



APPLICATION OF EMISSION DATA IN MODELLING AND ASSESSMENT

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EXECUTIVE SUMMARY

Impact assessment of new or expanding piggeries is increasingly involving odour modelling of the proposed development. Incorporating alternative piggery design and management processes at a site is often used to reduce the potential off-site odour impact. To adequately model these situations, it is important to understand the practical aspects of these processes.

A number of steps are required to undertake site-specific odour modelling for a piggery. In many situations, the process becomes iterative until an acceptable solution is found. Existing emissions data is often difficult to apply due to the lack of information presented with the results.

In Australia we now have a standardised method for olfactometry and a process has started to standardise sample collection methods. Other areas of odour emissions measurement requiring a common approach include units for reporting results and the measurement of influencing variables.

The APL funded review of piggery odour emissions (Watts, 1999) provided standard odour emission rates for the major odour sources at Australian piggeries. To update recommended standard emissions, all of the data collected since that report needs to be converted to a standard format that enables it to be compared to previous data and applied to different piggery designs.

A standard method across Australia is required for assessing new and expanding piggery developments in terms of odour impact. It is proposed to develop a three-tiered assessment approach and to include community consultation more commonly in the development process.

The first tier is to use a standard formula. The second tier would involve modelling using adopted "standard" emission rates and a meteorological file representative of the site. The third tier would involve site-specific odour emission rates with at least one year's worth of meteorological data collected for the site.



1. INTRODUCTION

Odour modelling and impact assessment of piggeries is most commonly applied in situations where new piggeries are proposed or existing units are seeking to expand. In recent years, a range of alternative piggery design and management processes have become increasingly common in Australia. Incorporating these processes at a site can substantially alter the potential off-site odour impact.

Piggery design may be influenced by a number of criteria, including desired herd performance, site access, construction costs, environmental management and off-site impacts. To adequately balance these requirements, it is necessary to understand the impact changes to piggery design and management have on the emission data used.

This paper considers the application of odour modelling to piggeries for the assessment of off-site odour impacts, and particularly the emissions information available for undertaking such modelling. Piggery odour emissions data from Australia is reviewed and standard emission rates applicable to modern piggeries are recommended. A process for undertaking piggery odour impact assessment is also suggested.

2. THE ODOUR MODELLING PROCESS FOR PIGGERIES

A number of steps are required to undertake site-specific odour modelling for a piggery:

1. Establish piggery size and performance data.
2. Establish physical siting constraints such as
 - a. land availability,
 - b. access to water supply, electricity and roads,
 - c. topographical constraints to construction,
 - d. effluent management requirements,
 - e. environmental protection requirements (flood zones, groundwater, etc),
 - f. fixed buffer requirements to roads, receptors, watercourses, bores.
3. Assess locally available meteorological data and the closest available meteorological data file suitable for modelling.
4. Select an appropriate impact assessment procedure based on regulatory requirements for the area, the level of detail required and site information.
5. Select appropriate impact criteria suitable for the assessment procedure used.
6. Establish piggery design and prepare emissions input information.
7. Undertake modelling and assess the risk of off-site impacts, considering the accuracy of input data used.

In many situations, this process becomes iterative until an acceptable solution is found. Odour modelling of unusual or innovative design and management processes is difficult due to the limited emissions data available and the high cost of obtaining new emissions data. Existing emissions data is often difficult to apply due to lack of information presented with the results.

In Australia we now have a standardised method for olfactometry and a process has started to standardise sample collection methods. Other areas of odour emissions measurement requiring a common approach include units for reporting and the measurement of influencing variables.



3. AUSTRALIAN PORK LIMITED ODOUR EMISSIONS DATABASE

Watts (1999) reviewed available piggery odour emissions data from Australia and overseas and recommended standard emission rates for the major sources at modern piggeries. A brief summary of the data included in that review is presented here, followed by new data that has been published since that review.

3.1. Shed Emissions

A significant number of odour emission measurements were collected from piggery sheds as part of an Australian Pork Limited project carried out by the National Centre for Engineering in Agriculture (NCEA). Measurements conducted by the NCEA (Dalton *et. al.*, 1997 and Smith *et. al.*, 1999) showed considerable variation in shed emissions. However, a strong relationship was found between odour emission rate and temperature, with emissions generally lower at low temperatures. All measurements were collected to the NVN 2820 olfactometry standard.

For grower/finisher sheds, all odour emission rates collected at temperatures below 21°C were lower than 10 OU.m³/s/SPU. Emission rates greater than 15 OU.m³/s/SPU were only observed at temperatures greater than approximately 26°C (other than a single measurement from a dirty shed under high humidity). Virtually all odour emission rates greater than 16 OU.m³/s/SPU were collected from very dirty pens with large and frequent piles of manure at temperatures greater than 27°C. The maximum odour emission rate observed for new sheds (10 years old or less) was approximately 18 OU.m³/s/SPU.

Watts (1999) noted that “*most studies conclude that ventilation rate does not have a strong affect on gross odour emission rate. It appears that when ventilation rate is increased, internal odour concentrations decrease so that the gross odour emission rate remains constant. This result appears to apply for both mechanically and naturally ventilated sheds. No published data was found discussing odour emissions from sheds at night when ventilation rates are very low (mechanical ventilation stopped and/or side vents closed).*”

A number of recommendations were made to maintain low shed odour emissions:

- Maintain the internal shed temperature below 25 – 30°C.
- Flush manure from sheds regularly (at least once per week).
- Clean sheds regularly.

AUSPLUME Emission Data – Conventional Piggery Sheds

Assuming that:

- Odour emission rate is independent of ventilation rate
- Odour emission rate is independent of animal type and stocking density
- Internal shed temperatures are typically 20-25°C.
- Sheds are regularly channel flushed (say daily) and laneways hosed clean daily,

then it is recommended that the average odour emission rate from a new piggery shed in Australia be 12 OU.m³/s per SPU (NVN 2820 olfactometry) when the shed is ventilated. When no ventilation occurs (e.g. at night), the emission rate drops, say to 10% of the daytime emission (*Queensland DPI has recommended a reduced emission rate of 50% to be used, not 10%*). The effect of temperature could be accounted for by changing the emission rate



by seasons. In winter, the emission rate could be 8 OUm³/s per SPU, in summer, 16 OUm³/s per SPU and in autumn and spring, 12 OUm³/s per SPU. This provides an annual average of 12 OUm³/s per SPU and has summer emissions twice as large as winter emissions. This is shown graphically in Figure 1.

This variation in odour emission rate could be included using the hour-of-day and season odour emission rate section in AUSPLUME. If sheds are closed during the periods of worst odour dispersion (night, early evening), then this should be accounted for in odour modelling.

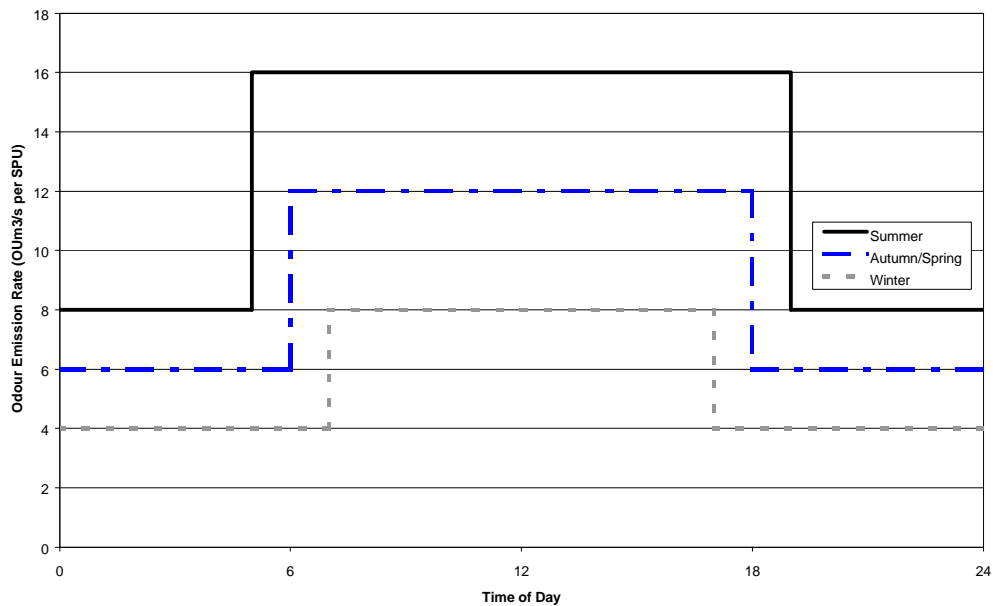


FIGURE 1 – PROPOSED ODOUR EMISSION RATES FOR PIGGERY SHEDS

Deep-Litter Sheds

Watts (1999) summarised deep-litter shed emissions as follows. The range of odour emission rates from deep litter sheds is from less than 1 OUm³/s per pig to over 40 OUm³/s per pig (NVN 2820 olfactometry standard). When standardised to rate per liveweight, the range is from 1 to 25 OUm³/s per 50-kg LWT. Several factors affect the odour emissions from deep litter sheds. The main factors are:

- Ventilation rate
- Air temperature
- Time of occupation
- Status of the manure / litter mix.

With the current paucity of data, it is difficult to determine an appropriate ‘average’ emission rate. This is mainly due to the significant variation in odour emission from deep-litter systems as manure accumulates. However, a reasonable long-term average might be 6 OUm³/s per SPU for a system where the manure / litter mix is maintained in optimal (aerobic) conditions. Hence, when compared with odour emissions from conventional grower / finisher sheds (10-12 OUm³/s per SPU), deep-litter shelters do appear to offer a reduction in odour emission rate per pig. This advantage would be lost though if poor design and management lead to anaerobic conditions in the litter.



AUSPLUME Emission Data – Deep-litter sheds

It is recommended that the average odour emission rate from a deep litter shed in Australia be 6 OUm³/s per SPU (NVN 2820 olfactometry) when the shed is ventilated. The effect of temperature could be accounted for by changing the emission rate by seasons. In winter, the emission rate could be 4 OUm³/s per SPU, in summer, 8 OUm³/s per SPU and in autumn and spring, 6 OUm³/s per SPU. This provides an annual average of 6 OUm³/s per SPU and has summer emissions twice as large as winter emissions. When no ventilation occurs (e.g. at night), the emission rate drops to say, 10% of the daytime value (*Queensland DPI has recommended a reduced emission rate of 50% to be used, not 10%*). This could be included using the hour-of-day and season odour emission rate section in AUSPLUME. If sheds are closed during the periods of worst odour dispersion (night, early evening), then this should be accounted for in odour modelling. These recommendations are based on the following assumptions

- The litter in the sheds is managed so that anaerobic conditions with high odour production do not occur.
- There are a number of deep-litter sheds at the location so that there is a range of pig occupation ages across the site and an average odour emission rate can be used.

3.2. Pond Emissions

Smith *et al.* (1999) concludes that ponds are the major source of odours at typical Australian piggeries contributing about 75% of all emissions. Camp Scott Furphy Pty Ltd (1993) concluded that 82% of odour emissions from the Scone piggery resulted from the pond system. However, given this importance, there were until recently a limited number of odour emission measurements available for piggery ponds in Australia.

Data collected by Smith *et al.* (1999) included pond emission rates collected from a number of sites with mostly old, heavily loaded anaerobic ponds. Emission rates from the heavily loaded anaerobic ponds (12-15 years old) at well managed units varied from 14.7 OU.m²/s to 33.6 OU.m²/s. All but one of these emission rates was collected in winter. An anaerobic pond at one of these units with lighter loading (10 years old) recorded winter emission rates of 3.1 and 6.3 OU.m²/s. An anaerobic pond at a different site (30 years old, poorly managed and severely overloaded) recorded 14.1 OU.m²/s to 58.1 OU.m²/s during summer. All emission rates were measured to the NVN 2820 olfactometry standard.

Emission rates were also collected from facultative (or wet-weather) ponds at these sites. For the well-managed units, winter emission rates varied from 1 to 5.1 OU.m²/s. For the old, poorly managed unit the range was 4 to 16.2 OU.m²/s during summer.

Given the data available at present, it is only possible to categorise piggery ponds as primary (anaerobic) or secondary (wet-weather). Using a standardised odour emission rate from an anaerobic pond of 30 OUm/s (NVN2820 olfactometry standard) and an emission rate from a secondary pond of 5 OUm/s (NVN2820 olfactometry standard), then Table 1 and Table 2 provide odour emission rates per unit area of pond surface.

**TABLE 1 – POND ODOUR EMISSIONS (PRIMARY POND)**

Wind Speed Category	Speed Rate (m/s)	Median Wind Speed (m/s)	Stability Class					
			A	B	C	D	E	F
			Odour Emission Rate (OUm/s)					
1	0-0.6	0.3	25.7	25.7	24.1	21.6	13.9	9.0
2	0.6-1.2	0.9	44.6	44.6	41.7	37.4	24.1	15.6
3	1.2-1.8	1.5	57.5	57.5	53.9	48.3	31.2	20.1
4	1.8-2.4	2.1	68.1	68.1	63.8	57.1	36.9	23.8
5	2.4-3.0	2.7	77.2	77.2	72.3	64.8	41.8	27.0
6	>3.0	6.5	119.8	119.8	112.2	100.5	64.9	41.8

Assumptions: Ambient wind speed measured at 10 m
Tunnel height – 0.125 m, Tunnel wind speed – 0.3 m/s,
'Base' Emission rate 30 OUm/s (NVN2820 olfactometry standard)

TABLE 2 – POND ODOUR EMISSIONS (SECONDARY POND)

Wind Speed Category	Speed Rate (m/s)	Median Wind Speed (m/s)	Stability Class					
			A	B	C	D	E	F
			Odour Emission Rate (OUm/s)					
1	0-0.6	0.3	4.3	4.3	4.0	3.6	2.3	1.5
2	0.6-1.2	0.9	7.4	7.4	7.0	6.2	4.0	2.6
3	1.2-1.8	1.5	9.6	9.6	9.0	8.0	5.2	3.4
4	1.8-2.4	2.1	11.3	11.3	10.6	9.5	6.1	4.0
5	2.4-3.0	2.7	12.9	12.9	12.0	10.8	7.0	4.5
6	>3.0	6.5	20.0	20.0	18.7	16.8	10.8	7.0

Assumptions: Ambient wind speed measured at 10 m
Tunnel height – 0.125 m, Tunnel wind speed – 0.3 m/s,
'Base' Emission rate 5 OUm/s (NVN2820 olfactometry standard)

3.3. Other Emissions

In Australia, ponds and sheds are regarded as the major odour sources at piggeries. However, odours can be emitted from sources other than sheds and ponds. These could be categorised as 'permanent' and 'transitory' odour sources.

Permanent odour sources could include screenings mounds, compost piles and manure slurry storage tanks. Transitory odour sources are usually involved with the handling of effluent and include effluent irrigation, land spreading of wastes, de-sludging of ponds and compost mixing.

Odour data from the UK suggest that the largest, single source of complaints from the public about farm odours arise from the spreading of slurries and manures on land (Pain & Misselbrook, 1991). Hence in Europe, work has been done on the odour emissions from land spreading of stored manure slurry. This is not a common practice in Australia and no work has been done in this area.

In Europe, a number of studies have examined the odour and ammonia emissions from manure slurries and manure slurry tanks. This data is of limited use in Australia because:



- Storage of manure as an untreated slurry is uncommon.
- Manure slurry storage occurs at much lower temperatures than would be applicable in Australia. Hence, manure breakdown characteristics would be significantly different.

3.3.1. Compost

Composting of various solid wastes (screenings, pond sludge, and pig carcasses) is becoming more popular. As environmental pressures increase, it is expected that more composting will occur. While little odour is emitted from well-managed aerobic compost heaps, it is also clear that significant odours can be emitted from poorly-managed, anaerobic compost. There is ample experience of this from the mushroom industry.

We could find no quantitative published data on odour emissions from composting.

4. RECENT DEVELOPMENTS IN EMISSION RATES FOR PIGGERIES

4.1. Overseas Data

4.1.1. Shed Emissions

Van Langenhove and De Bruyn (2001) reported odour emissions from a number of mechanically ventilated pig sheds in Europe to the new CEN standard. No description of the sheds was provided, but it is assumed that manure is stored in under-floor pits.

For grower/finisher sheds, summer emissions were 31 – 35 OU/s/animal, while winter emissions were 15 OU/s/animal. For dry sow sheds, summer emissions were 53 OU/s/animal, while winter emissions were 35 OU/s/animal.

No correlation was found between odour emissions and pen dirtiness, which varied from 4-14% of the floor covered with manure. These scores for pen dirtiness are low compared to the range that can be found in older Australian piggeries with partly slatted floors. A strong positive correlation was found between odour emission and ventilation rate within the pig sheds.

Gallmann *et al.* (2001) reported odour emissions from an experimental pig shed in Europe to the new CEN standard. Measurements were collected from two rooms of grower/finisher pigs. The first room was standard fully slatted accommodation with under floor slurry storage and mechanical ventilation of the manure pit. The second room was partially slatted with natural ventilation of the under-floor manure storage pit. Emissions were reported in livestock units (LU) where 1 LU = 500 kg live weight (hence, emissions could be divided by 12.5 to provide an approximate answer in SPU). Measurements were collected for three separate all-in all-out fattening periods over 13 months.

Summer emissions were 100–500 OU/s/LU, with an average of approximately 150 OU/s/LU while winter emissions were 4-175 OU/s/LU, with an average of approximately 60 OU/s/LU.



The variability in measured emissions increased substantially during summer, with the conventional system generally showing higher emissions. The temperature and relative humidity within the rooms remained relatively consistent throughout the sampling period. No relationship was found between odour emissions and ventilation rate.

Ogink and Groot Koerkamp (2001) reported odour emissions from a number of pig sheds in Europe to the new CEN standard. Measurements were collected from grower/finisher pigs on partially slatted flooring with under floor slurry storage (conventional and reduced emission storage pits). Measurements were collected from dry sows in partially slatted stalls with under floor slurry storage and a reduced emission group housed dry sow group on fully slatted flooring with under floor slurry storage. Emissions were reported per animal. Measurements were timed to assess seasonal variation in odour emissions.

Grower/finisher emissions for the conventional system were 7–85 OU/s/animal, with an average of 23 OU/s/animal, while results for the reduced emission systems were 5-23 OU/s/animal, with an average of approximately 11 OU/s/animal. For dry sows, conventional system emissions were 8–37 OU/s/animal, with an average of 19 OU/s/animal, while results for the group housing system was 3-19 OU/s/animal, with an average of 7 OU/s/animal.

Variability in emissions with season was not discussed. No relationship was found between odour emissions and ammonia emissions.

These results cannot be directly compared to shed emission measurements under Australian conditions due to the large differences in shed design and management between the two regions.

4.1.2. Pond Emissions

Odour emission measurements were collected by Heber *et al.* (2000a) from two anaerobic ponds with different loading rates. Two odour samples were collected from each of two locations on each pond at six separate visits. Samples were collected using a buoyant wind tunnel (Heber *et al.*, 2000b). This wind tunnel was designed to collect low concentration odour emissions, and hence differs considerably from the wind tunnels used in recent Australian piggery pond studies. It is difficult to estimate the relationship between this Heber wind tunnel and the wind tunnels used in Australian studies, but some difference in results would be expected.

Odour samples were analysed using an AC'SCENT olfactometer using methods compatible with the 1999 CEN TC264 Olfactometry Standard (ie equivalent to the Australian Standard). Lagoon effluent was analysed for pH, total solids (TS), volatile solids (VS), chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), ammoniacal nitrogen ($\text{NH}_4^+\text{-N}$) and phosphorous (P).

Both ponds sampled were the first cell of a two-stage lagoon for a breed-to-wean piggery. Pond A was estimated to have a typical loading rate equating to 62.5 g VS/m³/day. Pond B was estimated to have a light loading rate equating to 22.4 g VS/m³/day.

The mean odour emission from pond A was 6.2 OU/m²s and from pond B was 2.9 OU/m²s. The results indicated generally higher emissions from pond A, although after statistical analysis of the data, no significant difference was found. Of the effluent characteristics, pond A had higher concentrations of TS, TKN, $\text{NH}_4^+\text{-N}$ and P, but lower VS.



Due to the small amount of data obtained from this work, it is difficult to draw any conclusions. On most occasions, significant variation in odour emissions was found from the samples from different locations on the one pond on the same day. This agrees with results found in Australia suggesting significant variation in the odour emissions from different points on a pond surface at a given time (Galvin *et al.*, 2002a). Thus, to obtain an accurate estimate of overall pond emissions, it is necessary to take a number of samples across the pond.

4.2. Australian Data

4.2.1. Piggery Sheds

Jiang (2002) reported measurements of piggery shed odour emissions for naturally ventilated and tunnel ventilated sheds. No information was provided regarding the ambient or internal shed temperatures, the management of the ventilation or the cleanliness of the sheds. All odour measurements were undertaken to the Australian olfactometry standard. As a result of the lack of supporting information and the olfactometry standard used, direct comparisons to the shed emission rates reported by Smith *et al.* (1999) cannot be made accurately.

The reported data showed:

- Higher odour emissions from sheds housing pigs under seven weeks of age compared to pigs older than seven weeks of age. This result reflects practical experience where the pens of young pigs are dirtier and more odorous than those of older pigs.
- For mechanically ventilated sheds, emission rates are highest after ventilation starts in the morning, but reduce by midday to a lower average level.
- For mechanically ventilated sheds, emission rates varied with shed ventilation rate, with the lowest emission rate at the lowest ventilation rate.
- For naturally ventilated sheds, no consistent pattern was evident in odour concentration variation throughout the day, suggesting that odour concentration does not vary significantly throughout the day when ventilation rates are low.

Ventilation effects on shed odour emission

For the tunnel ventilated sheds studied by Jiang (2002), reported ventilation rates during fan operation varied from 7 – 57 m³/s for a shed capacity of 1200 pigs, or 21-171 m³/hr/head. The minimum ventilation requirements for pigs from 15 – 130 kg vary from approximately 5 – 18 m³/hr/head (Taylor *et al.*, 1994).

To assess the impact of ventilation rate on odour emission rate, a series of measurements were undertaken in one shed with different numbers of fans switched on. The data showed a low emission rate for the lowest ventilation setting, peak emission rate in the mid range and a low emission rate at the two highest settings. At the lowest ventilation setting, the emission rate measured for a grower/finisher shed was 4 OU/s/SPU (Australian olfactometry standard).

Given that the lowest mechanical ventilation rate setting showed low odour emission rates, and assuming that night-time odour concentrations are not significantly greater than day-time odour concentrations, low ventilation rates at night reduce the shed odour emission rate.



Assuming that odour concentration remains constant under minimum ventilation conditions, the odour emission rate would be approximately half of the emission rate measured for the lowest ventilation setting, or 2 OU/s/SPU (Australian olfactometry standard).

TABLE 3 – VENTILATION RATE EFFECTS ON TUNNEL VENTILATED SHED EMISSIONS (JIANG, 2002)

Number of fans on	Ventilation rate (m ³ /s)	Gross odour emission rate (OU/s)	Odour emission rate (OU/s/SPU)
6	53.2	9097	4.7
5	41.7	8590	4.5
4	34.5	19700	10.3
3	20.6	20682	10.8
2	15.3	13739	7.2
1	6.7	7524	3.9

These measurements were repeated on a different day, but no information was available regarding the number or age of pigs in the shed (it seems that all pigs had been moved out of the shed recently and it was empty). This data showed a similar trend, but with lower peak emissions and higher emissions at peak ventilation rates. This data has not been included in analysis due to the uncertainty with the shed stocking rate.

Time of day effects on shed odour emission

Jiang (2002) also collected a number of odour emission measurements from naturally ventilated piggery sheds at different times of the day. Three sampling times were chosen – early morning prior to the shed being opened for the day, mid-afternoon following the daily maximum temperature, and in the evening during still conditions least favourable to odour dispersion. No information was provided regarding the ambient or internal shed temperatures, ventilation rates, pig number within each shed, the management of the ventilation or the cleanliness of the sheds.

Odour concentrations were reported for samples collected from individual sheds on 8 different days over a 12 month period. The results for each shed varied by 3 to 5 times between the minimum concentration measured over the 12 months and the maximum concentration measured over the 12 months. The range of concentration results did not vary significantly between sheds.

Intra-day variations were considerably lower than the overall variation for each shed and were generally well within the factor of 3 that defines the precision of the olfactometer under the Australian olfactometry standard (compliance with the performance criteria of the standard ensures that the difference between two consecutive measurements on the same material in one laboratory will not be greater than a factor of 3). No consistent pattern was evident in odour concentration variation throughout the day.

The results from the naturally ventilated sheds suggest that odour concentration does not vary significantly throughout the day when ventilation rates are low. The odour concentration within the tunnel ventilated sheds was found to vary when the ventilation rate changed significantly. The reported odour emission rates for tunnel ventilated sheds also varied with time of day, as shown in Table 4. The morning emissions reported all apply to ventilation rates of approximately 40 m³/s.

**TABLE 4 – TUNNEL VENTILATED PIG SHED ODOUR EMISSIONS (JIANG, 2002)**

Pig Type	Time of Day	Odour Emission (OU/s/SPU – AS)
Early Weaner (4-6 weeks)	Morning	18.4 (average) 16.6 and 20.1 (only measurements)
	Afternoon	11.6 (average) 8.7 and 14.5 (only measurements)
Grower/Finisher (8-19 weeks)	Morning	3.2 – 12.5 (range) 9.3 (average)
	Afternoon	3.3 – 10.8 (range) 6.4 (average)

In tunnel ventilated sheds, temperature set-points are established to provide optimum conditions for the pigs, with younger pigs requiring higher shed temperatures due to their lower body weights. Practically, sheds can be operated in a four stage manner:

- at ambient temperatures below 10°C, the sheds are closed and the ventilation rate is reduced to minimum ventilation requirements.
- at temperatures above 10°C, the sides of the shed are opened to provide natural ventilation of the shed.
- at temperatures above 25°C, some ventilation fans are turned on with the shed sides still open to assist with the natural ventilation.
- at temperatures above approximately 28°C, the shed sides are closed and the shed is operated as fully tunnel ventilated, with some sheds using an evaporative cooling screen on the air intake to increase cooling efficiency.

Shed odour emission rates from this report could be summarised as follows (Australian olfactometry standard):

- 2 OU/s/SPU when ambient temperature is less than 10°C,
- 4 OU/s/SPU when ambient temperature is between 10-25°C,
- 6.5 OU/s/SPU when ambient temperature is greater than 25°C,
- 9.5 OU/s/SPU for 3 hours when ambient temperature rises above 25°C before noon.

Edgar *et al.* (2002) reported odour emission rates from deep litter piggery sheds containing grower pigs. The olfactometry standard used is not mentioned other than odour recognition threshold and standardised to 40 ppb n-butanol. Duplicate odour samples were collected on three occasions between 1am and 4.30am in the morning from one shed containing growers at their maximum size and duplicate samples were collected from a second shed at 4.30am containing younger growers. No information was provided regarding the number, weights or age of the pigs in the sheds sampled. Background odour samples were collected and ventilation rate from the sheds was estimated using measured exit air velocity. It is assumed that the sheds were naturally ventilated.

The total shed emission rate for the heavy growers varied from 22030 OUm³/s to 48820 OUm³/s as the ventilation rate increased from 10.48 m³/s to 26.97 m³/s. For the shed containing younger growers, the total shed emission rate was 2065 OUm³/s at a ventilation rate of 23.46 m³/s. These emissions are of the order of those reported by Jiang (2002), but cannot be fully compared without knowledge of the olfactometry method and pig weights within the sheds. It was noted by the authors that maximum emissions from a shed occur at the end of the grower batch.



4.2.2. Piggery Ponds

Variability of pond odour emissions

Recent work by the Queensland DPI has shown that odour emissions from anaerobic ponds vary significantly at different points on the pond (Galvin *et al.*, 2002a). Observations made during collection of the odour samples suggest that this variation is time dependent as much as location dependent. This work has also suggested a relationship between volatile solids (VS) loading rate and pond odour emission, with higher loading rates generally producing higher odour emissions. The VS loading rate is a function of the pond treatment volume and the mass of VS flowing into the pond.

Currently, the volume of the pond available for treating effluent is assumed to be the volume of supernatant, or liquid effluent. This is calculated as the total pond volume less deposited sludge. It is currently assumed that no significant treatment occurs within the sludge layer.

However, research by Anderson *et al.* (2000) investigated the properties of undisturbed sludge in anaerobic piggery effluent ponds. A grid was established across the pond and samples of sludge collected concurrently from varying depths in the profile. Properties measured included:

- solids concentration;
- chemical oxygen demand (COD);
- total phosphorous;
- potassium concentration;
- total Kjeldahl nitrogen (TKN); and
- particle size distribution.

Four strata within the sludge layer were defined

1. Concentrated zone (CZ) – bottom 33%, characterised by a significant increase in the concentration of nutrients with depth and larger sludge particle sizes.
2. Active zone (AZ) – 22% immediately above CZ, characterised by a slight increase in the concentration of nutrients with depth and active decomposition.
3. Dilute zone (DZ) – 22% immediately above AZ, characterised by low nutrient concentration as waste quickly passes through this layer.
4. Sludge/supernatant interface – 22% immediately above DZ, characterised by the mixing of fresh waste with the end products of AZ.

A detailed survey of the sludge layers was not performed as part of their study. However sludge was collected at 0.5 m intervals from each pond and analysed for TS and VS. This data was inconclusive in determining which parts of the sludge could be considered as active volume. Thus, active volume was assumed to be the supernatant volume only. An accurate estimate was obtained of the sludge volume in an anaerobic piggery pond after 15 years continuous use. The figure they obtained was found to be 79% lower than the sludge volume estimated using the ASAE method proposed by Barth (1985).

Basically, the work of Anderson *et al.* (2000) reinforces field observations that sludge settling in an anaerobic pond continues to react, giving off gases. When these gases are released in the lower layers of sludge, a gas bubble builds up until it has sufficient buoyancy to dislodge the covering layer of sludge. The larger gas bubbles reach the surface basically intact and release the gas to the atmosphere. Odour samples that include the gases given off by these



'upwellings' return results that can be several times greater than those collected off a calm area of pond surface.

The sludge in overloaded anaerobic ponds does not break down as fully as the sludge in lightly loaded ponds (McGahan *et al.*, 2001). Visual observation shows that lightly loaded ponds have many small bubbles breaking the surface regularly, whereas heavily overloaded ponds tend to have larger, forceful upwellings breaking the surface less regularly. As a result, more consistent odour measurements are found across the surface of lightly loaded ponds, and larger variation is found across the surface of heavily loaded ponds. Considering all points on the pond surface at any one time, the full range of emissions is likely to be occurring across the pond, hence averaging the range of values represents the actual situation.

Loading rate effects on pond odour emissions

McGahan *et al.* (2001) reported on the factors effecting odour emissions from 5 anaerobic ponds in south-east Queensland. This report discussed the relationship between odour emission rate and various design and management factors. As expected, the results showed an increase in odour emissions as more volatile solids (VS, also referred to as organic matter) are added to a pond. All odour emissions quoted in the report were measured to the new Australian olfactometry standard. As the report was seeking to establish relationships between odour emission rates and measured variable, all data analysis was completed using the measured odour emission rate E rather than the standardised odour emission rate E₁.

The amount of solids (total and volatile) and nutrients (N, P and K) produced on a daily basis for each piggery surveyed was calculated using PigBal, with actual diets used in the piggeries. Total and active pond volumes were also determined by measuring the depth to the sludge layer with both a turbidity meter and mechanically (T-bar).

The loading rate for each pond surveyed was calculated by dividing the amount of VS entering the pond per day (g) by the active volume (m³). The design standard for calculating the required active volume for anaerobic ponds is: 100 g VS/m³/day x k factor. The k factor for each piggery location was determined, along with the loading rate and the loading rate as a percentage of the maximum design.

Effluent analysis results for each pond can be seen in Table 5 below. Pond pH, EC, Redox potential and temperature were all measured in-situ at approximately 100 mm below the pond surface.

**TABLE 5 - EFFLUENT ANALYSIS RESULTS FOR EACH POND SURVEYED**

Parameter	A	B	C	D	E	B2
pH	7.4	7.7	7.8	7.7	8.0	7.5
Redox Potential (mV)	-275	-305	-344	-340	-285	-299
EC (dS/m)	6.36	6.84	8.36	8.99	9.2	6.41
Pond temperature (oC)	24.0	29.3	27.1	26.0	26.0	23.6
Total nitrogen (mg/L)	499	597	812	810	888	496
Ammonium (mg/L)	471	493	436	319	798	481
Total Phosphorus (mg/L)	68	59	65	41	72.9	53.6
Orthophosphate (mg/L)	35	55	13.5	13.6	56.3	50.6
Sulphates (mg/L)	40	35	10.2	11.3	16.0	52
Sulphides (mg/L)	0.08	0.12	0.51	1.23	0.30	<0.5
Total VFA (mmol/L)	0.525	0.027	0.778	0.478	0.002	0.72
Volatile solids (mg/L)	967	945	1275	1332	1311	938
Total Solids (mg/L)	3120	3046	3480	4584	3614	2753
VS/TS (%)	30.99	31.01	36.61	29.05	36.25	34.05
Chlorophyll a (mg/L)	0.695	0.495	0.455	0.433	0.024	2.258
Total Iron (mg/L)	0.74	0.78	0.78	0.79	1.72	0.49
Sodium (mg/L)	306	225	361	652	375	207
Calcium (mg/L)	23	51	16.8	30	1.8	2.4
Potassium (mg/L)	496	772	648	558	404	524
Magnesium (mg/L)	28	34	36	28	4.74	7.0
Copper (mg/L)	0.43	0.80	0.31	0.93	0.83	0.31
Zinc (mg/L)	0.98	0.59	0.56	5.45	8.31	0.26

B2: Second sampling period for pond B

Table 6 shows the average odour emission rate, total pond odour emission and odour emission per SPU for each pond. Total pond odour emission was calculated as the average OER (OU/m²s) multiplied by the pond surface area. All the data analysis was performed on the average odour emission from the 2 days sampling at each pond and on the measured odour emission rate E, NOT E₁.

TABLE 6 - TWO DAY AVERAGE OER, TOTAL ODOUR EMISSION AND ODOUR EMISSION PER SPU FOR ALL 5 PIGGERIES.

Piggery	OER, E (OU/m ² s)	OER, E ₁ (OU/m ² s)	Tot. Pond Emission (OU/s)	Odour Emission per SPU (OU/SPU.s)
A	5.8	9.1	16,987	11.7
B	5.5	7.9	19,836	11.3
C	10.9	17.3	50,191	4.4
D	5.3	8.7	45,222	6.7
E	7.1	11.4	119,337	8.0

The E₁ odour emission rates from all the ponds measured are approximately 10 OU/m²s (except the heavily loaded pond – piggery C). If a conversion ratio of 3 is used to convert these numbers measured to the new Draft Australian Standard (equivalent to CEN TC364) to the old NVN2820 standard, as suggested by Agapides and Welchman (2000) the odour emission rate compares favourably with the suggested emission rate by Watts (1999) of 30 OU/m²s for anaerobic (primary) ponds.

“Volatile solids provide a key input to the reactions that occur within an anaerobic pond, with some of the products being quite odorous. Figure 2 shows the relationship between total pond odour emission and the mass of volatile solids added to the pond ($r^2=0.87$). The relationship shown suggests that the more volatile solids (organic matter) produced by a



piggery and subsequently loaded in the pond, the more odour that will be produced by that pond. The graph also suggests that a direct linear relationship can be fitted to the data with reasonable accuracy. That is, if the amount of volatile solids loaded to the pond is doubled, the resultant total odour emission will be doubled."

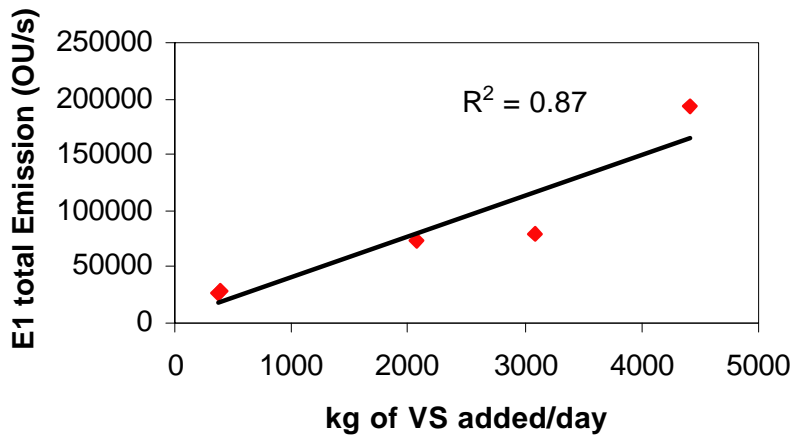


FIGURE 2 - TOTAL ODOUR EMISSION VERSUS KILOGRAMS OF VOLATILE SOLIDS ADDED PER DAY

To assess the effect of pond surface area on odour emissions, the odour emission rate was plotted against the loading rate per square metre of surface area (where loading rate is the mass of VS added per day).

"Figure 3 shows that as the VS loading rate per unit area increases, the odour emission rate (OU/m²s) increases ($r^2=0.94$). However, this relationship is influenced by the leverage caused by piggery C results (high loading rate per unit area). The graph shows that the odour emission rate (OU/m²s) does not increase at the same rate as the loading of VS per m² of surface area. An increase in the loading of VS per m² by three times increases the emission rate by less than a factor of two."

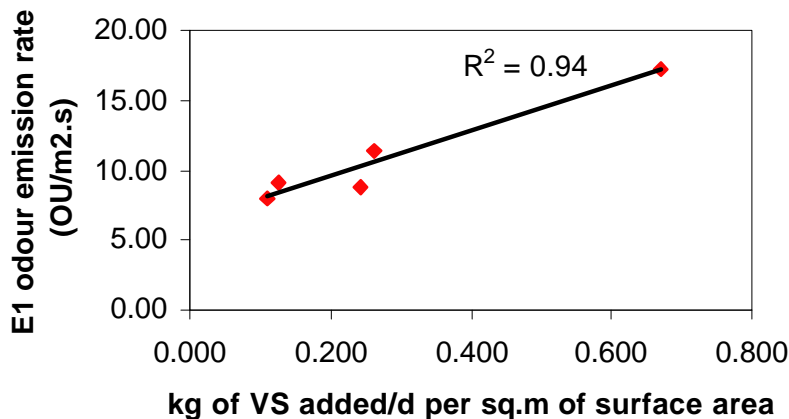


FIGURE 3 - ODOUR EMISSION RATE AS A FUNCTION OF LOADING RATE PER SQUARE METRE OF SURFACE AREA



These two results reflect practical experience with odour emissions from piggery anaerobic ponds. Their relationship to each other is described below.

“From Figure 2, it could be suggested that total pond odour emission increases at the same rate as the mass of VS added to the pond (double the mass of VS added to the pond will produce twice the total odour emission). However, Figure 3 suggests that on a square metre of surface area basis, the odour emission does not increase in the same proportion as the VS added to the pond. This suggests that while total odour emission may increase at the same rate as VS loading under similar pond configurations, the odour emission rate does not increase at the same rate as VS loading if pond configurations change. Specifically, a lower total emission could be expected if the surface area per unit of VS added is reduced (i.e. constructing a deeper pond). The following example illustrates this point.

Considering a 10,000 SPU piggery producing 900,000 kg of VS/yr or approximately 2,500 kg of VS/day. The total odour emission from Figure 2 would be approximately 95,000 OU/s. Simply doubling the size of the piggery to 20,000 SPU would increase the VS production to 5,000 kg of VS/day, with the resultant total odour emission being approximately 185,000 OU/s. This assumes that the pond is simply doubled in size at the same depth (twice the surface area). However, if the pond surface area remains the same and the amount of VS added per m² of surface area doubles (0.3 – 0.6 kg of VS added/m² of surface area/day), Figure 3 suggests that the resultant total odour emission will only be 135,000 OU/s.”

The relationship between odour emission and pond surface area was also investigated. Considering both measures as a function of the standard pig unit (SPU) capacity of the piggery enabled a comparison of the emission/surface area relationship independently of loading rate. (SPU is a term used for determining the effluent output of a piggery, where one SPU produces an amount of VS equivalent to a 40 kg pig). Figure 4 shows a reasonable linear relationship suggesting that emissions will decrease as pond surface area is decreased.

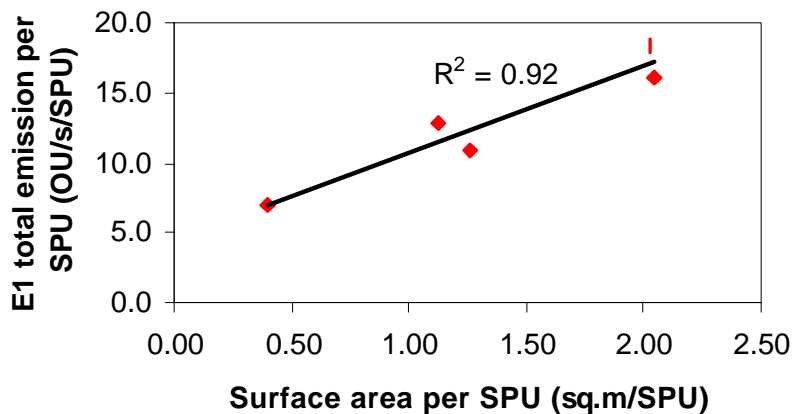


FIGURE 4 – EMISSIONS PER SPU AS A FUNCTION OF POND SURFACE AREA PER SPU

Galvin *et al.* (2002b) recently presented odour emission measurements from anaerobic piggery ponds in south-east Queensland. The data presented included the information reported by McGahan *et al.* (2001) as well as further measurements taken from the same ponds during a different season. The data suggested that the odour emissions from anaerobic piggery ponds during winter may be double summer emissions. It was suggested



that low temperatures may reduce activity within the pond and change the balance of bacteria and hence the nature of the gaseous emissions. Final analysis of this data has not been undertaken, so specific relationships cannot be presented.

4.2.3. Solids Stockpiles and Composting

There are no measured odour emissions from composting of piggery by-products reported in Australia. When properly managed, the composting process is aerobic, resulting in low odour emissions. The formation of piles in a trapezoidal shape retains higher moisture conditions in the centre of the pile, while the outer layer dries out. As composting requires air and moisture to for the process to establish, optimum conditions occur in the centre of the pile. The dry outer layer acts as a form of biofilter so that no significant odour emissions occur.

Practical experience suggests that establishing a compost material that is relatively dry (less than 70% moisture) and porous provides an effective, low odour process. Experience shows that the screenings produced by a screw press separator from piggery effluent match these requirements.

Short term odour emissions are released when piles are watered and turned, but this is generally restricted to the 3-4 hours after turning while the outer windrow layers are drying out. As turning operations occur during the middle of the day when odour dispersion is greatest, the low emissions resulting from turning are insignificant compared to overall piggery odour emissions. Practical experience suggests that composting emissions are very low.

4.2.4. Effluent Irrigation

Watts (1999) indicated that little information is available regarding odour emissions from effluent irrigation. Research into emissions from slurry spreading in the UK was reported. Piggery design and management factors are significantly different between northern Europe and Australia. In modern Australian piggeries, effluent storages have large volumes to adequately treat effluent (reduce volatile solids), with the treated water produced being irrigated to land. In Europe, piggeries have traditionally had little or no effluent treatment, with slurry (effluent plus solids) spread onto land when manure storage pits reach their capacity. As a result, slurry spreading is odorous and forms a significant part of overall piggery odour emissions. In contrast, treated effluent has low odour emissions and does not contain solids that remain on the soil surface after effluent application.

Irrigation of effluent generates odours through the release of offensive gases and by spray drift of fine aerosols through the atmosphere. Management practices to minimise odour generation include:

- The application or irrigation of piggery effluent should be managed so that effluent infiltrates or is incorporated into the soil soon after application.
- Surface ponding should be avoided, as should effluent irrigation during prolonged wet periods or when runoff would occur following further irrigation
- Timing of effluent application should be considered, including time of day, time or week (e.g. consider weekends and public holidays), prevailing weather conditions, and working conditions of the pond.
- Neighbours should be consulted when management practices are likely to cause excessive odour emission (e.g. the application of raw manure).



Potential sources of odour from effluent irrigation include waterlogged areas with ponded effluent on the soil surface and drift of aerosols from spray irrigation. Adequate irrigation design and management can prevent odour emissions from both of these sources.

The only effluent irrigation area measurement reported in Australia was collected at the Danpork piggery at Scone (Camp Scott Furphy Pty Ltd, 1993). An odour measurement was collected immediately after effluent irrigation, with an emission rate of 2.2 OU/m²s reported (it is assumed that the odour measurement standard would be similar to NVN 2820).

When a water and nutrient balance is conducted for a piggery, the application of effluent is almost always restricted by the nutrient loading rate, not hydraulic loading. Effluent application is generally less than 100 mm/yr of effluent. Due to these relatively small application rates, timing of the effluent applied can be restricted to ensure:

- It is applied when the soil is dry and crop is actively growing on the application area.
- It does not occur on weekends, public holidays and rain days.
- It occurs between 9:00 am and 3:00 pm to ensure maximum dispersion of any odour generated.

4.2.5. Ausplume Validation

Edgar *et al.* (2002) reported the results of an Ausplume validation trial undertaken at a commercial deep litter grower piggery in southern Australia. Odour samples were collected from a deep litter shed at the same time as ambient samples were collected downwind of the shed. The samples were collected under the period of lowest odour dispersion to enable ambient samples to be compared to odour modelling results.

The major conclusions of the study are:

- Ausplume may under-predict odour concentrations at the centre-line of the plume and over-predict the spread of the plume close to the source (<1000m). This result was attributed to limitations in the stability class functions used by Ausplume.
- The total odour plume measured was significantly less than predicted by Ausplume. This result was attributed to the assumption used in Ausplume that odour is conserved as it moves away from the source. Total odour measured at 1500 m from the piggery was 25% – 50% of the total odour measured at 700 m from the piggery. It was suggested that the reduction in total odour was due to odour being absorbed to deposited particles and the ground mist that was present at the time.



5. SUGGESTED EMISSION RATE DATA TO BE USED IN ODOUR MODELLING

5.1. Sheds

Odour emission rates for modelling of piggery sheds vary with the style of housing used.

For tunnel ventilated sheds, the available data suggests that the emission rate may vary with ventilation rate. Given that temperature is used as the basis for setting shed ventilation rates, odour emission rates for modelling should be varied with temperature as follows (Australian olfactometry standard):

- 2 OU/s/SPU when ambient temperature is less than 10°C,
- 4 OU/s/SPU when ambient temperature is between 10-25°C,
- 6.5 OU/s/SPU when ambient temperature is greater than 25°C,
- 9.5 OU/s/SPU for 3 hours when ambient temperature rises above 25°C before noon.

For tunnel ventilated sheds housing weaners less than 7 weeks old, these emission rates should be doubled.

For naturally ventilated sheds, Smith *et al.* (1999) suggested that odour emission rates are largely independent of ventilation rate. Jiang (2002) suggests that odour emission rates are not totally independent of ventilation rate. However, Jiang (2002) does not actually present or discuss the odour emission rates for naturally ventilated sheds, nor is any discussion provided regarding the influence of variables such as temperature, pen cleanliness or humidity. Given that this data represents the largest body of odour emissions collected from naturally ventilated piggery sheds to the Australian olfactometry standard, it is recommended that this information be re-examined to provide a meaningful data set which could potentially be used in the development of standard emission rates for naturally ventilated pig sheds. It is also recommended that the data of Edgar *et al.* (2002) be further examined to establish its suitability for use in developing standard odour emission rates for deep litter sheds.

5.2. Ponds

Based on currently available data, piggery anaerobic ponds should be modelled using a base emission rate of 10 OU/m².s (Australian olfactometry standard). The pond odour emission data currently being analysed by Queensland DPI may provide further information regarding seasonal variation to emissions and the factors influencing those emissions. This data may provide relationships between odour emissions and pond loading rate and odour emissions and pond surface area. Such relationships would enable proponents to model scenarios different to standard pond designs, providing more flexibility in the piggery design process.

There is insufficient experimental data to establish the significance of fetch factors when modelling odour emissions from piggery ponds.



It is recommended that pond odour emissions continue to be modelled with variation for stability and wind speed. The conversion factors to be applied to the base pond emission rate is listed in Table 7. This conversion table is based on the theory outlined in Watts (1999). It is assumed that for wind tunnel data, emission rate varies with wind speed according to:

$$E_v = E_m \times (U_t/U_m)^{0.5} \tag{1}$$

Where: E_v = Odour emission rate at tunnel wind speed, U_t
 E_m = Base odour emission rate measured at tunnel wind speed (U_m)
 U_m = Tunnel wind speed for measurements, i.e. 0.3 m/s
 U_t = Wind tunnel speed

To relate wind tunnel speed (U_t) to ambient wind speed the following is used:

$$U_t = U_{10} \times (0.125/10)^N \tag{2}$$

Where: U_{10} = Wind speed at 10 m
 N = Wind profile exponent (the wind profile exponents for stability classes A, B, C, D, E and F were 0.07, 0.07, 0.10, 0.15, 0.35 and 0.55 respectively)

TABLE 7 – POND ODOUR EMISSIONS VERSUS WIND SPEED AND STABILITY CLASS

Wind Speed Category	Speed Rate (m/s)	Median Wind Speed (m/s)	Stability Class					
			A	B	C	D	E	F
Relative Odour Emission Rate (%)								
1	0-0.6	0.3	86%	86%	80%	72%	46%	30%
2	0.6-1.2	0.9	149%	149%	139%	125%	80%	52%
3	1.2-1.8	1.5	192%	192%	180%	161%	104%	67%
4	1.8-2.4	2.1	227%	227%	213%	190%	123%	79%
5	2.4-3.0	2.7	257%	257%	241%	216%	139%	90%
6	>3.0	6.5	399%	399%	374%	335%	216%	139%

Assumptions: Ambient wind speed measured at 10 m
 Tunnel height – 0.125 m
 Tunnel wind speed – 0.3 m/s
 Eqns 1 and 2 above used.

Any pond receiving effluent from a properly functioning anaerobic pond should continue to be modelled with an emission rate of 1/6 of the rate for the anaerobic pond.

Temporary effluent retention ponds forming part of a primary treatment system should be modelled with the same emissions as an anaerobic pond providing the effluent retention time is 1 day or less. In situations where the effluent retention time for a temporary pond is significantly longer than 1 day and the pond has a loading rate very much higher than an anaerobic pond, the emission rate may be higher than an anaerobic pond. The DPI data may provide more information for such cases.



5.3. Other

Other potential odour sources at a piggery include solid by-product stockpiles and by-product application areas. Many piggeries now compost solid by-products on-site. From practical experience, well managed compost areas are not significant odour sources. The emissions from compost areas are also substantially different in character to emissions from other piggery odour sources and from experience, less offensive. Standard odour emission rates for modelling cannot be recommended due to the lack of data.

Odour emissions from well managed by-product application areas are minimal. Standard odour emission rates for modelling cannot be recommended due to the lack of data.

6. PROPOSED PROCESS FOR PIGGERY ODOUR IMPACT ASSESSMENT

FSA Environmental is currently contracted to develop National Guidelines for the pig industry. A component of these guidelines will be a suggested method for assessing new and expanding piggery developments in terms of odour impact. It is proposed to develop a three-tiered assessment approach and to include community consultation more commonly in the development process.

The first tier is to use a standard formula. The second tier would involve modelling using adopted "standard" emission rates and a meteorological file representative of the site. The third tier would involve site-specific odour emission rates with at least one year's worth of meteorological data collected for the site.

6.1. Community Consultation

Odour impact criteria can be developed that protect a community. However, the impact of detecting an odour can be elevated when an individual is convinced they will be significantly impacted. In these situations, the odour impact criteria may not reassure near receptors, potentially resulting in a poor community image for the piggery during the application and development stage. For proposed piggeries that are designed and managed to meet appropriately developed odour guidelines, community outrage represents the major risk for off-site odour impacts.

Where neighbours of a proposed piggery development are particularly concerned with the proposal, a consultation process with neighbours has been shown to reduce the effect of community outrage. This process requires

1. an explanation of the proposed operation,
2. opportunity for neighbours to voice their concerns,
3. a response from the proponent explaining how concerns are addressed,
4. a process for ongoing feedback from neighbours regarding potential impacts,
5. a process for addressing this feedback,
6. an explanation of the measures that are available to address impacts that may arise.

The majority of this information is already collated by most piggery developments and presented to regulatory authorities. The inclusion of neighbours in this process from the start should minimise objections and improve the image of the pig industry with the community.



6.2. First Tier

The first tier is to develop a standard empirical formula. The objective of assessment under this tier would be to provide a simple, cheap and quick method that offers high levels of protection for community amenity. Hence the formula developed will need to be relatively conservative in that it could be used as a first screen for a proposed development. It would need to be conservative enough that if a proposed development met the separation distance it would meet site-specific odour modelling. Community consultation would generally not be required as part of the development application.

The approach used to develop this standard formula could be based on the method used to develop the separation distance formula for Queensland piggeries. This method basically involves establishing standard piggery configurations for a range of piggery sizes and modelling these under a range of land use factors for a given odour impact objective.

Meteorological conditions vary significantly between regions and have a high impact on modelling results. As a result, it is proposed that a representative meteorological data file be established for each major pig production region and used to develop a regional empirical formula.

A major advantage of a formula based assessment over a fixed buffer guideline is that the formula can be established to take account of specific factors. This is particularly important with wind direction, where prevailing winds are relatively consistent across regions. For sites where a receptor is located downwind of the site in the prevailing direction, a factor could be applied to allow for this.

The factor used could be based on the modelling undertaken to establish regional formulas by assessing the difference between a receptor within the prevailing direction and a receptor located at a similar distance from the piggery in another direction.

6.3. Second Tier

The second tier would involve odour modelling with “standard” recommended emission data. The objective of assessment under this tier would be to provide a method that more closely matches the actual site configuration, but still offers high levels of protection for community amenity. This assessment would apply to situations where

- piggery design or management were substantially different to the standard designs used for the Tier 1 assessment,
- site representative meteorological data is available and differs substantially from the meteorological data used for the Tier 1 assessment,
- receptor locations are not accurately represented by the Tier 1 assessment.

Community consultation would be recommended as part of the development application.

The emission data would need to be based on accepted research results. The meteorological file could be a nearby file (<100 km) or be a generated file (e.g. The Air Pollution Model, TAPM). To allow for the uncertainty in emissions measurement and



meteorological data files, the odour modelling results should not exceed 80% of the odour impact objective.

6.4. Third Tier

The third tier would involve comprehensive site specific modelling. The objective of assessment under this tier would be to include site specific information for each of the major variables influencing odour impact assessment. This assessment would apply largely to situations where innovative or unusual piggery design or management processes are implemented on-site, or where particular odour reduction strategies are used. Community consultation would be required as part of the development application.

The modelling would incorporate the use of site specific emission data, based on system measurements collected to appropriate standards. The modelling would also require the collection of at least one year of reliable meteorological data. The odour modelling results would need to comply with the odour impact objective.

6.5. Modelling Parameters

6.5.1. Model Used

AUSPLUME is currently the accepted emissions model around Australia. Several shortcomings are acknowledged for the model in odour applications. Whichever model is chosen of use in the assessment process, the assessment criteria should be developed using that particular model. This will ensure that the strengths and weaknesses of each model are incorporated into the assessment criteria used.

6.5.2. Averaging Time

The averaging time should agree with the meteorological data file averaging, which is generally one hour. The use of peak-to-mean ratios requires robust data obtained using the same sampling and assessment standards as other emissions data used in the formation of the odour modelling protocol.

6.5.3. Percentile Occurrence

This should be reviewed in light of the recent work from Europe. The 98-percentile odour concentration occurrence has been introduced in the Netherlands to reduce the impact on results of outliers in meteorological data files. It has also been suggested that 3 years of meteorological data be used to complete the modelling. It is recommended that consideration be given to the use of a 98% or 99% occurrence rather than higher order percentiles. Ausplume modelling results can be used to convert between different percentile occurrences while maintaining a consistent total annoyance (e.g. 10 OU at 99.9% to 3 OU at 99% with the same area within the plotted annoyance contour).



7. CONCLUSIONS

The APL funded review of piggery odour emissions (Watts, 1999) provided standard odour emission rates for the major odour sources at Australian piggeries. Since the completion of that report, a new olfactometry standard has been introduced into Australia and a substantial amount of odour emissions data has been collected to the new standard. To update recommended standard emissions, all of the new data needs to be converted to emission rates rather than concentrations and presented in a standard format that enables it to be applied to different piggery designs.

A standard method across Australia is required for assessing new and expanding piggery developments in terms of odour impact. It is proposed to develop a three-tiered assessment approach and to include community consultation more commonly in the development process.

The first tier is to use a standard formula. The second tier would involve modelling using adopted "standard" emission rates and a meteorological file representative of the site. The third tier would involve site-specific odour emission rates with at least one year's worth of meteorological data collected for the site.



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