Odour Methodology Guideline

Department of Environmental Protection
Perth, Western Australia
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Executive Summary

The purpose of this guideline is to describe methodology acceptable to the Western Australian Department of Environmental Protection (DEP) for odour sampling and analysis using dynamic olfactometry.

The guideline presents some principles of odour science before describing the accepted methodology in Western Australia for measurement and assessment of odour impacts for a range of situations. Reporting requirements are also included.

The objective of the odour measurement program should be identified before any sampling is undertaken, as the objective will influence the sampling requirements for the study and subsequent analysis and modelling, as well as the type of information which should be reported. The objective must be clearly outlined in reports on odour studies, and be referred to when justifying the sampling program undertaken.

The DEP's approach to management of existing odour sources is briefly outlined in section 7 of the guideline.

This guideline does not include criteria for acceptable odour levels, although some criteria have been set by the Environmental Protection Authority (EPA) for assessment of new proposals (see *EPA Guidance No 47: Assessment of Odour Impacts from New Proposals*). Setting of appropriate criteria for existing sources will depend on case-specific circumstances, and advice on this matter should be sought from the DEP. Criteria set out in the EPA's Guidance Statement No 47 should only be applied to proposals for new odorous facilities, development of new odour sensitive land uses near existing odorous facilities, and expansions of existing facilities which may result in odour impacts. For more details please refer to the EPA Guidance Statement.

Contents

1. Introduction

The Department of Environmental Protection (DEP) must deal with odour complaints which are impacting on the amenity of the community. The *Environmental Protection Act 1986* protects against "unreasonable emissions" – *emissions of noise, odour or electromagnetic radiation which unreasonably interfere with the health, welfare, convenience, comfort or amenity of any person*. Criteria for what is considered "unreasonable" must be determined on a case by case basis.

Odour is likely to become an issue in situations where conflicting land uses result in sensitive receptors locating close to odour sources. The EPA has set criteria in its Guidance Statement No 47 Assessment of Odour Impacts from New Proposals (EPA, 2002) for new proposals and expansions of existing facilities. Odour criteria for existing facilities will differ depending on the situation.

Odour measurement may be used for assessment of a range of situations including:

1. Proposals for a new and expansion of an existing odorous facility;
2. Proposals for sensitive land use near an existing odorous facility;
3. Investigation of complaints to the DEP of odour from existing facilities;
4. Setting of licence conditions;
5. Buffer definition studies where surrounding land is not yet zoned for urban use;
6. Assessing odour during contaminated site remediation;
7. Determination of odour emission rates before and after a plant upgrade in order to quantify emission reduction.

In order to compare odour levels with relevant criteria, sampling and analysis must be undertaken in accordance with standards adopted for use in Western Australia. Use of other methods is likely to result in measurements which are inconsistent with criteria used in Western Australia.

The purpose of this guideline is to provide guidance on methodology acceptable to the DEP for odour sampling and analysis using dynamic olfactometry, computer modelling of odour impacts, and the reporting format required by the DEP.

2. Background

The DEP has consistently recorded odour as the cause of about one-third[1] of all public pollution complaints received. Most odour complaints against industry have centred around animal products processing activities.

Odour problems arise when incompatible land uses are allowed to occur. For example, subdivision of land close to existing poultry farms began to cause land use conflicts in the 1980s as Perth's urban development spread to areas which had previously been considered rural.

The then DEP considered that the development of a quantitative approach to the management of odour should be preceded by a case study to investigate the odour impacts from a representative industry. Poultry farms were chosen to provide immediate guidance on how to deal with this particular industry and develop the level of understanding of quantitative odour assessment necessary to develop a more far-reaching approach. This methodology guideline builds upon the results and experience gained from the Poultry Farm Odour Study and the work of the EPA (1999).

The components of the Poultry Farm Odour study (Jiang and Sands 1998a and 1998b) were:

1. Sampling of odorous air within poultry sheds;
2. Measurement of meteorological parameters and shed ventilation rates;
3. Analysis of odour samples (using dynamic olfactometry, described in section 3.1 below) to determine the odour characteristics (detection threshold, odour emission rate and the intensity - concentration relationship);
4. Modelling of odour impacts using a full year of meteorological data;
5. Recommendations of appropriate odour acceptability criteria.

Subsequent work was undertaken by Welker Environmental Consultancy for the EPA (EPA, 1999) to develop the findings of Jiang and Sands (1998a and 1998b) for use in the regulatory framework of environmental protection in Western Australia.

The experience gained through the process of undertaking the poultry farm study resulted in a lengthy peer review process after which the EPA developed a draft Guidance Statement for the Assessment of Odour Impacts (EPA 2000). The EPA Guidance Statement has now been finalised and includes odour criteria for new proposals. This DEP guideline outlines the appropriate methodology for measurement and modelling of odour emissions.

[1] Data for 1/7/94 to 30/6/97, primary complaint, head office database.

3. Odour Science

To completely describe an odour, four different dimensions are often considered:

- **Odour detection threshold** is the lowest odorant concentration necessary for detection by a certain percentage of the population, normally 50%. This concentration is defined as 1 odour unit. A more rigourous definition can be found in section 8.

- **Odour intensity** is the perceived strength of an odour above its threshold. It is determined by an odour panel and is described in categories which progress from "not perceptible", then "very weak", through to "extremely strong".

- **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, inter alia, by previous experience and emotions at the time of odour perception.

- **Odour character** is basically what the odour smells like. It allows one to distinguish between different odours. For example, ammonia gas has a pungent and irritating smell. The character of an odour may change with dilution.

This guideline focuses primarily on the odour threshold and intensity for assessing odour impacts. Attempts to encompass hedonic tone and odour character are presently considered too subjective for use within a regulatory framework.

Odour complaints occur when individuals consider the odour to be unacceptable and are sufficiently annoyed by the odour to take action. The New Zealand Ministry for the Environment (1995) suggests there are five factors that influence odour complaints:

- Frequency of the odour occurrence;
- Intensity of the odour;
- Duration of the exposure to the odour;
- Offensiveness of the odour;
- Location of the odour.

Frequency, intensity, duration and location are quantifiable and can be built into a regulatory guideline. Odour offensiveness is subjective and relates closely to an odour's hedonic tone so is difficult to quantify. The intention of the DEP is to protect the community from odours which can reasonably be considered to be offensive (in terms of hedonic tone), such as those associated with waste water treatment, putrescible waste, rural odours, processing of animal products, etc. Chemical odours associated with heavy industry may also be offensive and assessment of such odours would also need to consider possible impacts on human health and the environment.

As with other air pollutants, odour impacts can be assessed by undertaking measurement, modelling and comparison of model results with an appropriate criterion.

Because of the historical lack of standardised methods and terminology, it is difficult to interpret and compare the odour measurements which appear in the literature. The recently completed Australian Standard (along with other international standards) for odour measurement will improve the situation in the future.

Once odour measurements are available, dispersion modelling can be used to predict the area likely to be affected by the odour. There are many dispersion models available that are able to predict odour impacts and can provide graphical representations that are useful in communicating the impacts associated with a given project.

3.1 Odour Concentration

There are no instrument-based methods that can measure an odour response in the same way as the human nose. Therefore "dynamic olfactometry" is typically used as the basis of odour management by regulatory authorities.

Dynamic olfactometry is the measurement of odour by presenting a sample of odorous air to a panel of people at a range of dilutions and seeking responses from the panellists on whether they can detect the odour. The correlations between the known dilution ratios and the panellists' responses are then used to calculate the number of dilutions of the original sample required to achieve the odour detection threshold. The units for odour measurement using dynamic olfactometry are "odour units" (OU) which are dimensionless and are effectively "dilutions to threshold".

During the 1990s significant research was undertaken in Europe to refine the olfactometry method. This led to considerable improvements in panellist management and standardisation and, importantly, clear criteria for repeatability and reproducibility of results.

The draft Committé Européen de Normalisation (CEN) odour measurement standard (CEN, 1996) is a performance based standard with strict criteria for repeatability and reproducibility. Odour laboratory performance was tested during its development which highlighted that repeatability and reproducibility of odour threshold measurement improved to levels similar to those associated with noise measurements (van Harreveld and Dönszelmann, 1994).

It is important that proponents undertaking odour assessment studies realise that the different methods of dynamic olfactometry provide different results for the odour threshold. It is vital that any use of published odour thresholds should be thoroughly checked for the method used and appropriate adjustment factors, prior to use in current assessments. The DEP expects that submissions using published odour data will document the type of olfactometry used and the appropriate adjustment factor. For example, Bardsley and Demetriou (1997) indicate that the Dutch NVN 2820 method (one of the methods preferred by the DEP) will give an odour threshold of approximately twice as many odour units as when the Victorian EPA B2 method is performed at the Victorian EPA laboratories.

3.2 Odour Intensity

As outlined above, the perceived strength, or intensity of an odour can be described using terms such as "not perceptible", "weak", "strong" etc. The German standard Olfactometry Determination of Odour Intensity VDI 3882 Part 1 (VDI, 1992) provides qualitative descriptions of odour intensity with a numerical scale that may be used in back-calculating the corresponding odour concentration. These descriptions are reproduced in Table 1.

Like odour threshold determination, assessment of odour intensity is undertaken in the laboratory by odour panels and dynamic olfactometry equipment. Panel members are presented with odour at concentrations greater than the odour threshold (by definition 1 OU/m^3) and asked to rate the odour strength on the scale in Table 1. The concentration presented to the panel is known because the threshold is known from the determination described in section 3.1 above, and the dilution level of the sample is controlled by the equipment.

Table 1: Odour Intensity Categories.

Odour Strength	Intensity Level
Extremely strong	6
Very strong	5
Strong	4
Distinct	3
Weak	2
Very weak	1
Not perceptible	0

It is usually accepted that a "distinct" odour may just be able to be recognised (ie. has a concentration equivalent to its recognition threshold). An odour described as "distinct" under highly controlled laboratory conditions is likely to be harder to detect in the environment.

3.3 Relationship between Odour Concentration and Odour Intensity

Odour intensity is a useful dimension to quantify because some odours are perceived as being stronger than others. In other words, all odours will be just detectable at a concentration of 1 OU/m^3, however, at twice the concentration, or 2 OU/m^3, some odours may be perceived as very weak while others may be perceived as distinct. At ten times the concentration, or 10 OU/m^3, one odour may be perceived as distinct while another odour at 10 OU/m^3 concentration may be very strong. This means that defining an odour criterion based on odour concentration, as has historically been done for the purposes of managing odour impact on the community, will result in different perceived odour strengths. The only time this will not occur is when the odour criterion is equal to the detection threshold (ie. 1 odour unit) which effectively becomes a "no impact" criterion.

Using dynamic olfactometry to determine odour threshold (and therefore odour concentration) and then odour intensity, a suitable relationship between concentration and intensity can be determined, allowing different odour types to be compared. Stevens Law and the Weber-Fechner Law are examples of formulae which have widespread acceptance for defining the relationship between odour intensity and concentration for a particular odorant (including complex mixtures). The formula for the Weber-Fechner Law is given in section 4.2 below.

For example, the Weber-Fechner relationship between intensity, concentration and thresholds is consistent for hydrogen sulphide and butanol, but the coefficients used within this relationship differ for the two odorants. Figure 1 illustrates this point using data from the German VDI 3882 standard.

As can be seen from Figure 1, if an odour concentration of 10 odour units was chosen as the appropriate criterion, butanol would be perceived as a weak odour, whereas hydrogen sulphide would be perceived as a distinct odour. To have equivalent protection against odours would require choosing an intensity level for the criterion and then working across the graph to determine the appropriate concentration for that odorant. For example, if the criterion were set at a “distinct” perceived odour (in the laboratory) then the appropriate concentrations would be 11 and 33 odour units for hydrogen sulphide and butanol respectively.

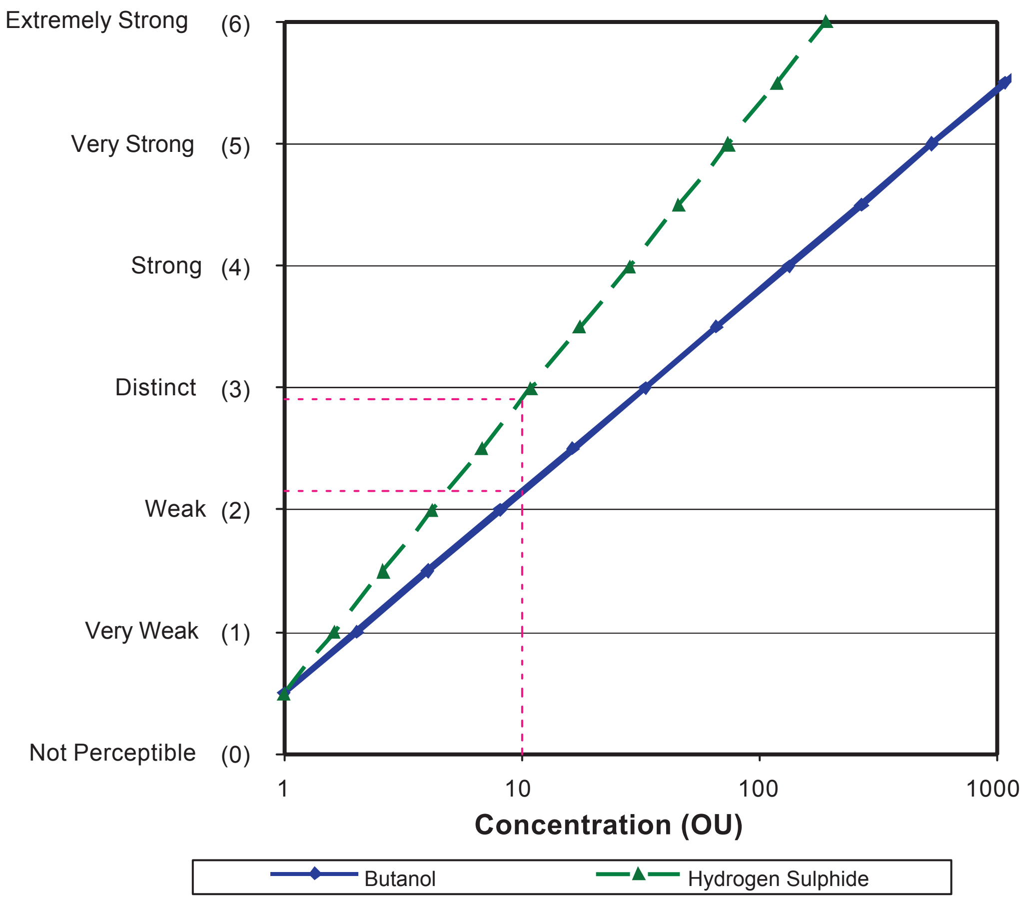

Figure 1: Relationship between Perceived Odour Intensity and Odour Concentration for Butanol and Hydrogen Sulphide (as reported in the German standard VDI 3882) using the Weber-Fechner Law.

4. Guideline

The DEP considers the appropriate methods for measuring odour concentration to be:

- The Dutch Standard NVN 2820 "Air Quality, Sensory odour measurement using an olfactometer", March 1995;
- Committé Européen de Normalisation, "Odour Concentration measurement by dynamic olfactometry, CEN TC264/WG2 'Odours' Final WG2 Draft prEN", 1995; or
- Australian Standard 4323.3:2001 *Stationary source emissions - Determination of odour concentration by dynamic olfactometry* (Note that the Australian Standard has been based on the CEN standard).

The German Standard VDI 3882 Part 1, "Olfactometry Determination of Odour Intensity", October 1992 should then be used for the subsequent odour intensity calculations.

The following sections present guidelines for undertaking odour sampling, odour analysis and calculation of odour emission rates, for the purpose of odour modelling as well as guidance on reporting requirements.

4.1 Odour Sampling Methods

Sampling of odours from point and non-point sources should be undertaken with reference to the abovementioned Dutch or CEN Standards, or the equivalent Australian Standard.

Standard methods are not available for sampling of odour from fugitive sources, however as a guide, direct sampling of odour (using appropriate equipment such as enclosures or tunnel hoods), or calculation of likely odour emission rate based on process calculations is preferred, rather than indirect methods such as down-wind ambient sampling followed by "back calculation" of source emission rate.

4.2 Odour Analysis

Determination of odour emission rate for the purposes of modelling odour impacts may be determined in one of the following ways:

1. When only a single odorant in an air stream is present and there are appropriately reviewed odour thresholds for the odorant available (US EPA, 1992) then the geometric mean air odour threshold may be used.

2. Odour sampling of sources, undertaken as outlined above, and determination of odour concentration using dynamic olfactometry methods (to Dutch, CEN or Australian Standards).

3. Odour sampling of sources, undertaken as outlined above, and determination of odour concentration using dynamic olfactometry methods (to Dutch, CEN or Australian Standards) and determination of the concentration-intensity relationship (using the VDI method for determining odour intensity).

To model odour impacts, following the recommendations of this guideline, the proponent must undertake both odour threshold and intensity analyses (using the methods proposed within the NVN 2820, CEN or Australian Standard 4323.3 and VDI 3882 standards). Once the odour intensity/concentration data are available, the Weber-Fechner law (Equation 1) should be used to develop the mathematical relationship between intensity and concentration. This relationship may then be solved for the odorant concentration which corresponds to an appropriate criterion (for example, the EPA suggests an intensity of 3 ("distinct") for use as the comparative criterion for new proposals).

$$I = k_w \log(C/C_o) + \text{const} \qquad (1)$$

where:

I: Intensity (perceived strength), dimensionless;

k_W: Weber-Fechner constant;

C: Concentration of odorant;

C_o: Concentration of odorant at the detection threshold (by definition equals 1 when using odour units);

const: a constant which relates to the use of mean intensity levels. This constant is calculated from the line of best fit for each odorant.

The Weber-Fechner law has been chosen over Stevens Law because it is simpler to derive from experimental data. It is also described in the German Standard with a worked example.

NOTE: As the intensity-concentration relationship has been determined for Western Australian broiler growout farms, redetermination for individual proposals for new poultry farms or for sensitive land use developments close to existing poultry farms is not necessary.

4.3 Odour Emission Rate

Following determination of odour concentration in OU/m^3, odour emission rate in $OU/m^3/s$ must be calculated for input into the dispersion model. Odour emission rate can be calculated after determining velocity or volumetric flow rate and emission temperature for each odour source.

4.4 Modelling

Dispersion modelling shall be performed using a minimum of one (preferably two) years of high quality (validated) meteorological data. Obtaining suitable data is the proponent's responsibility. The DEP may have suitable meteorological data for some locations and consultants are advised to contact the DEP to determine what data sets are available. Advice on acceptability of meteorological data sets should be sought from the DEP prior to their use. Proponents should be aware of the usual requirements for dispersion modelling as advised by the DEP. The current requirements have been included as Appendix A and should be followed to the extent that they apply to odour modelling. Proponents should check with the DEP to ensure that they have a current copy of these guidelines.

In some instances, terrain or other effects may preclude the use of a simple Gaussian plume model for assessing odour impacts. In these circumstances, the proponent should refer to the modelling guidelines in Appendix A and seek advice from the DEP where necessary on appropriate dispersion modelling methods.

Generally gaussian models for assessment of odour impact will only be appropriate for sources which may be classified as "volume sources" (eg poultry sheds), "large area sources" (eg effluent treatment ponds) or "strongly wake-affected plumes". Advice should be sought from the DEP where it is not clear whether a particular source fits into one of these classes.

For other source types such as “line”, “surface point source”, “tall wake-free stack”, etc, a modelling study which adequately considers the ratios of peak to mean concentration fluctuations must be undertaken. The DEP will be developing modelling methodology and criteria for peak to mean assessment as resources permit.

The proponent must include contour plots of the odour impact predictions. These shall reflect the criteria or guidelines applicable to the specific situation, depending on the objective of the odour study. This will help interested parties visualise where the odour impacts may occur.

Any modelling assessment documentation shall include an electronic copy of the dispersion modelling input and meteorological files for verification by the DEP.

4.5 Criteria

EPA criteria for new proposals can be found in EPA Guidance No 47: *Assessment of Odour Impacts from New Proposals*. Criteria for circumstances other than new proposals should be discussed with the DEP in the first instance.

4.6 Complaints Verification/Ground Truthing

It should not be expected that observations in the field will relate directly to model results, as model results relate to nominated time averages whereas observations in the field are dominated by very short term peaks, the magnitude of which is related to source type and meteorological conditions.

Pending development and testing of ground truthing methods, the DEP recommends ground truthing be used as a tool to attempt to resolve major anomalies between complaints and model results. Any such ground truthing should take account of the state of knowledge on short term peaks such as outlined in the New South Wales draft odour policy (EPA NSW, 2001).

A field verification standard has been developed in Germany (VDI, 1993b) which is understood to present a more rigorous approach to ground truthing, and which should be referred to when undertaking ground truthing.

As part of the longer-term odour management, proponents may wish to perform community odour surveys and complaint verification to validate their odour predictions against the longer-term community perceptions. This would mainly be appropriate for proposed industrial facilities, but may also be appropriate for staged residential developments near existing odorous facilities. Care should be taken when undertaking community surveys that biases are not introduced through the types of questions asked. Standards for community surveys have been developed in Germany (VDI, 1993a) and may be useful to refer to in designing a questionnaire.

It should be noted that ground truthing and complaint verification are presented as techniques for verifying dispersion modelling results, not as an alternative to modelling or as an alternative method for determining source emission rate.

4.7 Conclusion

The above discussion points should be considered to be the minimum required information to be supplied in an odour assessment. Where further relevant information is available, it should be included.

In some cases (such as extremely offensive odours) the proponent may be required to undertake significantly more work to justify the proposal. This may extend to providing greater commitments to odour management to ensure odour impacts are minimised under accidental release conditions.

5. Special Cases

5.1 Poultry farms

The objective of the Jiang and Sands (1998a) poultry farm study was to investigate odour impacts from poultry farms for consideration in development of a quantitative odour policy. Prior to the poultry farm study, a number of factors were identified as being responsible for the level of odorous emissions from poultry farms. These are summarised in Table 3 for an individual shed and for a farm.

Table 2: Factors affecting poultry odour emissions.

"Shed" factors	"Farm" factors
• Shed capacity (number of birds) • Stage of growth cycle • Ventilation rate • Temperature • Humidity • Feed, bird species, water spillage from drinkers and leaking pipes, dead bird removal, shed physical condition and preventing rain water ingress, insulation, general housekeeping etc	• Farm capacity (number of sheds/birds) • Shed type (cross-ventilated, tunnel ventilated) • Shed orientation (e.g. north-south, east-west etc) and layout (e.g. in a line, grouped etc)

Clearly, many of the above factors are interdependent and related to ambient conditions. This makes defining a model to continuously predict odour emission rates extremely complex.

General observations from poultry farm odour analysis

It was beyond the scope of the Jiang and Sands (1998a) study to identify the relationships between the above factors and odour emission rate. To do this would require considerably more sampling and a much bigger project budget. The design philosophy of the study was, therefore, to sample odours from three reasonably representative farms:

- During the stage of the growth cycle when emissions were likely to be highest (i.e. 4 weeks onwards, just prior to, and just after, a disturbance in the form of harvesting);
- At the time of year when odour emissions were likely to be highest (i.e. summer);
- At times of day when the combination of high odour emission rates and meteorology were likely to cause the highest level of odour impact (i.e. mornings and evenings).

Odour samples were taken from poultry sheds under various conditions and analysed to determine odour threshold and to establish the relationship between odour intensity and concentration for poultry odour. A summary of the results is shown below, including results from analyses using the Weber-Fechner law and using Stevens Law.

Table 3: Poultry odour concentration corresponding to intensity levels.

Odour strength	Intensity level	Concentration using Weber-Fechner (OU)	Concentration using Stevens Law (OU)
Extremely strong	6	144	79
Very strong	5	52	42
Strong	4	19	20
Distinct	3	7.0	7.8
Weak	2	2.5	2.6
Very weak	1	0.92	1.1
Not perceptible	0	0.34[a]	-[b]

[a] For an odour concentration of 1 OU (ie. the 50% odour detection threshold), VDI 3882 effectively defines the corresponding Intensity as 0.5. Intuitively then, the odour "detection" level can be thought of as being higher than "not perceptible" (which it must be by definition) but lower than "very weak".

[b] Stevens Law is calculated by taking the logarithm of intensity (I) which for I = 0 is not mathematically possible. By definition, the odour "detection" level is defined as 1 odour unit, so from a practical consideration the "not perceptible" level is beyond the range of interest.

Two farm factors found to be significant were:

- Size of farm (expressed in terms of numbers of birds);
- Orientation/layout of sheds.

The farm size will clearly have a significant impact on the level of odour emissions and extent of odour impact. Different shed orientation/layouts for farms of the same size could significantly affect the shape of odour impact contours. The effect is dependent on the local meteorology, particularly wind directions. A farm, which has all the sheds in a line, would cause odour impacts to be relatively extended both sides along the main axis of the shed line-up and relatively contracted both sides perpendicular to the main axis.

The average odour emission rate was found to be 4488 OU/m^3/s for an average shed capacity of 22,996 birds. This relationship can be used to determine odour emission rates for different shed sizes.

Modelling Impact of Poultry Farms

Because the relationship between odour concentration and intensity has been determined for Western Australian poultry farms, redetermination of this relationship for individual proposals for new poultry farms or for sensitive land use developments close to existing poultry farms is not necessary.

The approach taken to determine appropriate separation distances between poultry farms and sensitive land uses is outlined as follows:

1. Define the emission rates for the farm layout, based on the nominal number of total birds (eg. the maximum likely number of birds on the farm with consideration of farm expansion).

2. Use AUSPLUME to model the odour impacts using the same assumptions used for modelling in the Jiang and Sands (1997a) study. Naturally ventilated sheds should be treated as volume sources with the horizontal and vertical initial dispersion parameters assigned conservatively i.e. ¼ of minimum building length and ¼ of building height. Better precision is possible by dividing the shed into a series of approximately square sources.

   As tunnel[2] sheds in Western Australia are generally operated in this mode only for a short duration of the year when temperatures are extreme, these sheds should be modelled as for naturally ventilated sheds. If, however, for any reason, the sheds are operated substantially in tunnel ventilation mode, then the source location should be at the air exit end of the shed with the initial dispersion parameters assigned conservatively as described above.

3. Plot contours corresponding to appropriate criteria for the purposes of the study. For example, for proposed new poultry farms or new proposals for sensitive land uses near existing poultry farms, the 7 OU concentration 3 minute average 99.5 percentile contour should be plotted. This gives a plot showing expected annual odour impacts based on reasonably realistic odour emissions. Land use planning data such as lot boundaries, nearby residents etc should be included in the plots so that impacts can be visualised in relation to the specific planning application.

While the procedure described defines reasonably realistic but slightly conservative odour buffers, some important non-conservative assumptions are embodied. These are:

- Higher odour emissions likely to occur during shed clean-outs have not been considered;
- Variations in odour emissions which may occur with different feed types have not been considered;

[2] Currently, there are no known "tunnel-only" sheds in Perth. Tunnel sheds with cross ventilation shutters are operated in cross ventilation mode whenever possible, to minimise operating costs. Furthermore, tunnel operating mode is usually during very hot conditions which favour the dispersion of odour emissions. Hence tunnel sheds with cross ventilation can usually be treated as normal cross-ventilated sheds for the determination of buffer distances.

- Higher odour emissions during extreme times of year for odour generation (e.g. hot summer days with bird cooling by water fogging, or still evenings / mornings) have not been considered.

Limitations of Model Results

It is beyond the scope of this document to address implementation issues in detail. The following provide information to assist practical implementation.

Occasionally, odours may still be detectable for short periods of time outside the plotted contour, due to poor meteorology for dispersion and/or farm operations which cause excessive odour emissions. Hence neither generic nor specific separation distances can absolutely prevent unacceptable odour impacts.

When a separation distance is determined for a specific farm, significant expansion of the farm is essentially prevented. It is therefore important to consider the eventual size of the farm when establishing the separation distance.

In time, a farm owner may wish to expand their farm above the limit imposed by an established separation distance. It is desirable to potentially allow this because:

- the intent of the separation distance concept is to prevent an unacceptable environmental impact. If, for a proposed expansion, achieving this objective can be clearly met (for example, through the use of advanced odour control measures), then there is no need to be bound by criteria based on generic separation distances.
- it is likely and desirable that the poultry industry as a whole will continue to improve its odour control performance. Allowing specific farms to expand where odour impacts will meet the odour criteria provides a form of encouragement to the industry to find ways to continually reduce odours. This often leads to "across-the-board" industry improvement.

Egg Farms

Results from sampling odours from egg farms are reported in Jiang and Sands (1998b). The odour emissions from the sampling of a single shed are 0.079 OU/s/bird. The average odour emissions from broiler farms is about 0.20 OU/s/bird (18 samples from 5 sheds on 3 farms). This indicates that, on a "per bird" basis, odour emissions from egg farms may be about 0.4 times that from broiler farms. This confirms anecdotal evidence that odour emissions from egg farms are likely to be less than from broiler farms. The use of a single sample however, is considered to be a far too unreliable basis on which to make recommendations for generic buffer distances. Hence the buffers recommended apply to broiler farms only although the methodology used for determining broiler farms buffers should be applicable to egg farms.

5.2 Use of Existing Odour Data

It is expected that over time more case studies on specific industries will be published, with greater data comparability with the adoption of the Australian standard method for odour measurement. The proponent should seek advice from the DEP on using published odour measurement data prior to their use in a submission. Published data will not automatically be considered acceptable by the DEP unless adequate justification is provided. A submission may be rejected where the DEP considers the data unacceptable.

Care should be taken when utilising existing odour data. Key points for consideration include:

- data quality;
- accounting for seasonal or other temporal factors which impact on odour emissions;
- similarity of climatic conditions;
- similarity of industry, infrastructure and management practices;
- the aim of the study which provided the data;
- possible effects of terrain features on the collection of the initial data;
- odour measurement methodology and the general level of agreement on any adjustment factors;
- completeness of the odour data as reported in the literature;
- the professional competence of the person who conducted the reported odour study.

At a minimum, a proponent who wishes to use existing odour data should seek to convince themselves that the data listed in section 6 below are available and that the professional competence of the person who conducted the initial study is sound.

Where the use of existing data is acceptable to the DEP, discussion of the above factors (and other factors as appropriate) must be included in a submission justifying the use and treatment of existing data.

5.3 Multiple Odour Sources and Cumulative Impacts

Little is currently understood about the cumulative impacts of multiple odour sources. It would seem reasonable to expect multiple sources of the same type of odorant (eg. multiple sheds on a poultry farm) to be additive in nature (notwithstanding the non-linear olfactory response to odour concentration). Consideration of cumulative impacts is needed for multiple sources with different odour types. In some cases the effects may be additive and in other cases it may be positively synergistic (an odour greater than the sum of the individual odorant impacts) or negatively synergistic (an odour less than the sum of the individual odorant impacts). Some anecdotal evidence suggests that the effect is likely to be positive and synergistic.

While the cumulative and interactive effects of odours are not well understood, it is fair to say that unacceptable odour impacts are more likely where several odour sources are co-located.

Facilities which have multiple odour sources should determine the odour intensity concentration relationship for each source and, as a minimum, use the concentration which relates to the strongest odour (highest intensity) for comparison with designated criteria. However, other factors which may influence odour impact must also be considered, such as odours from tall stacks which may result in high peak to mean ratios, or “chemical” odours which may be perceived differently by odour sensitive receptors.

5.4 Industrial Sources

Industrial facilities with odorous emissions may cause concern within nearby communities if odours are “chemical” in nature rather than “organic” odours or odours which are the result of agricultural activities. In addition to meeting appropriate odour criteria, such industries will be required to satisfy the DEP that ground level concentrations of pollutants are not of concern for human health or the environment, both in the short and longer term.

6. Reporting Requirements

Reports presenting results of odour studies should include:

Objective

Prior to undertaking an odour measurement program, it is important to identify the objective of the program so that an appropriate program structure can be developed. The objective should be stated, and referred to when justifying the sampling method and modelling undertaken.

Criteria

If applicable, the report should state what criteria will be used for comparison of results.

Sampling program

Justification of sampling method in relation to the measurement objective and the relevant criterion should be included in the report. The sources sampled, and the timing of the samples taken will depend on the objectives of the measurement program. Plant conditions at the time of sampling should be appropriate for the purposes of modelling. For example, for most environmental impact assessments it will be necessary to sample during “worst case normal” conditions, and possibly during upset or maintenance conditions where these occur regularly and may impact on nearby sensitive receptors. In this case the objective will be to estimate the highest impacts on the surrounding area during the year.

Contour plots

The report should include plots of odour contours at appropriate intervals and values to indicate the predicted impact of the odour source on the surrounding area. Contours should be overlaid on a map of the area if possible, or should at least provide a clear indication of major features such as the source, nearest receptors and major roads.

Complaint verification/ ground truthing

Maps and tables indicating results of any ground truthing (including comparison with modelled results) should be included in the report. Where complaints mapping has been used, a map showing locations from which complaints were received should also be included in the report.

Technical Information to be Provided with Results of Olfactometry Testing

All results of olfactometry analysis should include the following information:

- How “worst case” conditions were captured by sampling.
- Confirmation of sampling methodology and protocols (what standards were used).
- Confirmation of what, if any, sample dilution was used during sample collection.
- Laboratory where olfactometry undertaken.
- Confirmation of method used such as:
  - Dutch Standard NVN2820 "Air Quality, Sensory odour measurement using an olfactometer", March 1995;
  - Comitté Européen de Normalisation (CEN), 1995, “Document 064/e, Draft European Standard, Odour Concentration measurement by dynamic olfactometry, CEN TC264/WG2 ‘Odours’ Final WG2 Draft prEN”;
  - Australian Standard 4323.3 *Stationary source emissions - Determination of odour concentration by dynamic olfactometry.*
- Method of calculating odour threshold (eg “forced choice, certainty” or “yes/no”) and whether retrospective panellist screening was applied.
- Order of presentation (eg weak-to-strong, random).
- Ports per panellist.
- Minimum flow rate per port. Date and time of olfactometry analysis.
- Time between sample collection and olfactometry analysis.

- Number of panellists and identification code of each.
- Certified reference material (CRM) used and its concentration.
- Calibration plots (from data less than 6 months old) for the olfactometer verifying:
  - stability at each dilution step within 5%;
  - accuracy at each dilution step within 20%.
- Result matrices for odour intensity analyses (see Figure 1 of the VDI 3882 standard).
- Plot of the odour intensity-concentration relationship(s).
- Estimates of the precision of the analyses.
- Estimates of the odour laboratory's repeatability and reproducibility parameters for the odour threshold determination, as per the CEN standard.
- Signature of authorised person of the company performing the olfactometry analysis, and date.

7. Odour Management Guidelines

It should be noted that despite the best efforts in measuring the odour strength (at the source) and in predicting the impact areas, conditions may be such that unacceptable odours can occur beyond the predicted impact area. This can occur because of extremely poor dispersion conditions, however facility managers should be able to demonstrate that appropriate checks have been performed to ensure correct operation prior to assuming that meteorological conditions have resulted in poor dispersion. These checks could include assessment of meteorological data for stability patterns.

The criterion chosen for management of an odour issue depends on the management objective. For example, the criteria adopted by the EPA for assessment of new proposals (as set out in EPA Guidance No 47: Assessment of Odour Impacts from New Proposals) allow the EPA to determine whether odour impacts from a new proposal are likely to be acceptable in terms of their impact on amenity and are essentially "screening" criteria rather than "limits" for determining when impact is "unreasonable". For other situations DEP advice should be sought on appropriate criteria. When investigating incidents of odour nuisance, DEP inspectors will ascertain whether an odour is "strong" in intensity and will take action as appropriate.

Developments in the field of odour assessment and policy are continuing, for example the NSW EPA released a draft policy in early 2001 which requires assessment of peak to mean ratios in odour modelling to help protect the community from very high peak odour levels. The Western Australian DEP would like to assess the NSW approach more fully before adopting it for use in this State, but sees merit in the principle of peak to mean assessment, particularly in relation to odour from tall stacks over short averaging periods. The associated modelling is more complex than conventional computer modelling and further work will be required to develop appropriate methodology and criteria for tall stacks. In the mean time proponents should seek DEP advice on peak to mean odour modelling, and modelling would need to be performed by, or have input from, persons with expert knowledge in this field.

8. Definitions and/or Abbreviations

CEN — Committé Européen de Normalisation.

DEP — Department of Environmental Protection.

Dynamic Olfactometer — A dynamic olfactometer delivers a flow of mixtures of odorous and neutral gas with known dilution factors in a common outlet. (CEN 1995)

Dynamic Olfactometry — Olfactometry using a dynamic olfactometer. (CEN 1995)

EPA — Environmental Protection Authority.

Forced-Choice Method — An olfactometric method in which assessors are forced to make a choice out of two or more air flows, one of which is the diluted sample, even if no difference is observed. (CEN 1995) When using forced choice methods certainty thresholds are preferred for use.

Hedonic Tone — Is the degree to which an odour is perceived as pleasant or unpleasant. (EPA 1999)

Industry — Industry is used in the widest possible sense to include industry and infrastructure. As a guide, industry should be taken to include (but not limited to) the following categories from the State Industrial Buffer Policy (WAPC 1997):
Extractive industry;
General industry;
Hazardous industry;
Light industry;
Noxious industry;
Resource processing industry;
Infrastructure.

Odorant — A substance which stimulates a human olfactory system so that an odour is perceived. (CEN 1995)

Odour Character — Odour character is basically what an odour smells like. (Ministry for the Environment (New Zealand) 1995))

Odour Intensity — Is the relative perceived strength of an odour above its threshold. (EPA 1999)

Odour Detection Threshold	The highest dilution factor at which the sample has a probability of 0.5 of eliciting, with certainty, the correct perception that an odour is present. This dilution factor will be too high for the sample to be recognised. (Standards Australia/Standards New Zealand, 2001)
Odour Unit	The amount of odorant(s) that, when evaporated into 1 cubic metre of neutral gas at standard conditions, elicits a physiological response from a panel (detection threshold) equivalent to that elicited by one Reference Odour Mass (ROM), evaporated in one cubic metre of neutral gas at standard conditions.
Olfactometry	The measurement of the response of human assessors to olfactory stimuli. (CEN 1995)
OU	Odour unit.
Reference Odour Mass (ROM)	The accepted reference value for the odour unit, equal to a defined mass of a certified reference material. One ROM is equivalent to 132 μg n-butanol (CAS 71-36-3), which evaporated in 1 cubic metre of neutral gas at standard conditions produces a concentration of 40 ppb (μmol/mol).
Sensitive Land Uses	Land uses considered "sensitive" include residential, hospitals, hotels, caravan parks, schools, aged care facilities, child care facilities, shopping centres, play grounds, recreational centres etc. (EPA 1997)
Yes-No Method	An olfactometric method in which assessors are asked to judge whether an odour is detected or not. (CEN 1995)

9. References

Bardsley T and Demetriou J, 1997, "Odour Measurements That Don't Stink", National Workshop on Odour Measurement Standardisation, Sydney, 20-22 August 1997.

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Environmental Protection Authority (Western Australia), 2002, "Guidance for the Assessment of Environmental Factors – Assessment of Odour Impacts from New Proposals – No. 47", Environmental Protection Authority (Western Australia), Perth.

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Ministry for the Environment (New Zealand), 1995, "Odour Management under the Resource Management Act", Ministry for the Environment (New Zealand), Wellington.

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United States Environmental Protection Agency, 1992, "Reference Guide to Odor Thresholds for Hazardous Air Pollutants Listed in the Clean Air Act Amendments of 1990", Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. Available for viewing in the DEP library.

van Harreveld A P and Dönszelmann C E P, 1994, "Odour Nuisance: policy options and regulatory approach", Chartered Institute of Environmental Health, Welsh Council Weekend Course.

Verein Deutscher Ingenieure (VDI), 1992, "Olfactometry Determination of Odour Intensity - VDI 3882 Part 1", Verein Deutscher Ingenieure, Düsseldorf. Available through the Internet at http://www.beuth.de (recommend searching for the keyword "olfactometry".) A copy is available for viewing in the DEP Library.

Verein Deutscher Ingenieure (VDI), 1993a, "Determination of annoyance parameters; repeated questioning of neighbour panelists VDI 3883 Part 2", Verein Deutscher Ingenieure, Düsseldorf.

Verein Deutscher Ingenieure (VDI), 1993b, "Determination of Odorants in Ambient Air by Field Inspections VDI 3940", Verein Deutscher Ingenieure, Düsseldorf.

APPENDIX A

Air Quality and Air Pollution Modelling Guidance Notes

DEPARTMENT OF ENVIRONMENTAL PROTECTION
WESTERN AUSTRALIA
June 2000

1 Introduction

The Department of Environmental Protection (DEP) is frequently required to review assessments of the air quality impact of existing or proposed sources of air pollutants. This often occurs in the course of individuals or companies (generically called "proponents" below) meeting their obligations under the *Environmental Protection Act 1986* ("the Act"), notably environmental impact assessment under Part IV of the Act or in relation to Works Approvals and Licences under Part V of the Act.

Most air quality assessments employ computer modelling to provide estimates of the environmental (ambient) air quality impact. The quality of modelling efforts reviewed by the DEP over many years has varied from highly skilled to very inadequate. These guidance notes have been prepared to provide a clear understanding of the DEP's expectations with respect to air quality modelling.

2 Identify emissions and secondary pollutants

The proponent is responsible for identifying and quantifying all emissions to atmosphere with a potential to have a non-trivial impact on the environment (including impact on human health and well-being, odour, nuisance, amenity, vegetation - natural and agricultural, fauna - natural and agricultural). Emissions of potential concern include SO_2, NO_x, CO, particulates, volatile organic compounds, fluorides, hydrogen sulphide, other odorous gases, heavy metals, dioxins, furans, PAH and other toxic compounds, unless the emission rates of these are insignificant (to be justified). Additionally, the formation and impact of secondary pollutants such as photochemical smog and aerosols should be assessed if applicable. Greenhouse gases and ozone depleting compounds are beyond the scope of these guidelines.

3 Modelling to predict impacts (overview)

For all primary and secondary pollutants which cannot be dismissed as being of no significance, the proponent must provide model predictions of the impact of emissions on the various elements of the environment, in the form of concentrations and/or rates of deposition over the range of averaging periods normally associated with "relevant standards" for each pollutant, and assess the magnitude of this impact against the "relevant standards". "Relevant standards" means guidelines/goals/standards which the EPA/DEP has adopted or advised or, in the absence of an EPA/DEP position, guidelines/goals/standards proposed by the proponent on the basis of national or international practice and/or field investigations of environmental sensitivity. Data from experiments or justifiable extrapolations from published literature will also be required on the susceptibility of natural vegetation and crops.

NOTE:

The proponent may choose to carry out "worst case" screening analyses for particular pollutants (eg via simplified, conservative calculations or models) in order to demonstrate to the DEP that air quality impacts are insignificant and therefore that comprehensive modelling procedures are not warranted. The worst case analysis procedures (calculations, models) must be adequately described, with reference to their source. Most of the discussion which follows is directed towards full modelling exercises rather than screening analyses. Nevertheless, a screening analysis will be considered inadequate if it ignores any of the features or factors described below which may be potentially significant.

4 Presentation of model results

Modelling results should be presented in the form of:

- contour plots covering the region of interest (including population centres or isolated residences), with a grid density adequate to avoid significant loss of resolution;
- numerical values of concentrations at the point(s) of maximum impact (explain where this occurs) and other locations (receptors) of interest (eg places of human residence).

For each pollutant so modelled, the contours and numerical values should be presented with reference to relevant standards (eg at the averaging period and percentile level of the relevant standard) and the results evaluated against the standard. The meteorological conditions causing highest concentrations at important receptors should be determined (if possible) to check that the model is yielding sensible results.

5 Modelling cumulative impacts

For each pollutant modelled, the assessment must account for existing concentrations caused by other sources plus (if significant) the background concentration (whether natural or man-made) in order to estimate the cumulative concentration. When cumulative concentrations are modelled, the contribution of the proposal to high percentile short term (say 1-hour) averages is often masked. Consequently, in order for the contribution to be properly assessed, the DEP requires modelling results (as described in the foregoing point) to be presented for:

- existing emissions plus background concentration (pre-proposal);
- proposed development in isolation (excluding existing emissions);
- combined (existing plus proposed plus background) emissions.

The "existing emissions" must include not only those of existing, operating sources of emissions but also those expected from yet-to-be-constructed sources which are at a stage of approval, and commitment to proceed, ahead of the proposal. Such sources will need to be identified on a case-by-case basis. Industries proposed for location in Kwinana or other regions with airshed management policies will need to be assessed in accordance with the provisions of those policies; the DEP will provide details.

6 Emissions estimates

The DEP requires assurance that the estimates of emissions employed in modelling assessments are realistic and that uncertainty is balanced by conservatism. Details on how the source parameters (stack dimensions, mass emission rates, gas flow rate, temperature, density, etc) were derived should be summarised. This is to include whether these parameters were derived from stack testing (in relation to an existing facility), from theoretical calculations such as from a mass balance approach, from other existing facilities or standard emission factors (eg USEPA AP42). If the emissions are derived from stack testing, details should be given on how many stack tests were taken and how representative these were. Unless otherwise agreed, the level at which emissions should be set for modelling purposes is described in EPA Vic (1985).

7 Variable or intermittent emissions

In the experience of the DEP, intermittent emissions (plant start-ups, plant upsets, etc) result in more pollution complaints than normal emissions from operating industries. The modelling must properly assess both emissions which are continuous in nature and emissions which are intermittent. Intermittent emissions which are insignificant in magnitude and/or very improbable in the lifetime of the plant may be screened out; the remaining emissions should be modelled together on a probabilistic basis to estimate the total plant impact. Screening of emissions cases must be based on the joint consideration of probability and magnitude of emission. The DEP is able to provide guidance on how to screen and model intermittent emissions.

8 Model capability

The models and/or worst case calculation procedures and data employed in the assessment must be demonstrably capable of simulating, or accounting for, all of the features which are important in the context of determining the air quality impact of the project. The proponent is responsible for identifying and properly accommodating these. The following list may not be exhaustive but is provided for checking purposes:

- trapping of plumes in mixed layers of limited height or, alternatively, penetration of plumes through elevated temperature inversions;
- vertical plume dispersion in convective conditions;
- fumigation of plumes into an encroaching mixed layer or thermal internal boundary layer near a coastline. Investigations of this phenomenon may require estimates of wind direction shear in stable layers;
- sea breeze trapping, recirculation of pollutants;
- near-surface dispersion under very stable calm conditions (a feature of Western Australian winter meteorology);
- topographic influences - impact of plumes on elevated terrain, effect on spatially varying wind fields, valley winds (anabatic and katabatic winds), ponding of air in stable conditions;
- surface roughness;
- building wake effects, stack tip downwash (avoided by good engineering stack design);
- deposition, chemical transformation;
- effects of positive or negative buoyancy;
- radiation from flares.

The modelling report should describe how each of the relevant features were treated. Examples are:

- Physical description of the site to be modelled. This is to include details on the topography, ie highest hill/mountain within the model region, distance to coast or any other major water bodies and how this was dealt with in the modelling;
- For a coastal site, details on how sea breeze effects were incorporated in the modelling;
- The value(s) of the roughness length and details on how this was determined (refer to USEPA (1997) for recommended approaches).

9 Meteorological data for conventional models applied to simple situations

If using a conventional model, the proponent will need to obtain at least one (preferably two or more) year's data on the meteorology of the area, with high data recovery and verifiable data accuracy. In the simplest situations, the data may be limited to that necessary to provide reliable hourly average estimates of:

- wind speed;
- wind direction;
- air temperature;
- mixing height, estimated or measured via methods acceptable to the DEP;
- atmospheric stability, estimated by a method acceptable to the DEP.

Methods described in USEPA (1997) are generally acceptable to the DEP. The report should include a description of the meteorological data used or alternatively a reference to a publicly available report which contains this information. The description is to include details on the methodology used to derive stability classes and mixing heights and is to present (as a minimum) the annual wind rose, annual stability frequency distribution and details on the mixing height distribution. The description should also include details on the quality of the anemometer used and its starting threshold.

10 Meteorological data for complex models and/or complex situations

Specialised and detailed meteorological data and associated calculations are necessary to accurately model some of the features listed in point 8. For example, to model shoreline fumigation, knowledge of the onshore-flow vertical temperature structure is required. The proponent is responsible for assessing the full range of pollution dispersion issues and designing an appropriate monitoring program. Where items of data are not based on the results of continuous monitoring (eg. based instead on intermittent field experiments or unverified hypotheses), the uncertainty of estimates must be offset by conservatism in these estimates. The proponent is invited to demonstrate to the DEP that complicated or costly monitoring programs and/or modelling procedures for particular meteorological parameters are not warranted.

11 Advanced models

The DEP accepts that advanced prognostic models may be less reliant on measurements than conventional (eg Gaussian) models. These advanced models would need to be well supported by published validation studies before the DEP would accept their use in isolation.

12 Model acceptability and verification

The DEP does not generally prescribe which models must be used in particular circumstances. The DEP takes this position in order to allow scientific and technical advances to be introduced without regulatory delays. However the DEP reserves the right to reject a proposed model, or application thereof, if it considers it to be inadequate, inappropriate or unproven. The AUSPLUME and ISCST3 models are frequently used in an acceptable manner for modelling industrial emissions, but they have limitations which model users should understand and respect.

Unless the DEP agrees otherwise, proponents are required to present, in addition to model results, all of the model input files and configuration details to allow the DEP to check and reproduce the model results. Model output which describes the model configuration should also be provided. If the model has not been well validated and documented in the public domain (like AUSPLUME, USEPA regulatory models), references to model validation reports (and provision of these on request) are required.

References

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