Controlling Noxious Animal Odours : An Imperative at the Rural-Urban Interface* - Review -

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ABSTRACT : Reaction by neighbours to odours is increasingly affecting operations of existing animal farming operations and may adversely constrain the further development of the animal production industry in some parts of Australia. It is critical that the scale of such odour impact on the rural-urban interface be estimated to provide useful information both for environmental protection and animal farming operations. Furthermore, the information can be used to modify odour reduction strategies as economic conditions change. The Centre for Water and Waste Technology at The University of New South Wales has developed a comprehensive set of odour control techniques in the course of its research and development effort over the past eight years. Techniques have been developed for odour sampling at point, area and volume sources, monitoring environmental parameters such as ventilation rate, shed temperature, shed humidity, litter water content and ambient meteorological condition, olfactometry and odour dispersion modelling. The work has paved the way for the establishment of odour reduction strategies based on best environmental management practice and advanced odour abatement technologies. ***(Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 4 : 633-641)***

Key Words : Environmental Management, Odour, Odour Impact Assessment, Odour Control, Olfactometry

INTRODUCTION

Odour nuisance in the vicinity of animal production farms has become a serious social and environmental issue. Odour complaints by neighbours are increasing as greater numbers of urban commuters and others take up residence in rural areas around large centres of employment and newer and more diverse peri-urban rural uses of land are introduced. Increasing living standards and changing life style values in urban and rural communities and a demand for a cleaner environment have contributed to an increased intolerance towards farmyard type odours. Furthermore, urban expansion into previously rural areas has increased pressure on those farmers remaining to maintain a cleaner environment.

Such reaction is increasingly affecting operations of existing animal production farming and may adversely constrain the further development of the industry in some parts of Australia. The availability of repeatable quantitative data meeting international standards, coupled with the adoption by producers of improved management and operational practices can be expected to lead to more effective communication and better relations with farmers, local communities and local councils.

Environmental pressures and management practice vary between regions within Australia depending on factors such as climate, local custom, availability of advisory services and local regulatory arrangements. Sands (1995) has reviewed environmental aspects of the Australian poultry meat industry in relation to world practice. For the broiler growout-contractor phase of the industry, Sands concluded that objective odour measurement surveys in relation to regional best practice were needed to facilitate an effective industry response to odour impact as a precursor to the development of appropriate cost effective management practices to suit the various regional natural and social environments in Australia. The industry is currently implementing a strategy for improvement based on quantifying odour emission levels, then identifying odour generation processes in relation to odour levels and finally identifying and specifying appropriate remedial measures.

In Australia, piggery, cattle feedlot, poultry farms, rendering plants, and abattoirs are major sources of odour complaints. A number of substantial research and development projects have been undertaken at the Odour Research Laboratory of the Centre for Water and Waste Technology at The University of New South Wales in Sydney during the last ten years. During that period the Pig Research and Development Corporation has funded major odour research including work at the Laboratory on the determination of odour emissions from piggeries using a modern dynamic olfactometer. Arising from the research program, the Dutch standard on odour measurement using a dynamic olfactometer was introduced into Australia. The laboratory has also been engaged on odour work for other industries including wastewater management, fertiliser manufacturing, timber processing and mushroom growing. Currently the Rural Industries Research and Development Corporation is supporting a comprehensive study at the Laboratory to measure odour emissions over time at selected poultry farms, to investigate odour emission processes and to determine odour impacts on the nearby areas. A related study has been carried out for the Western Australian Department of Environmental Protection. Consequently

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the Odour Research laboratory has become a major research and development unit in Australia to undertake practical odour control projects.

The paper will discuss odour dispersion processes, techniques for quantifying odour emissions and predicting odour impacts, and research requirements for improved odour control in the animal production industry.

ODOUR NATURE

The sensation of odour in humans, as in other mammals, is brought about by odorants acting on olfactory sensors in an individual nose.

Under laboratory conditions, a pure odorant can have four different dimensions:

1. Odour character allows one to distinguish between different odours. For example, ammonia gas has a pungent and irritating smell. It may be evaluated by a comparison with some known odours (direct comparison method) or through the use of descriptive words (describing profile method). The character of an odour may change with dilution, for example during the atmospheric dispersion process (e.g. hydrogen sulfide at levels of 20 ppm or above ceases to be perceived as a rotten egg smell).
2. Hedonic tone is the degree to which an odour is perceived as pleasant or unpleasant. Such perception differs widely from person to person and is strongly influenced by previous experience and the emotional context in which the odour is perceived. For example, in some situations, a coffee smell could be very unpleasant.
3. Odour intensity is the relative perceived psychological strength of an odour above its threshold. Odour intensity increases as a power function of chemical concentration. The intensity can only be used to describe an odour at a certain concentration above its threshold.
4. Odour threshold is the chemical concentration of an odorous substance at which 50% of panelists during an olfactometry analysis detect the odour and 50% do not. This value is used to represent how an odour is perceived at a given chemical concentration level or how physically strong the odour is. It can be calculated from the results of chemical analysis and sensory measurement (by olfactometer). This will involve both the quantification of the chemical concentration level and odour threshold level.

In the natural environment, pure odorants barely exist. In general, it is a mixture of gases released from an odour source that leads to an odour nuisance problem. It is not known whether a perceived odour results from one of the constituents or from a number of constituents. The perceived odour depends on chemical characteristics and chemical concentration levels. For instance, whereas the major constituent of a poultry odour sample taken in a poultry shed may be ammonia the poultry odour perceived is hardly ever perceived as ammonia. Dimethyl-disulfide is generally considered to be closer to the characteristic smell of poultry. In practice, the odour threshold for an environmental odour (a gas mixture) can not be determined directly and the chemical concentration of a mixture of substances can not be quantified by a single value. However, for an environmental odour sample, it may be practicable to evaluate odour strength using dynamic olfactometry to measure odour concentration.

Furthermore, perceived odour in the real world is often influenced by other factors:

- Concentration (odour or chemical concentration level);
- Duration of exposure to the odour;
- Frequency of odour occurrence;
- Intensity of perceived odour (a mixture of offensiveness, odour character and hedonic tone);
- Tolerance degree and expectation of the receptor.

These CDFIT factors closely represent the aspects of a perceived odour that have been found by experience to influence a member of the public to lodge a complaint to a local authority or other regulatory body. Intensity and tolerance are related to odour concentration. With inputs of odour emission rate, meteorological data and terrain conditions, the fall off in environmental odour concentration (ie odour strength) at points away from a source can be predicted using an air dispersion model such as Ausplume or Auspuff. As intensity and tolerance are related to odour concentration, the modelling results may be used to assess likely human response in an odour impact area surrounding the odour source. The odour annoyance model outlined is depicted diagrammatically in figure 1.

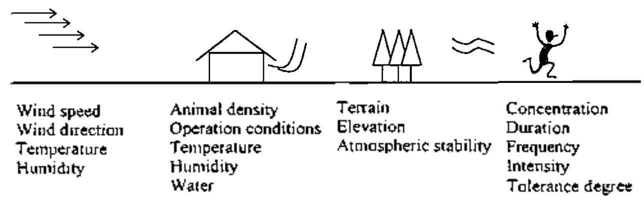

Figure 1. Odour annoyance model

Accurate measurement of the odour emission rate at the odour emission source is an essential element of the odour annoyance model outlined. In general, odour emission rate is the product of odour concentration and volume flow rate. Both data have significant effect on the output of odour dispersion modeling.

ODOUR MEASUREMENT

Gas-chromatography mass-spectrometry (GC-MS), and dynamic olfactometry can be used for identification and quantification of animal odorants. (Kaye, 1994, Hartung and Phillips, 1994, Hobbs, et al., 1997). GC-MS can provide excellent sensitivity (about 0.2 ppb) and separation for a gas mixture. Gas-chromatography separates individual components according to their vapor pressures and solubility inside the GC column material. Mass-spectrometry identifies the eluted components by their ionized molecular fragmentation patterns. With proper selection of GC column material and GC temperature programming procedures, the method can be adapted theoretically for analyzing animal odorants. To date, more than 200 specific odorants have been reported. Major categories of odorants found in animal production are:

- Inorganic compounds: Hydrogen Sulfide, Ammonia;
- Sulfide compounds: Dimethyl Sulphide, Diphenyl Sulphide, Ethyl Mercaptan, Methyl Mercaptan, Thiophenol;
- Nitrogen compounds: Butylamine, Methylamine, Indole, Skatole;
- Volatile fat acids: Acetic acid, Butyric acid, Propionic acid.

Much effort has been put into the development of chemical analysis technology using GC-MS. The chief limitations of the technique are:

- Many identifications remain ambiguous or questionable as a result of the presence of unknown components at very low concentration level (ppt) in the odour samples. Experience gained from previous projects at the Odour Research Laboratory has indicated that GC-MS may not be effective in analysing ammonia, hydrogen sulfide and polar compounds such as amines in a gas mixture but may be suitable for non-polar compounds such as reduced sulphur compounds. However, preparation of standard odorants has to date proved impracticable.
- No indication is obtained as to the relevance of individual compounds to the odour of the sample as a whole. Even if individual chemical concentrations and their odour threshold values are known, it is not possible to deduce the overall sample odour threshold or the odour character of the mixture of odorants.
- The removal rate for a specific chemical substance, such as hydrogen sulfide, may bear little relationship to the odour removal efficiency of an odour control facility or individual process unit. Some chemical components may exhibit a very strong odour strength or odour intensity even at extremely low chemical concentration (e.g. skatole).

In summary, the results of chemical analysis are usually insufficient to define an odour problem or to provide information on the odour removal efficiency of an odour abatement process. However, chemical analysis may help a process design engineer select equipment if the type of odour is unknown, and may help researchers understand the mechanisms of odour removal. On the other hand, the use of dynamic olfactometry can provide the basis of an effective and comprehensive approach to establishing odour strength and odour intensity levels of simple and complex odours and when coupled with odour dispersion modelling, can provide a useful basis for odour impact assessment.

ODOUR SOURCE AND SAMPLING METHOD

The major odorants from animal production farms come from animal growth housing and waste disposal facilities. In both situations, anaerobic and aerobic decomposition of animal waste by microorganisms leads to the generation of a wide range of odorous compounds. From an odour measurement point of view, an odour source may be classified as a point source, an area source or a building (or volume) source.

Point sources

Typically a point source will be a stack with a know flow rate such as a discharge stack from abattoir or a vent from a pig shed. It is relatively easy to determine an odour emission rate from a point source. Samples are taken through clean Teflon tubing probes inserted into the stack at different points. The number of points is determined by the dimensions at the point where the sample is taken. As a rule of thumb, the number of sampling points needed to average air velocity across a stack cross section can be used as a guide.

The odour sample is collected using an odour sampling system as shown in figure 2. A vacuum pump and a 12-Volt battery are built into the sampling drum as shown. A new and cleaned Tedlar bag is placed into the sealed sampling vessel. Air is then pumped out of the sampling drum by a battery operated pump creating a vacuum inside the drum. Sample air is drawn into the bag by the pressure difference between the inside and outside of the bag.

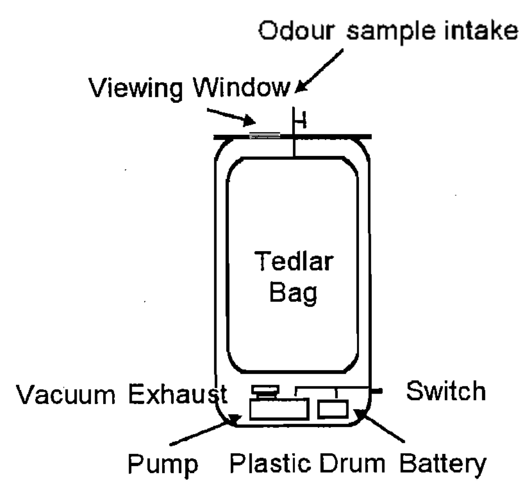

Figure 2. Odour sampling system

It is important that air velocity, dimensions of the vent, temperature and humidity are measured before a sample is taken. For those samples with a high temperature and pressure, the gas flow rate is calculated and adjusted to NTP (Normal Temperature and Pressure ie 20℃ and 1 atmosphere) conditions. If possible, the flow pattern will also be monitored in order to understand flow fluctuations.

A pre-dilution procedure is employed to prevent condensation for those sources with a high temperature (above 50℃) and humidity (above 95%). For a very high strength odour source such as a boiler discharge, a gas pre-dilution system is used to ensure that the measured odour concentration is within the range of the olfactometer (4-65000 OU/m^3).

The Odour Emission Rate (OER) is then calculated using the odour concentration measured by olfactometer and the measured gas flow rate:

$$OER = Q \times OC \qquad [1]$$

where,

Q : gas flow rate, m^3/sec

OC : odour concentration, OU/m^3

Area sources:

Typically, an area source will be a water or solid surface such as the water surface of a slurry storage tank or the base of a cattle feedlot. A portable wind tunnel system can be used to determine specific odour emission rates. The principle of the wind tunnel system is that controlled air, filtered by activated carbon through a series of devices, forms a consistent flow over a defined liquid or solid surface. Convective mass transfer takes place above the surface. The odour emissions are then mixed with clean air and vented out of the hood. A proportion of the mixture is sucked into a Tedlar bag via Teflon tubing using the sampling vessel. The air velocity used inside the wind tunnel is 0.3 m/s. An isometric sketch of a portable wind tunnel system is shown at figure 3 (Jiang, et al. 1995, Bliss, et. al. 1995).

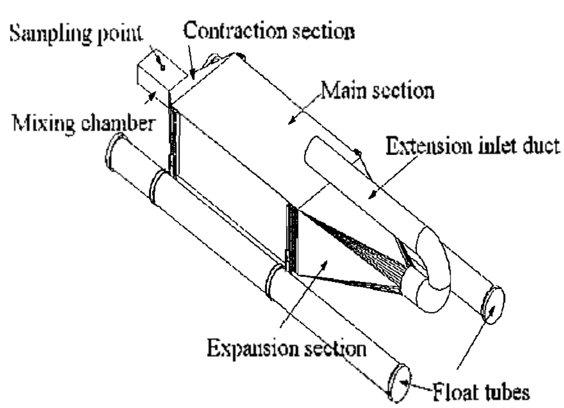

Figure 3. Isometric sketch of portable wind tunnel system

The Specific Odour Emission Rate (SOER) may be defined as the quantity (mass) of odour emitted per unit time from a unit surface area. The quantity of odour emitted is not determined directly by olfactometry but is calculated from the concentration of odour (as measured by olfactometry) which is then multiplied by the volume of air passing through the hood per unit time. The volume per unit time is calculated from the measured velocity through the wind tunnel which is then multiplied by the known cross sectional area of the wind tunnel. SOER is calculated by the equation:

$$SOER = \frac{A}{Q \times OC} \qquad [2]$$

where,

SOER: specific odour emission rate (SOERs), OU/sec

Q: flow rate through the wind tunnel, m^3/sec

OC: odour concentration, OU/m^3

A: area covered by the wind tunnel, m^2

Building sources

Typically building sources, such as chicken and pig sheds, have a number of openings. Prior to about ten years ago, little research was undertaken on the determination of odour emissions from buildings. For building sources, measurements of both odour concentration and air ventilation rate are required. The air ventilation rate from animal housing is dependent on operational conditions (e.g. opening or closure of side flaps or shutters), and ambient wind speed and direction. Unfortunately, there is little literature available in the determination of air ventilation rate through an animal shed. Typically the Centre has used a data acquisition system including two velocity transducers, two temperature and humidity sensors to continuously monitor air velocity through openings and other shed conditions. figure 4 provides a typical pattern for air velocity and ambient wind speed and direction at a broiler growout shed on a meat poultry farm.

For animal sheds, odour samples are normally taken from several points within a shed. Experience indicates that one composite sample is sufficient to represent a single shed at a particular time. Dalton et al (1997) have reported a similar finding for a piggery shed. Additional samples can be taken at different times of the day or week or to understand the fluctuation of the odour concentration levels within a day or a week. Similarly sampling may be carried out for different weeks during a growout cycle or for different seasons during a year or longer.

The Odour Emission Rate (OER) can be calculated from odour concentration measured by olfactometer and gas flow rate through the door and window opening. The equation is applied to point and volume sources:

$$OER = V \times OC \qquad [3]$$

where,

V: gas ventilation rate, m^3/sec

OC: odour concentration, OU/m^3

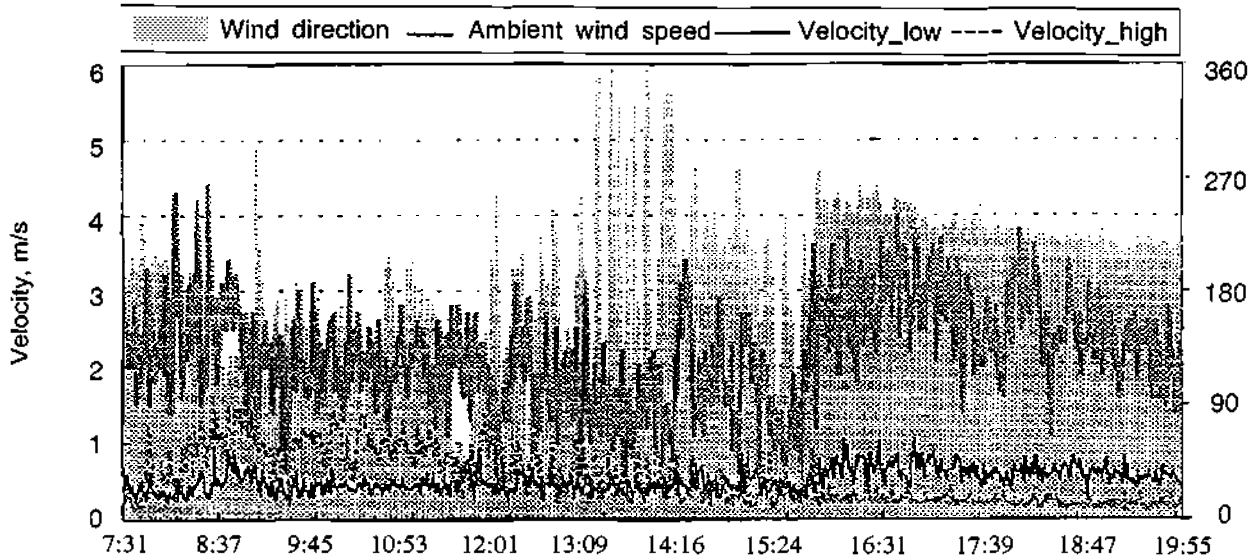

Figure 4. Air velocity and ambient wind speed and direction at a broiler growout shed

After the sample collection, the odour samples should be tested within 24 hours to minimise any sample losses through the transport and storage.

OLFACTOMETRY

Olfactometry is a psychophysical method based upon the olfactory responses of individuals sniffing odours through dilution apparatus to define an odour strength or odour concentration. The results can be expressed in terms of odour units per cubic metre (OU/M^3). Recent developments in the olfactometry method, particularly in dilution instrument calibration and panelist management, have dramatically improved the repeatability and reproducibility of olfactometry measurements (Jiang, 1997).

In the past, olfactometry techniques have been considered as highly subjective due to the huge variation of sensitivity to odours in the population. Not until the early 1990s did improvements in the design of olfactometers (ie highly repeatable gas dilution instruments) and the methodology of conducting odour measurements (e.g. selection of panelists of average sensitivity) result in the first standard method on odour concentration measurement (The Dutch Normalization Institute, 1996). Now odour concentration measurement can produce an analytical error of 38% (coefficient of variation) in a single laboratory (Jiang, 1996). A single standard method of odour concentration measurement will be in place in European countries by the end of 1998.

A dynamic olfactometer is a gas diluting apparatus and also an interface between a panel of human observers and an odorous gas sample diluted at various concentrations. Olfactometry requires a very high standard of testing conditions. These include an odour-free testing environment, an odour-free air supply, a highly accurate and repeatable olfactometer and effective panelist management.

Odour-free testing environment

An odour-free testing environment is an important element in the olfactometry testing process. An odour-free room provides not only a relaxed testing environment for the comfort of panelists, but also eliminates background odour that may lead to olfactory adaptation and fatigue, which would otherwise affect the sense of smell of panelists and result in a failure to detect odour at low concentrations. The test room air should be filtered using an activated carbon filter with a minimum air exchange rate of at least 12 times per hour.

Panelist management

Panelists should be trained and screened using reference air incorporating certified n-butanol at a concentration of 60 ppm using the same procedure as used for environmental samples. Means and standard deviation are calculated for 12 logarithms of individual thresholds (break points). The criterion is that means should be in the range of 3.00 to 4.38 with a standard deviation less than 0.916.

Figure 5 illustrate a set of screening results. Panelist 1 had a consistent performance but his sensitivity was too low and he should be removed from future participation. Panelist 2 had a good average threshold but her consistency of performance was very poor. panelist 2 did not pass the screening test. Panelist 3 met both average threshold and standard deviation standard and was selected as a panelist.

Olfactometer calibration

The olfactometer must be calibrated against a tracer gas to check that the dilution setting of the olfactometer

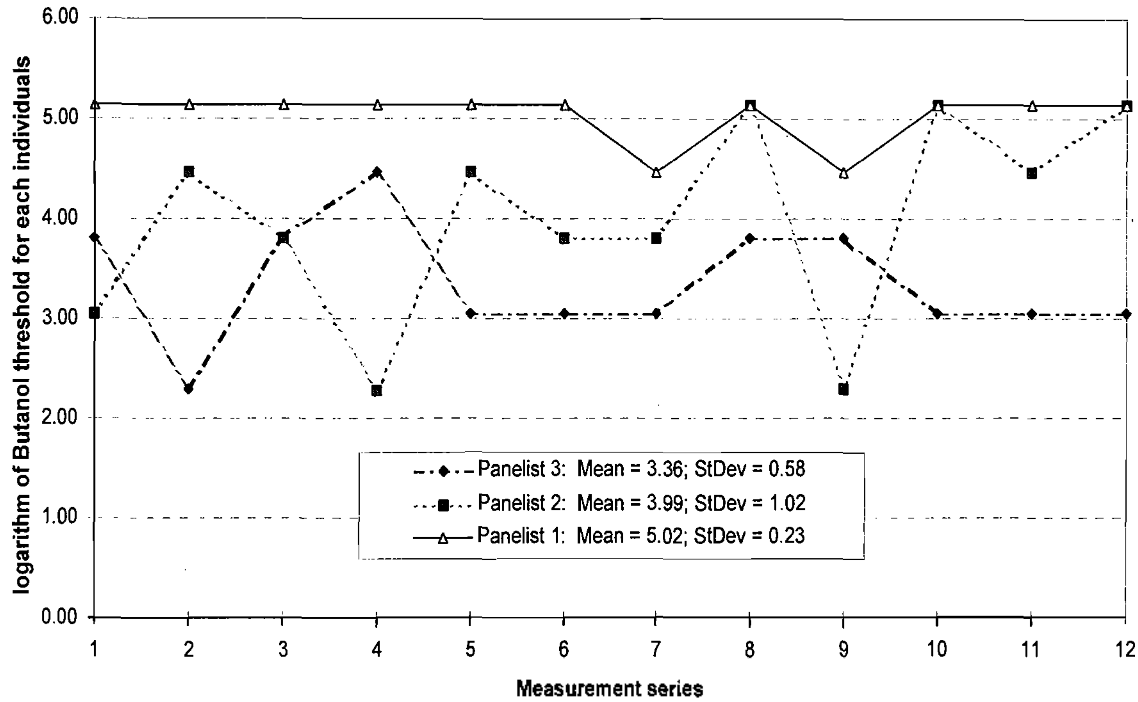

Figure 5. Simulated panelist screening results

meets repeatability and stability criteria. It is not sufficient to check dilution setting simply against gas flow rate. Firstly, the olfactometer must be able to demonstrate its stability within 5% at each dilution level. This ensures that all panelists receive the same level of odour concentration. Secondly, the olfactometer must be able to repeat each dilution level within 20% of the setting value. This ensures that the dilution steps will be evenly distributed across the testing range. Further details are provided in Dutch standard NVN 2820. (The Dutch Normalization Institute, 1996)

Olfactometer results calculation

In the olfactometry testing procedure used in the study, a diluted odorous mixture and an odour-free gas (as a reference) are presented separately from two sniffing ports at 20 L/min to a group of eight panelists in succession. In comparing the gases emitted from each port, the panelists are asked to report the presence of odour together with a confidence level such as guessing, inkling, or certainty. The gas dilution ratio is then decreased by a factor of two (ie chemical concentration is increased by a factor of two). The panelists are asked to repeat their judgment. This continues for six different dilution levels, resulting in a total of $8 \times 6 \times 2=96$ judgments (sniffings) from eight panelists. As a result of the panelists responses and dilution settings, odour concentration expressed as odour dilution units can be calculated from individual threshold estimates.

Table 1 provides a demonstration of an odour concentration calculation. The break-point is determined as geometric mean of two dilution ratios. The first ratio is the lowest correctly chosen dilution ratio given with certainty and consistency of correct choice and the second ratio is the dilution level before this correct one. For forced choice dynamic olfactometry, two sniffing ports are used. One port, randomly provides odour-free air to prevent panelist anticipation. Another provides an odour mixture. During a panel session of four hours, a 15 minute break will be given to the panelist to minimise olfactometric fatigue.

Based on the confidence level (guessing, inkling or certainty) used in the calculation method, odour concentration can be reported on the basis of panelist judgment in terms of two criteria - guess and correct or certainty and correct thresholds. It is necessary to cite olfactometry results in terms of the type of olfactometer and calculation method. Analysis of CWWT odour test data indicates that odour concentration based on certainty has a lower standard deviation than one based on a guessing criterion (Jiang, 1997). This means that the certainty confidence level can produce a better result.

ODOUR DISPERSION MODELLING

Having measured odour emission rates at a source, regulatory air dispersion models such as Ausplume, Auspuff, and ISC3 can be used to predict downwind concentration levels at selected locations away from the

Table 1. Odour concentration calculation demonstration

Series 1	Dilution steps						
Panelist	32	64	128	256	512	1024	Break-point
1	6	6	5	3	2	2	90.5
2	6	6	4	3	4	4	90.5
3	6	3	4	3	3	1	45.3
4	6	6	6	4	2	1	181.0
5	6	3	3	4	3	1	45.3
6	6	5	3	3	2	2	45.3
7	6	6	6	4	2	1	181.0
8	6	6	5	3	1	2	90.5
Series 2							
1	6	6	6	3	2	2	181.0
2	6	5	4	3	4	4	45.3
3	6	6	4	3	3	1	90.5
4	6	6	4	4	2	1	90.5
5	6	5	3	4	3	1	45.3
6	6	6	3	3	2	2	90.5
7	6	6	4	4	2	1	90.5
8	6	6	6	3	1	2	181.0
Geometric Average (Odour Concentation)							87

N.B. 1: guessing and wrong; 2: guessing and correct; 3: inkling and wrong; 4: inkling and correct; 5:certain and wrong; 6 : certain and correct.

source under various atmospheric conditions. Ausplume is widely used in regulatory modelling in Australia and New Zealand. A large number of concentrations are calculated using available hourly meteorological or other defined time period for points away from the source. Odour concentration contours for various levels of annual compliance can be plotted as shown in figure 6. The contour for a specified odour impact criterion, such as not exceeding a concentration limit 10 OU/m^3 for a specified number of hours in one year (e.g. 44 hours also known as the 99.5th percentile), may be taken to define an odour impact area. Source information such as odour emission rate, type of sources (point, area, and volume sources), meteorological conditions, terrain and receptor locations all influence the odour dispersion mechanism.

Currently odour impact criteria are parameters or maximum levels of odour concentration that scientific evidence and informed judgement indicate are likely to be tolerated by persons using the land around the odour source for purposes consistent with the local government planning provisions for the locality. By using air dispersion modelling and selecting odour impact criteria appropriate to the landuse or landuses surrounding an odour source, odour impact areas around sources, such as a group of broiler chicken growout sheds, may be defined. Within a defined odour impact area, typical receptors (e.g. residents) can be expected to experience odour nuisance. Odour impact criteria are not ambient odour standards but rather a scientifically derived benchmark for the making of informed decisions in planning, design, environmental management and regulation. Table 2 lists some odour impact criteria used in several jurisdictions.

As shown in table 2, a wide range of odour impact criteria have been reported for various jurisdictions. Consequently, it is important to assess the significance of the variation, particularly that relating to the odour concentration limit. During recent years, modern performance based forced choice dynamic olfactometry has greatly improved the sensitivity of odour measurement.

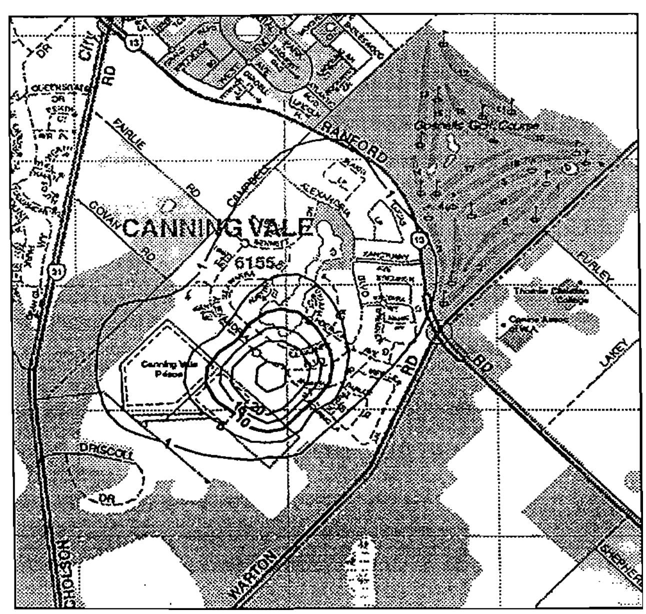

Figure 6. An example of odour dispersion modelling results at the 99.5th percentile

Table 2. Some odour impact criteria used in several jurisdictions

Jurisdiction	Odour concentration limit (OU/m^3)	Percentage time compliance	Averaging time	Critical receptor location	Source
New South Wales, Australia	2	99.5%	3 minutes	Resident	CASANZ, 1995
Queensland, Australia	10	99.5%	1 hour	Resident	Verrall, 1997
Victoria, Australia	1	99.9%	3 minutes	Resident	CASANZ, 1995
The Netherlands (New installations)	1	99.5%	1 hour	Domestic dwelling	Hermia and Vigneron, 1994
Denmark	5-10	99%	1 mimute	plant	Boholt, 1992
	0.6-20	99%	1 hour	surrounding	
New Zealand	2	99.5%	1 hour	Property boundary	Ministry for Environment, New Zealand, 1995
Massachusetts, USA	5	Highest	1 hour	plant boundary	Mahin, 1997

For instance, the butanol threshold measured using a three port IITRI (Illinios Industrial Triangle Research Institute) olfactometer, ranged from 80-200 ppb while modern dynamic olfactometry is capable of measuring butanol threshold levels from 10 to 30 ppb. Assuming the same sensitivity applies to environmental odour samples, comparable odour impact thresholds could be 3-20 times lower and for example, a nuisance threshold determined as 1 OU/m^3 using the less sensitive earlier equipment could be rated 3-20 OU/m^3 using modern equipment. In summary, the use of advanced olfactometer based methods could result in nominally much higher odour concentration limits included in odour impact criteria.

In the future it may be expected that the scope of odour impact criteria will be extended beyond odour concentration (ie odour strength) to encompass other dimensions such as odour intensity. There is already a German standard for the determination of odour intensity but much work needs to be done before sufficient data become available to enable the formulation of an intensity component in odour impact criteria.

FURTHER RESEARCH OPPORTUNITIES

During the past decade, the technology and methodology of odour concentration measurement have improved to become a practicable and accepted environmental management tool. Research is now required to enable the concept of odour intensity to be included in the measurement of odour emissions so that a more direct assessment of the impact on persons by odours generated by various types of industrial and farming operations can be established. . Unlike odour concentration, which provides only odour strength information, odour intensity measurement provides information on the perceived effect of an odour on a human. Currently the repeatability of assessments of odour intensity using available methods is poor. To improve repeatability (within a laboratory) and reproducibility (between laboratories), a new protocol needs to be developed.

The complexity of odour characterization and measurement reflects the complex nature of the human olfactory system. Technology such as a cheap and quick electronic nose could prove very useful as an environmental management tool. However, the currently available dynamic olfactometer used for odour concentrations and odour intensity can be expected to remain the basis of odour measurement and assessment prior to the development of a cost effective, robust, repeatable and reproducible electronic nose.

CONCLUSIONS

Complaints of odour annoyance at the rural urban interface have been increasing during the past decade. In response to the complaints, industries have given great priority to reducing odours from farm operations and regulatory agencies have sought improved methods of measuring and predicting odour impact. As a result of the increased focus on odour, the use of dynamic olfactometry coupled with odour dispersion modelling has been developed to provide an effective basis for quantifying odour impacts around existing and potential odour sources. Major conclusions are:

- CDFIT (Concentration, Duration, Frequency, Intensity and Tolerance) factors have been identified as the most important factors in the assessment of odour annoyance problems.
- In determining the odour emission rate from an emission source, measurement of both odour concentration and volumetric flow rate are required, with particular care taken to accurately measure flow rate.
- Compared to GC-MS, dynamic olfactometry provides a cost effective and quick method to quantify odour strength. The modern olfactometer with instrumental calibration, panelist selection and appropriate calculation procedure has greatly improved the reliability of odour concentration measurement.
- An air dispersion model can be used to predict odour concentration away from a source. Using odour impact criteria, an odour impact area can be defined. This approach, based on defining an odour impact area, provides an effective tool in the control

of odour emissions from animal production farming.

The increasingly popular and more diverse peri-urban localities dotted around the Australian coastline present major challenges to odour management. The approach to odour measurement and assessment outlined in this paper is expected to contribute to the development of appropriate and cost effective management practices for animal production facilities located in a wide range of natural and social environments.

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