IAQM
c/o Institution of Environmental Sciences
3rd Floor
140 London Wall
London
EC2Y 5DN

T: +44 (0)20 7601 1920

info@the-ies.org
www.iaqm.co.uk

IAQM Institute of Air Quality Management