Australian Poultry Cooperative Research Centre

Environmental Management Programme

A report for the Poultry CRC

By GHD Pty Ltd

Review of Modelling, Emission Measurement and Treatment of Odour and Dust Emissions from Broiler Farms

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INTRODUCTION

The Australian Poultry Cooperative Research Centre (Poultry CRC) is a new Centre formed under the Commonwealth Government's Research Centres Program. The CRC aims to enhance the competitiveness of the Australian Egg and Chicken Meat Industries through an integrated program of strategic research that will enable the industries to deliver cost-effective and socially responsible production of safe, superior quality products for domestic consumption and emerging export markets.

The Poultry CRC Program objectives include establishing a healthy balance between the gastrointestinal tissue and its commensal bacteria early in the life of the chicken; maintaining that balance throughout life without selective removal of the organisms using antibiotics, in ways that are acceptable to consumers; developing and applying new technologies towards improving poultry health, including rationally attenuated live vaccines and projects aimed at developing new treatment methods and improved vaccine adjuvants and diagnostics; improving the welfare of poultry and reducing the impact of poultry production on the environment.

The Current CRC Participants

There are two types of Participants in the Poultry CRC; the Core Participants and the Supporting Participants. The Core Participants are signatory to two agreements; one with the Commonwealth (The Commonwealth Agreement) and the other amongst themselves (The Centre Agreement). The Core Participants are ultimately responsible to the Government and the industry for delivery of the outcomes. In the Poultry CRC, the Core Participants are The University of New England, The University of Melbourne, The Rural Industries Research and Development Corporation (RIRDC, Chicken Meat Program), The Australian Egg Corporation Ltd and Bioproperties (Australia) Pty Ltd. The organizations are complemented by the 16 Supporting Participants which include Agribiz Engineering, The Agricultural University of Norway, Alltech Biotechnology Pty Ltd, James Cook University, Monash University through the Animal Welfare Centre, Queensland University of Technology, The RMIT University, South Australian R&D Institute, Victorian Department of Primary Industries, The University of Adelaide, The University of Queensland, and The University of Sydney.

The Research Programs

The CRC offers wide ranging research project opportunities which are at the leading edge of their respective scientific disciplines, including:

- **Sustainable poultry production without reliance on antibiotics.** Novel approaches to better understanding of digestive physiology and metabolism; managing intestinal microflora, development of non invasive tests for measurement of nutrient requirements and health.
- **Developing and applying molecular and other new technologies towards optimizing poultry health and product quality.** A National Poultry Genomics Centre with state-of-the-art micro-array technology has been established as a CRC facility. Genomic-phenomic approaches to development of new vaccines and therapeutics including RNA interference; cytokines as immune modulators.
- **Improving the welfare of poultry.** Alternative housing systems and best practice welfare management systems; objective non invasive tests for welfare assessment.
- **Reducing the impact of poultry production on the environment.** Technologies for minimizing dust and odour emissions; controlling air quality in sheds; strategies for value adding poultry wastes.

FOREWORD

The Australian Poultry Cooperative Research Centre commenced on 1st July 2003, in order to establish a strategic research and development program in the poultry environmental management area, the initial environmental project; Development of Australian Poultry Cooperative Research Centre Program on The Impact of Poultry Production on the Environment commissioned three review papers:

1. Review of Modelling, Emission Measurement and Treatment of Odour and Dust Emissions from Broiler Farms.

2. Review of Public Health Risks Identified with the Utilization of Poultry Farm Waste Products.

3. Review of Best (known) Waste Management Practices for the egg and chicken meat industries and opportunities for adding value to the wastes.

This report is the first of the review papers and has been used in developing the project submissions for the 2004-2005 funding round. The report has now been published as a CRC report for general use by the poultry industry, researchers, regulators, planners and the community as part of the public good component of the Australian Poultry Cooperative Research Centre.

Readers are invited to make comment on this review or the development of the CRC Environmental Program to the program manager, Ian Farran by email ianfarran@rrg.com.au or by mail to PO Box 279, Geelong, VIC 3220.

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Australian Poultry CRC

Review of Modelling, Emission Measurement and Treatment of Odour and Dust Emissions from Broiler Farms

Report

November 2003

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Preface

GHD have been commissioned by the Australian Poultry Cooperative Research Centre (CRC) to provide a review of developments in the poultry industry in relation to; (i) predicting off-site impact, and (ii) treating emissions at source. The review is to be used as a background briefing paper at a forthcoming seminar on these topics later in the year. The seminar will have the aim of determining which areas require further efforts to improve industry performance. This review has been divided into two parts. Part A deals with the prediction of odour impact from poultry farms, while Part B deals with treatment technologies used to reduce odour (and dust) emissions at source.

The Part A review seeks to identify and evaluate the evolution of the use of odour dispersion modelling of poultry sheds – as a technique to predict off-site odour impact. Dispersion modelling requires two classes of input data namely (i) meteorology and (ii) shed odour emission rate (OER). As with any model, the accuracy of the predicted odour impact is dependant on the accuracy of these inputs, and the review is structured to the following elements;

- Modelling technique
- Meteorological data
- Odour emission rate data

The bulk of odour modelling for poultry operations has been for broiler (i.e. meat production) farms – odour complaint records demonstrate that egg layer farms and breeder farms generate less complaints, and the limited OER measurements of these types of farm confirms that their emissions are substantially lower than that measured from broiler farms. This review focuses on broiler farms, but does include the sparser data known for layer and breeder farms.

This report addresses each review in sequence and chapters are prefixed with the relevant review part letter.

The Part B review makes extensive use of a recent compilation of poultry data (RIRDC, 2002) conducted by Pacific Air & Environment (PAE) for the Rural Industries Research and Development Corporation (RIRDC). In particular, that compilation gives a thorough review of odour treatment options for broiler sheds, and this review simply addresses those developments that have occurred since that review (July 2001).

Part A-
Modelling Off-site Impact of Poultry Sheds

1. Odour Modelling in the Broiler Industry

1.1 Historical Context

In Australia, dispersion modelling of emissions to air was first required in Victoria where the Environment Protection Authority Victoria (EPAV) instituted the State Environment Protection Policy - The Air Environment (SEPPA) in 1982. The SEPPA referred to a 'dispersion calculation procedure' in Schedule F as the tool to predict maximum ground level concentrations (GLCs) for a given array of sources from industrial premises emitting one or more pollutants. Schedule C to the policy specified the 'design GLCs' for a list of 112 pollutants, and the test for compliance was that the maximum predicted GLC was not to exceed the design GLC. Of the 112 pollutants, 37 were highly odorous, and for these the design GLC was set at the odour threshold concentration (i.e. at 1 odour unit (OU)). In practise, dispersion modelling to determine compliance to these criteria enabled the minimum stack height/maximum emission rate for each pollutant emission to be determined.

In early years, the 'dispersion calculation procedure' was an adaptation of the USEPA computer dispersion model ISC (Industrial Source Complex), - and it was available only on mainframe computers. Accordingly its use was limited to regulatory authorities, research institutes and large consultancies. The description of the model computations and the interpretation of model output were detailed in EPA publication 210 *(EPAV, 1985).*

Dispersion modelling did not gain wide currency until 1988, when the model code was revised and adapted for PCs. The exercise was conducted by the Centre for Applied Mathematical Modelling (CAMM) at Chisholm Institute of Technology (later part of Monash University) for EPAV and the model was christened AUSPLUME.

From this time on, the model tool AUSPLUME was available to rural intensive industries to predict odour impact, however in practise the established device of the buffer distance was (and still is) used, either in planning schemes or in industry codes, to ensure that odour emissions did not impact on nearby residences.

The broiler industry in Victoria had two methods to determine buffer distance. The Buffer Distance Guidelines *(EPAV, 1990)* used by EPAV nominate 500m as the appropriate distance for 'poultry farms'. The guidelines make it clear that this distance is to be measured outward from the envelope encompassing the odour emission sources (i.e. the sheds) to the nearest 'sensitive receptor'. In turn a sensitive receptor is taken to be a residence or residentially zoned land.

These guidelines were rarely incorporated into local planning schemes, however a more specific policy *(WRPCC, 1998)* for broiler farms in the Mornington Peninsula and Westernport Region, which defined buffer distances, was incorporated into planning schemes of local authorities in that region. The so-called Westernport Broiler Farm policy required setbacks of 500m, 300m, and 100m respectively from urban residential zones, rural residential zones and an isolated dwelling respectively. These setbacks were relied on and were accepted in planning appeal situations up until 1998 when a VCAT (Victorian Civil Administration Tribunal) decision made it clear that dispersion modelling using site specific data would be required in order to determine whether the separation was adequate to prevent odour nuisance.

Since that time odour dispersion modelling has been conducted for most new broiler farms and for proposed extensions to existing farms. It is the developments in this modelling that are examined later in this chapter.

1.2 Choice of model

Most modelling of broiler farms has been conducted with Gaussian plume models, generally AUSPLUME, and in NSW (prior to the version 5 upgrade of AUSPLUME in 2000), the USEPA equivalent model ISC3. These models are the default options to be used when testing for compliance to EPA odour criteria, and are relatively simple to apply. They also require a minimum of meteorological data input – a 12 month data set at hourly intervals from a single point.

The limitations of such models are well known and are listed below;

- The assumption of straight line trajectories and constant wind conditions each hour means that these models will be inaccurate where there is significant terrain variation between odour source and receptors and, importantly, where winds are calm or very light.
- The use of the six stage Pasquil-Gifford scheme of atmospheric stability, with only a two step ('E' and 'F') for stable conditions, limits the model's ability to predict downwind concentrations especially in stable atmospheres.
- The model requires the meteorological data to be site specific to predict a reasonable odour 'footprint' for emissions to air from a given site.

The second point is particularly relevant for broiler shed modelling, as these are low-level sources for which the conditions giving peak off-site odour impact are almost exclusively light wind, stable flows. The first point is less telling where there is no complex terrain between the farm and the receptors, especially given that the zone of interest (i.e. where odour levels could reach 5 OU or more) is generally less than 2km.

Gaussian plume models are available that use continuous specification of stability via the Monin Obukhov length L, and thereby avoid the second limitation. One commercially available is the U.K. based gaussian model ADMS *(CERC, 1999)*. AMDS is widely used in Europe, however it is expensive (£6000 plus £600 yearly for upgrades) and has not been used for other than research purposes in Australia. Another is the recent USEPA endorsed model AERMOD, soon to be adopted as the primary regulatory dispersion model in the US. This model is available free of charge from the USEPA web site.

All of these limitations are avoided by the use of appropriate puff-based dispersion models such as CALPUFF, and by prognostic wind field models of which TAPM (developed by CSIRO and released in 1999) is the representative used in Australia. In the last five years both models have seen increasing application in Australia, though to the authors' knowledge the only applications to broiler farms are that by Pacific Air & Environment (PAE 2003) for the Queensland Chicken Meat Council, and a modelling exercise conducted at Karuah, Newcastle by Holmes Air Sciences.

However TAPM has been used to provide synthesised 12 month meteorological data sets at sites with no representative anemometer stations – for use in AUSPLUME modelling of broiler farms *(Egis 2001)*, *(Mirrabooka 2002)*.

1.3 Definition of source

AUSPLUME is able to model point (stack), area and volume sources, but can only take account of source initial momentum and buoyancy for the first of these. Depending on the mode of ventilation used in a given broiler shed ,one or more of these source types can approximate the mode of odour emission in the exhaust ventilation from the shed.

Examples of the characterisation of odour source for different shed types as used by Egis are tabled below.

Table 1 Characterisation of Odour Sources in AUSPLUME

Case	Shed Ventilation	Shed Arrangement	Source Characterisation
1	Natural	Side curtain	Volume, L x H*
2	Forced	Crossflow	Volume, L x H*
3	Forced	Tunnel	Volume, W x H
4	Forced	Combo	Volume, W x H + ridgeline stacks
5	Forced	'Duty' stacks	Volume, W x W + end stack
6	Forced	Dispersion enclosure	End stack

L = shed length H = shed ridgeline height W = shed width * sub-volumes used

Note that in Cases 4 and 5, the modelling required use of an external emissions data file so as to enable the switch from one mode of release to the other to be effected as a function of batch age, time of day and ambient temperature. Prior to the issue of version 5 of AUSPLUME in June 2000 this feature was not available without coding modifications to the model.

More recently there have been attempts *(PAE)*, *(Mirrabooka 2002)* to model the effect of buoyancy present in tunnel shed emissions by choosing to model these by an array of at-ground stub stacks with nominal exit velocities but of a diameter and time-varying exit temperature chosen to replicate the buoyancy of the exhaust air relative to the surrounding cooler ambient air. The use of point source arrays (rather than volume source) has the advantages in that (i) plume/building wake interactions can be simulated, and (ii) response to terrain can be accounted for. It is true that inspection of tunnel shed exhaust indicates that on occasions when it is made visible (e.g. by raised moisture levels caused by disturbance of the birds leading to the cooling of the exhaust plume to dew point), the plume rises off the ground. However it is not clear that the device used (array of virtual stacks) will replicate the degree of lift seen, and further investigation is warranted to check the correspondence between model prediction and tunnel plume performance in relation to height of rise under different atmospheric conditions.

1.4 Characterisation of source odour emission rate.

Constant shed OER

The simplest option to characterise shed OER is to assume that it remains constant through the batch – effectively ignoring the direct experience of broiler farm operators that shed OER progressively increases through the batch until the time of first harvest of birds (typically at week 5 of the 8 week grow-out).

The shed OER chosen is normally the peak measured through the batch, and generally taken at the point of maximum bird mass in the shed (i.e. just prior to the first harvest). Clearly when this is done the predicted peak odour levels will be overestimates (i.e. conservative) of the actual situation, as the peak shed OER is combined with all 8,760 hours of meteorological conditions, giving maximum incidence of poor dispersion for each wind direction. In reality, many of these instances will coincide with earlier times in the batch when shed OER is much lower, or with the two week interval between batches when shed emissions are negligible.

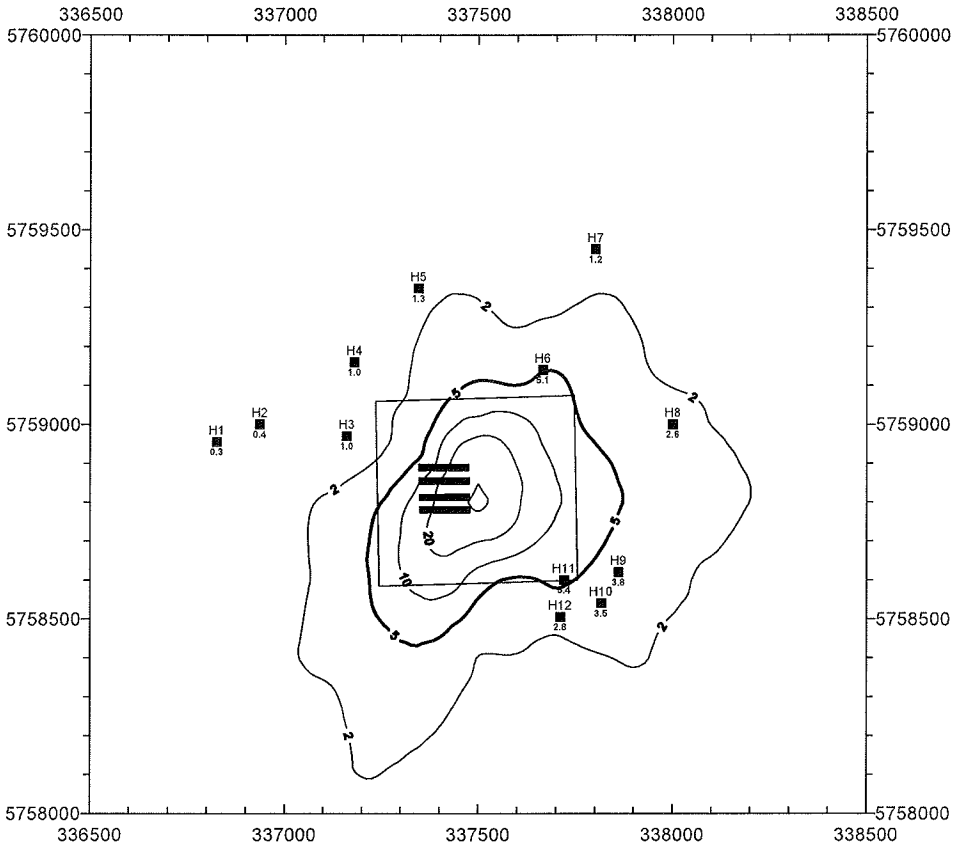
In the early cases of broiler shed odour modelling in VCAT appeal hearings, EPAV advocated strict compliance to modelling as specified in Publication 210 *(EPAV 1985)*. That is, maximum shed OER was to be used and the criterion for compliance was to be 1 odour unit at the 99.9 percentile non-exceedance level. Modelling under these strictures led to results as shown in Figure 1, where a 4 shed 40 000 bird/shed farm, is seen to require a separation of up to 5km in order to satisfy the 1 OU criterion!

Figure 1 **Predicted extent of 99.9% 1 odour unit (3 minute average) contour for fixed OER at 396 OU m^3/1000 birds - 4 tunnel shed farm, 40000 birds/shed**

(Egis report VP8050.001.003Rev0, February 1999)

In a succession of VCAT cases, tribunals rejected model results based on the EPAV 1 OU 99.9% criterion, and in lieu of any developed broiler code, often adopted the criterion of 5 OU, 99.5% as advocated by Egis. Figure 2 shows the corresponding 5 OU 99.5% contour when the effect of batch age is accounted for - the required separation distance reduces to 450m. This situation helped trigger moves to develop a broiler code in Victoria, and also led on Egis' part to persist with the more realistic characterisation of shed OER.

Figure 2 Predicted extent of 99.5% odour levels (3 minute average) – 4 tunnel shed farm, 40000 birds/shed



(Egis report VP8050.001.001.Rev0, January 1999)

Effect of batch age

The effect of batch age on shed OER was first measured in the UK *(Clarkson C.R., Misselbrook T.H., 1991)*. That data showed a roughly linear increase in shed OER until week five at the first harvest – thereafter the OER plateaued. Measurements of shed ammonia levels as a function of batch age were first measured in Australia by Jiang & Sands *(RIRDC 1999)* in 1997. Egis *(Pollock & Friebel ., 2000)* used ammonia level data as a surrogate for OER to determine a batch age factor as shown in Table 2. Egis *(Pollock &, Friebel ., 2002)* later adopted a unity age factor for weeks 6 to 8 so as to be conservative for all harvest sequences.

Recent OER measurements conducted a tunnel shed in Tamworth NSW by Unilabs have been reported *(Mirrabooka 2002)* and these are included in Table 2. Note, however that these measurements were done on a batch with a harvest sequence that had a single major (17 900 birds from a placement of 27 000) harvest at end of week 5. As such, the resulting age factor will not be representative of a multi-harvest scenario through a batch.

Table 2 Batch Age Factors

Source	Age Factor – Week							
	1	2	3	4	5	6	7	8
Clarkson et al	-	-	0.34	-	0.90	0.76	-	1.0
Egis	0.06	0.07	0.24	0.62	1.0	0.96	0.58	0.54
Mirrabooka	-	0.09	0.11	0.27	1.0	0.63	0.38	0.30

Effect of ambient temperature

In common with the bedded faecal matter from both cattle feed lots and deep litter piggeries, the broiler shed litter has been measured to show an increase of OER as the air flow across the litter increases. PAE *(PAE, 2003)*, neatly describe the likely mechanism (p 20). Given that the first response in the operation of broiler sheds to an increasing ambient temperature is to increase ventilation rate, the shed OER can also be presented as an increasing function of ambient temperature. When this is done the difference of both diurnal and seasonal changes in temperature on shed OER can be accounted for in odour modelling.

It is desirable to correctly model this effect, as the dispersive capability of the atmosphere can range over two orders of magnitude between day and night. Thus if OER is a minimum at night when dispersion is generally poor and a maximum at day when dispersion is better, then modelling this correlation will give a substantially lower off-site impact then if a fixed daily mean OER is used.

The relation used by Egis is based on measurements at three tunnel sheds and is given by a linear relation namely

$$OER_{|\,1000\ birds} = -229 + 25.56T \qquad \text{Equation 1}$$

where the olfactometry is expressed in B2 units.

A more recent measurement on a broiler shed in NSW with olfactometry to AS 4323.3 gives;

$$OER_{|\,1000\ birds} = -146 + 24.19T \qquad \text{Equation 2}$$

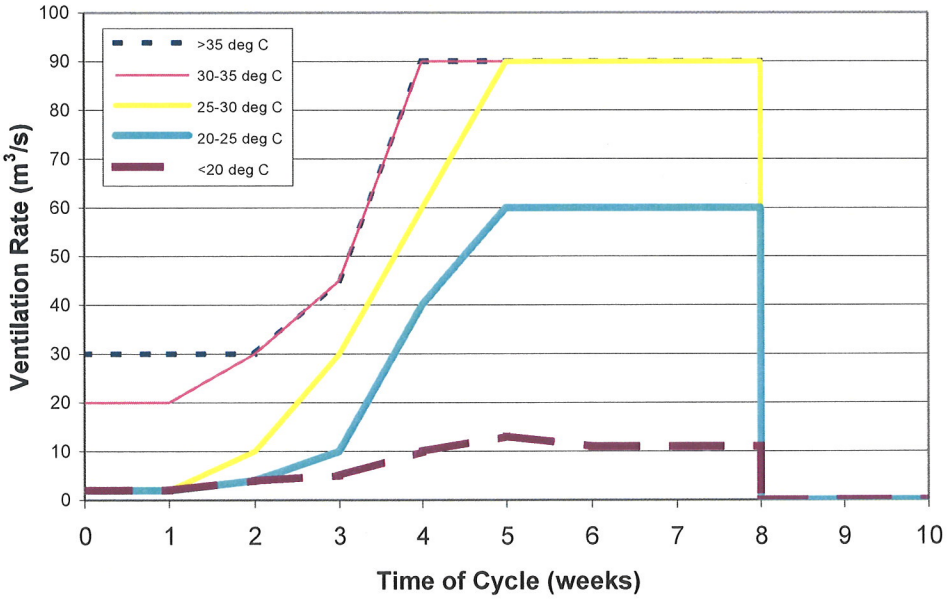
PAE *(RIRDC, 2001)* have proposed an alternate relation based on combining OER data from temperate (VIC) and tropical (QLD) areas as;

$$OER_{|\,1000\ birds} = 1.2\ T^{2.05} \qquad \text{Equation 3}$$

Equation 3 shows a much stronger response of OER to increase in temperature than is given in equations 1 and 2, and it may be this effect is being driven by increased humidity applying to Queensland broiler sheds. It would also be the case, that at the ambient temperature range of the PAE data (26 - 32°C), the evaporative coolers of the sheds would be in operation – most of the Victorian data was at temperatures below the onset of use of coolers. If as a class, Queensland broiler shed litter is at higher moisture content than Victorian or NSW sheds, then equation 3 may be incorporating two effects – litter moisture content and ambient temperature.

The recent work reported by Mirrabooka in contrast shows little or no variation in week 5 shed OER with ventilation rate Q. As a consequence, the shed OER scheme adopted by Mirrabooka is not linked to ambient temperature – except through a table that links the number of fans ON as a function of ambient temperature for each week of the batch (see Fig 3 below). However, given that the measurements showed little variation of $OER|_{wk5}$ with Q (see section A4.2), there will be little response of the modelled shed OER to either diurnal or seasonal fluctuations in ambient temperature. The difference in OER results is discussed further in A4.2.

Figure 3 Ventilation rate as a function of ambient temperature for all tunnel-ventilated sheds (after Mirrabooka 2002, Figure 15)



1.5 Choice of averaging time – peak to mean ratios

Since the human nose has a short response time to an odour stimulus, it makes sense that odour dispersion modelling be conducted to predict odour level on a short term time averaging interval. AUSPLUME conducts simulations at hourly intervals, so that concentration variation at shorter time scales cannot be directly simulated. Instead AUSPLUME reduces the lateral spread by the factor $(\frac{60}{t})^{0.2}$ where t is the averaging time in minutes. For point sources this factor can yield C_{3min} at up to 1.82 x C_{1hr}.

Most Australian states have followed Victoria's lead where in SEPPA, 3 minutes was set as the averaging time to apply for Class 2 (including odorous) constituents. However in NSW, EPA have introduced in 1999 and confirmed as an approved method in 2001 *(NSW EPA, 2001a)*, the requirement that the odour criterion be met on a 1 second averaging time. The reasoning used was that if the physiological response time of the human nose is ~ 0.1 – 1 sec, then the odour limit criterion should also be

met on a similar averaging time. The 0.2 power relation used to factor in AUSPLUME does not apply to such low values of *t*, so NSW EPA commissioned Katestone Scientific to conduct an extensive study *(KS, 1998)* involving wind tunnel testing, to develop peak-to-mean ratios (P/M) linking 1 second peak concentrations to 3 minute and 1 hour averages. The testing was for a range of source types (area, volume, wake affected stack, wake free stack) and was conducted under neutral, stable and unstable conditions.

These ratios are included in the modelling guidelines *(NSW EPA, 2001b)* issued by NSW EPA as Table 7.1 and are repeated below.

Table 3 Factors for estimating peak concentrations in flat terrain

Source Type	Pasquill-Gifford stability class	Near Field P/M60*	Far-field P/M60*
Area	A,B,C,D	2.5	2.3
	E,F	2.3	1.9
Line	A-F	6	6
Surface Point	A,B,C	12	4
	D,E,F	25	7
Tall wake-free point	A,B,C	17	3
	D,E,F	35	6
Wake-affected point	A-F	2.3	2.3
Volume	A-F	2.3	2.3

* Ratio of peak 1-second average concentrations to mean 1-hour concentrations.

Generally these factors are incorporated into AUSPLUME simply by factoring the emission rates by the P/M60 ratio as given in Table 3. Where that ratio varies with stability category, then either the emission rate option - wind speed and stability category – can be used, or else the hourly varying emission file option can be invoked.

The latter will require pre-processor coding (eg. by Excel or Visual Basic) to form the emission rate sequence after determining the stability category for each hour from the meteorological data file.

Wake affected stacks

A further complication arises when modelling short stacks where under strong wind conditions the stack plume will be bent and entrained into the building wake, but under light winds will rise clear of the wake. In that situation Table 3 requires different P/M60 ratios to apply – and which cannot be simply done without access into AUSPLUME source code during the simulation. Holmes Air Sciences *(HAS 2001)* were the first modellers to encounter this problem for a food-processing premise.

In relation to tunnel broiler sheds with short stacks, modelling of this situation has been conducted by Egis in November 2001 *(Egis 2001)*. In this study, EPA required that the effect of increasing the proposed short stack height of 5m for tunnel sheds to 7, 10m and 12m be evaluated. The procedure used to determine for each hour whether the stack plumes were wake affected is listed below;

- Conduct simulations over a small area around the broiler farm buildings with and without the wake algorithm invoked.
- Conduct an hour-by-hour check using a purpose built program of the ensemble grid predictions from each model output.
- A difference of, say, 1%, would indicate that the relevant stack was wake affected for a particular hour.
- Another purpose built procedure was then used to account for the NSW protocol by applying the far-field PM60 values as given in Table 3, applying the appropriate ratio to each stack OER for each hour.

As this procedure indicates, there is substantial additional effort required to model short stacks when the NSW criterion is to be used. Broad-brush assumptions of wake affects, based on meteorological data alone, are too simplistic given that the emission conditions for broiler farms are changing on an hourly basis.

2. Meteorological Data Input

2.1 Anemometer data

The minimum requirement for meteorological data input to AUSPLUME is 12 months of hourly site specific or site representative data for wind speed (V), wind direction (Θ) and ambient temperature (T). In most recent installations the data loggers are capable of sampling these parameters at short (~ 1 sec) intervals, so that the vector and scalar average of V and Θ for the averaging period can be determined and logged. These systems also allow the short term (i.e. < 1 hour) standard deviation of wind direction σ_Θ to be calculated and logged, thus giving a direct measure of lateral turbulence intensity. It is recommended that the option to also obtain data that will allow a measure of vertical turbulence and temperature gradient, by installing a solar radiation sensor and a second temperature sensor at the top of the mast (generally 10m), respectively, be considered. These data would allow a more accurate determination of atmospheric stability during the day and night.

In Australia the main sources of anemometer data are;

- Automatic Weather Stations (AWS) operated by the Bureau of Meteorology (BoM).
- State EPA networks of Air Quality (AQ) stations generally centred around the metropolitan area.
- State Instrumentalities (e.g. Sydney Water, former SECV, CFA of Victoria).
- Some of the larger industrial facilities.
- Private Wind Power Operators

In the past 5 years there has been extensive prospecting for wind farm sites (generally on coastal areas) in SA, VIC, NSW & QLD. Well over 100 anemometer towers have been erected, and monitoring is normally for a minimum of 18 months.

2.2 Processing of raw data to AUSPLUME files

There are established protocols to validate the raw data and to calculate the required derived parameters of Pasquil Gifford stability category and mixing depth. These techniques are best left to meteorologists, but guidance is given by a number of authorities on this matter, eg:

- NSW: *Approved Methods And Guidance For The Modelling And Assessment Of Air Pollutants In NSW*, NSW EPA, August 2001..
- USA: *Meteorological Monitoring Guidance For Regulatory Air Quality Models*, EPA-454, February 2000.
- NZ: *Guidelines For The Application Of Meteorological Data Sets To Dispersion Models*, National Institute for Water and Atmospheric Research (NIWA), June 1998.

2.3 Site-Representative data

Broiler farm emissions to air are typically transported by and dispersed within near-surface flows. This is particularly the case during nocturnal periods where the emissions are often held within a shallow temperature inversion bordering terrain induced cool-air drainage (katabatic) flows. The directions of these complex stable nocturnal flows are defined by either the local or regional terrain orientation in combination with whatever broader synoptic influences exist at the time (if any). They are a function of short term (diurnal) heating and cooling as well as the long term (seasonal) effects.

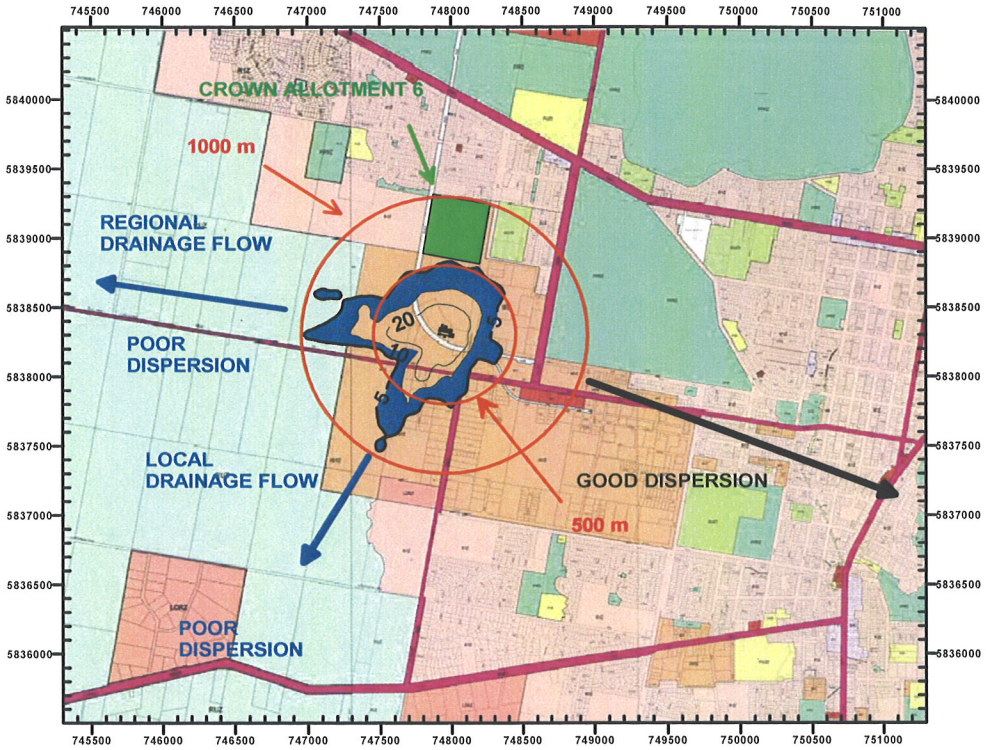
An important judgement in any proposed odour modelling exercise is determining whether the nearest meteorological station is representative of the site to be modelled. The distance between the sites and the intervening terrain and surrounding regional topography are important factors. In essence both sites must be similarly positioned relative to the regional topographic features that will drive the regional cool air drainage flows. In addition, one or both sites may be subject to local cool air drainage flows. These flows are generally aligned to the direction of local land slope so both sites may need similar land slope directions for full site representation.

In making this judgement, topographic maps of the area are essential, and 3D terrain 'models' are also useful. The 'check' to evaluate whether regional and/or local drainage flows are important at the anemometer site is to conduct an AUSPLUME simulation of a nominal ground level (area or volume) source.

The outline of the 99.5 percentile contours will then show the influence on dispersion of the local and regional cool air drainage flows – by the relative extent of the contours in those directions.

Figure 4 below illustrates the technique for the Ballarat area.

Figure 4 Predicted off-site odour impact 99.5 percentile odour contour



(GHD report 3112778/45193, November 2002)

2.4 Synthetic meteorological data

Where there is no available meteorological data that is representative of the site to be modelled then, until the advent of TAPM *(Hurley P., 2002)*, there were only two options to conduct modelling, namely;

- Defer until 12 months of data from a newly installed anemometer have been retrieved.
- Model with the 'worst case' synthetic meteorological file METSAMP.

The latter would be sufficient if the proposed farm modelled with METSAMP as input shows compliance. If compliance is not obtained, then arguments in relation to the alignment or otherwise of the direction from the farm to the most exposed sensitive receptor, to the directions of poor dispersion can be advanced.

However definitive modelling could not be done within the 12 month time frame. That situation has changed since TAPM's introduction in 1999, and one of its main uses is to develop synthesised meteorological data sets at nominated sites. It does this by using databases of synoptic analyses from the BoM and applying corrections to this, using databases of regional geophysical characteristics, to take into account local influences such as katabatic flows, the penetration into the area of sea breezes and the channelling of the wind by local terrain.

However, the prognostic TAPM meteorological simulations should be checked and calibrated against a meteorological data set in the broader region so as to lend confidence to the validity of the required site-specific data. This calibration should consider comparative frequency distributions, on a seasonal basis, of wind vectors within broad-brush atmospheric stability determinations, i.e. within stable, neutral and unstable conditions. The output from the TAPM model can vary quite significantly depending upon how it is configured and this necessitates some form of check and iterative calibration.

3. Emission Rate Data

3.1 Introduction

The collection of emission rate data from poultry sheds in Australia has been almost exclusively of odour (not dust), and until the mid 1990's has been on an ad hoc project basis. Odour emission rate data was held by state EPAs and by consultants active in this field.

The first, and to date most extensive systematic measurement of broiler shed odour and ammonia emissions was conducted by the Centre for Water and Waste Technology (CWWT), University of NSW under a research contract with RIRDC *(RIRDC, 1999)*. Measurements were conducted in both naturally ventilated and forced ventilated broiler sheds in NSW and Victoria and took several years to complete.

More recently, since the promulgation of the odour modelling guidelines in NSW, the EPA of that state has required new poultry farms of > 250 000 bird capacity to conduct very intensive research grade monitoring of both odour and dust emissions. The results of this work have only partially been released to interested parties. The first example of this was the proposed Murrami broiler farm north of Tamworth operated by Baiada. The most recent examples known to the authors is a proposed broiler farm at Bungonia, NSW for Redlea Poultry, and a proposed farm at Karuah, Newcastle for Proten.

This chapter will describe each of these data bases in more detail and also cites project specific OER data.

3.2 Broiler shed OER data

CWWT – RIRDC database

This study provides detailed measurements of odour and ammonia levels in two naturally ventilated broiler farms in NSW throughout a batch grow-out. However concurrent exhaust flow rates were not measured so that OER data can not be calculated. The second part of the survey involved odour measurements at week 6 in the batch at 12 farms, 7 in NSW and 5 in Victoria. Of these farms, four (all in Victoria) were tunnel sheds, and for these, odour levels were measured at several shed flow rates (different numbers of fans ON). The survey results do not directly report either OER or $OER|_{1000\ birds}$. However OER data may be retrieved from the study data given in Appendices 3 and 4, and then normalised to the number of thousands of birds placed at the start of the batch.

When this is attempted however, there is no record of shed flow rate at each time of sampling given to Appendix 3, there is only a single flow rate, each given in Table 17 for farms VA, VB, VD, and VE.

It is known that these records were taken by CWWT, so that the shed OER measurements on the crossflow and tunnel sheds may be able to be retrieved, on enquiry to CWWT.

CWWT – Western Australia survey

This survey *(CWWT, 1998)* was conducted in March 1997 on three farms. Two farms were naturally ventilated with adjustable louvre flaps and ridgeline vents. On the third farm one shed had been converted to operate in tunnel mode. The measured sheds on each of the first two farms were instrumented to log; (i) shed temperature and humidity at louvre and ridgeline height (ii) shed exhaust velocity at the louvre and ridgeline (iii) ammonia concentration within the shed. In addition, a weather station was set up at each farm to measure and log wind speed and wind direction.

As such this survey represents the most detailed measurement of OER for naturally ventilated broiler sheds in Australia. Table 4 gives the measured odour levels and calculated OERs for each of these farms. The naturally ventilated sheds show a mean $OER|_{1000\ birds}$ of ~ 200.

The data shows no clear trend of OER with variation in flow rate Q.

Table 4 OER data CWWT survey – Western Australia broiler sheds

Farm /Type	Shed # (birds placed)	Date	Time	Odour	Exhaust Velocity m/s	Q m^3/s	OER OU m^3/s	OER | 1000 birds	Mean OER | 1000 birds
P nat.	4 (18 900)	18/3	0630	1380	0.37	3.46	4301	227	210
			1900	228	0.43	20.8	4057	215	
		19/3	0710	1250	0.26	3.15	4193	222	
			1810	121	0.57	27.6	3337	177	
D nat.	7 (24 000)	23/3	1840	598	0.54	14.6	8587	358	191
		24/3	0640	213	0.40	10.8	2300	96	
			1830	286	0.62	16.7	3884	162	
		25/3	0650	184	0.60	16.2	3532	147	
G tunnel	7 (29 180)	20/3	1205	127[1]					239
			1420	140[1]	0.9[2]	52.4	6973	239	
			Mean	133					

1. Mean of duplicates

2. Mean velocity on shed crossection

Egis tunnel shed OER data

The OER measurement of tunnel sheds from farms at Lang Lang, Pakenham and Rockbank have been combined and plotted against ambient temperature *(Pollock T.J., Friebel E., 2002)* – the line of best fit is given in equation 1 in section A2.4. Note however that this data was measured in two protocols – B2 (Lang Lang) and NVN 2820 (Pakenham& Rockbank) – and a factor of 2:1 was assumed to convert to a common unit *(Demetriou J., Bardsley T., 1997)*.

Queensland tunnel sheds – PAE *(PAE, 2003)*

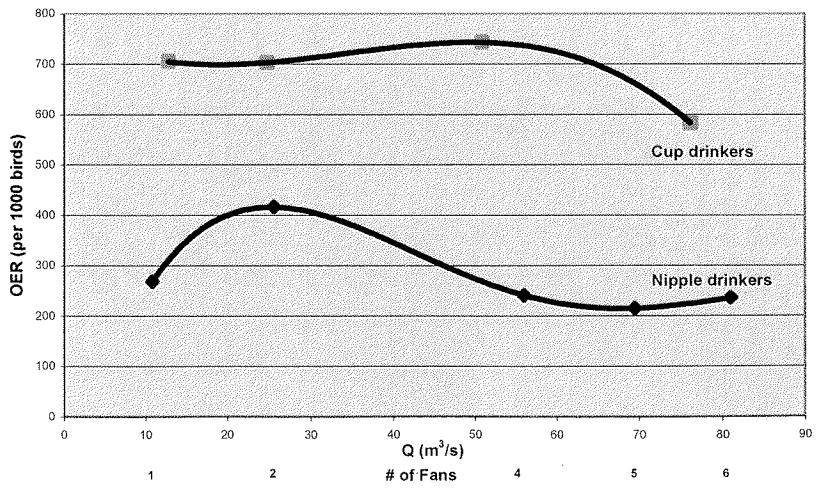
This data is from three tunnel shed farms, with two measurements at each farm – at weeks 5 & 7 for farms A & C, and weeks 8 & 9 for farm B. This data gave substantially higher values of $OER|_{1000\ birds}$ at from 500 to 2300 OUm^3/s compared to that measured in Vic or NSW.

Murrami data – Mirrabooka

The OER measurements were calculated in May-July 2002 at weekly intervals on a tunnel shed with cup drinkers. In addition at week 5, just prior to a major harvest, OERs were measured with 1, 2, 4 and 6 fans ON. A month later a similar set of week 5 OER measurements were conducted on a tunnel shed from the same farm, but fitted with nipple drinkers.

The OER measurements were conducted by Unilabs, for Mirrabooka, and the summarised results are tabled in the Mirrabooka report *(Mirrabooka, 2002)*. When normalised to the number of birds placed, the data for each shed at week 5 show the following relation to ventilation rate Q as seen in Figure 5.

Figure 5 Odour emission rate as a function of ventilation rate (Bective Lane, 'Cup' and 'Nipple' Drinker sheds)



These results show little if any increase in OER with flow rate Q, therefore countering the earlier work conducted by AWT for Egis.

The discrepancy may in part be explained by the timing of the monitoring. In the AWT measurements, the sequence started at 0630 hours when two fans were operating and ambient temperature was 12°C, and finished at 1200 hours when six fans were operating and ambient temperature was 25°C. Hence both the increase in ambient and shed temperatures were at play during the automatic sequencing of more fans to counter the increase in ambient temperature.

In contrast, no information is given in the Mirrabooka report as to the timing of the measurements at week 5 on either the cup drinker or nipple drinker shed. If in fact the sequence of 1, 2, 4 & 6 fans was done in succession by manual override, rather than awaiting the timing dictated by ambient temperature, then the extra factor of increasing shed temperature with Q would not be present in the results.

The discrepancy is not unimportant, as the modelling by Mirrabooka has ignored any diurnal variation in shed OER as a consequence – see A2.4.

3.3 Layer and Breeder shed OER data

Few OER measurements have been conducted in Australia or elsewhere on layer farms or breeder farms – reflecting their generally lower complaint profile. The three data sets known to the authors are listed below.

Layer farm in Western Australia – *(CWWT, 1997)*

Measurements of odour level, ambient wind speed and shed exit velocity were made by CWWT on a 16 000 bird caged layer shed in June 1997. A total of six odour level measurements were made, three at ~ 7am and three at ~ 6pm. The mean OER reported from these measurements was 1260 OU m^3/s, or 79 OU $m^3/s\,|_{1000\ birds}$.

Layer farm on outskirts of Melbourne – *(Egis, 2000)*

Measurements were made on three caged layer sheds, one shed (20 000 bird triple deck) was naturally ventilated and two (30 000 bird triple deck & 40 000 bird quad deck were forced ventilated. Table 5 gives the results for this and for the CWWT measurement. Note however that the Egis measurements are to the B2 protocol, and were normalised to an equivalent 80ppb response to n-butanol.

Table 5 Layer shed & Breeder shed OER data

Source		Shed Type	Capacity	OU	Q	$OER_{1000\ birds}$
Layer					m^3/s	
	CWWT	Nat vent	16 000	144	8.75	79[1]
	Egis	Nat vent	20 000	30[3]	46.7	70[2] (41)
		Force vent	30 000	50[3]	25	80.5[2] (47.3)
		Force vent	40 000	85[3]	43.3	85.4[2] (50.2)
Breeder						
	AWT	Force vent	8 000	46[4]	15.2	87.4

1 CEN protocol

2. B2 protocol, bracketed normalised to 80ppb n-butanol

3. Mean of duplicate samples

4. NVN 2820, IITRI olfactometer detection

Breeder farm – Hoxton Park, NSW *(AWT, 1994)*

The only measurement of this type of farm is that conducted by AWT in 1994 of the Ingham breeder farm at Hoxton Park, NSW

Measurement of shed OER was made of the breeder or multiplier sheds, and the results are given in Table 5. Note that the odour level is reported as 'detection' OU, and would require a reduction in the ratio 2.5:1 to convert to certainty OU. However the olfactometry was done using an IITRI unit whose sensitivity is known to be lower than current units.

3.4 Dust Emission Rate Data

3.4.1 Broiler Sheds

Comparatively little measurement has been made of dust emission rates (DERs) from broiler sheds – reflecting the industry experience that odour, not dust, is the critical emission with respect to off-site impacts. However recently NSW EPA have been requiring detailed DER measurements to be made so as to be able to predict compliance to TSP, PM10 and dust deposition criteria for large (> 250,000 birds) proposed broiler farms.

Literature Review

Cargill (2001) reviewed mainly European and UK research, with a focus on in-shed dust concentration at the various size ranges of interest (i.e. inspirable - median <30μm, respirable - median <5μm) and on the components and sources of dust in broiler sheds.

Where DERs are mentioned, they are expressed as g/hr per 500kg of live bird weight. The mean DERs for UK sheds are given as 5g/hr/500kg and 8g/hr/500kg for winter and summer respectively.

Based on a week 5 bird weight of 1.8kg, these rates convert for a 40 000 bird shed to;

Table 6 Dust Emission Rates – UK Broiler Sheds

Season	DER (mg/s)	$DER_{\|1000\ birds}$ (mg/s)
Winter	200	5
Summer	320	8

Cargill also in his summary, claims that odour levels in broiler shed exhaust air can be reduced by 60-70% if dust is removed. The issue of what fraction of shed OER is in a particulate form is addressed below in Section 3.5.

U.S.A. DER Measurements – Texas

TSP concentrations and ventilation rates were measured in four commercial, tunnel-ventilated broiler sheds to determine TSP emission rates (Lacey et al., 2002). The mass fraction of PM10 in the TSP samples was used to calculate the PM10 emission rates. The reported TSP and PM10 emission rates were 2214 mg/hr per 500kg live weight and 131.5 mg/hr per 500kg live weight, respectively.

Based on a week five bird weight of 1.8kg these rates convert for a 40,000 bird shed to the DERs given in Table 7.

Table 7 Dust Emission Rates – Texas Broiler Sheds

Constituent	DER (mg/s)	$DER_{\|1000\ birds}$ (mg/s)
TSP	88	2.2
PM10	5	0.12

Bird size and ventilation rates were both shown to be significant factors to overall emission rates. PM10 emission rates increased with bird weight and higher PM10 rates were reported in summer than winter. Lower winter rates are attributed to the lower ventilation rates required to maintain optimum temperature conditions inside the shed.

Additional results from the Texas broiler shed study are presented in a separate paper by Redwine et al. (2002). TSP concentrations during summer and winter ranged from 0.737 mg/m^3 to 5.245 mg/m^3 and 2.102 mg/m^3 and 11.387 mg/m^3, respectively. In-shed TSP concentrations are shown to increase with bird age. This change in TSP concentration is attributed to the increase in body area, manure production and feeding frequency as the birds increase in age. TSP concentrations were also reported to be higher during winter conditions when ventilation rates are lower.

Both of the papers cited above include a review of European and UK literature, with a focus on in-shed dust concentrations and emission rates for inspirable and respirable particulate matter.

Australian DER Measurements – Geelong

A DER measurement was conducted in November 1998 on a tunnel shed at day 41 in the batch (40 000 birds placed, 7000 harvested at day 35) *(Egis, 1999)*. At the time of measurement, ~ 1500hrs four of the ten fans were operating, however all ten were turned ON to simulate worst case conditions. Isokinetic sampling for TSP concentration was conducted by EML-Air with the following results;

DER = 74g/min = 1.23g/s = 30.8mg/s$_{|1000\ birds}$

TSP conc. = 16mg/m^3

Australian DER Measurements – Tamworth

A substantial set of measurements of DER were conducted by Unilabs, on two tunnel sheds at a farm near Tamworth in 2002. One set of measurements was conducted on a shed fitted with cup drinkers in May – July at weekly intervals through a batch growout, with additional measurements made at different ventilation rates at week 5. A second set was conducted in August at week 5 of a batch growout on a shed fitted with nipple drinkers. Monitoring was conducted isokinetically on one fan outlet fitted with a cylindrical 'tube', so that the sampling conformed to AS 4323.1 & AS 4323.2. Sampling was conducted using an Anderson 7 stage cascade impact sampler.

The results for TSP concentrations are reported in Mirrabooka *(Mirrabooka, 2002)*, p18, and extracts are given below in Tables 8 & 9. Several features can be seen in these results and are listed below;

- The peak TSP concentrations seen (16mg/m^3 on the shed with cup drinkers, 13mg/m^3 on the shed with nipple drinkers) are similar to that measured in the Geelong broiler shed
- The peak TSP DER$_{|1000\ birds}$ of 14.3 and 13.9 mg/s$_{|1000\ birds}$ for cup drinker and nipple drinker sheds are about half that measured at the Geelong sheds and about one quarter that cited by Cargill in UK sheds.

The factors influencing dust levels in layer sheds were not investigated in this study.

Table 8 Particulate Monitoring Results[1] Tunnel Shed – Cup drinker, Tamworth May-July 2002

Week	Q m^3/s	#Fan	TSP			PM10			PM10/TSP Ratio
			Conc mg/m^3	DER g/s	$DER_{\|1000\ birds}$	Conc mg/m^3	DER g/s	$DER_{\|1000\ birds}$	
1	10.8	1	5.0	0.054	2.0	1.6	0.017	0.63	
2	10.7	1	6.0	0.064	2.4	1.9	0.020	0.74	
3	10.9	1	9.6	0.105	3.9	3.0	0.033	1.2	
4	12.5	1	14	0.175	6.5	5.1	0.064	2.4	
5	12.6	1	16	0.202	7.5	6.3	0.079	2.9	0.39
5	24.6	2	11	0.271	10.0	5.6	0.138	5.1	0.51
5	50.5	4	7.3	0.369	13.6	2.1	0.106	3.9	0.29
5	75.7	6	5.1	0.386	14.3	1.6	0.121	4.5	0.31
6	11.9	1	5.6	0.067	2.5	1.7	0.020	0.7	
7	11.3	1	8.4	0.095	3.5	2.6	0.029	1.1	
8	11.5	1	6.9	0.079	2.9	2.1	0.024	0.9	

1 Mirrabooka Report October 2002

Table 9 Particulate Monitoring Results[1] Tunnel Shed Week 5 – Nipple drinkers August 2002

Week	Q	#Fans	TSP			PM10			PM10/TSP Ratios
	m^3/s		Conc mg/m^3	DER g/s	$DER_{\|1000\ birds}$	Conc mg/m^3	DER g/s	$DER_{\|1000\ birds}$	
5	10.7	1	13.0	0.139	4.5	5.2	0.056	1.8	0.40
5	25.4	2	8.6	0.218	7.0	3.5	0.089	2.9	0.41
5	55.4	4	6.4	0.355	11.5	2.5	0.139	4.5	0.39
5	69	5	5.0	0.345	12.8	1.7	0.117	3.8	0.34
5	80.1	6	4.7	0.376	13.9	1.6	0.128	4.1	0.34

1 Mirrabooka Report October 2002

- Both sheds show a clear increase in DER with increase in ventilation rate
- At week 5, $DER_{|1000\ birds}$ is higher for the cup drinker shed than for the nipple drinker shed.
- The PM10/TSP ratio at week 5 is seen to decrease from about 0.40 to 0.30 as ventilation increases for both sheds.

Of these features, the fourth is unexpected. It would have been expected that the DER from the cup drinker shed would be lower than that for the nipple drinker shed, as the increase in spillage from cup drinkers would increase litter moisture content and consequently decrease dust suspension from the shed floor.

Mean particle size distributions based on the week 5 measurements at each shed were also reported, and are repeated below in Table 9.

Table 10 Particle Size Distributions for Tunnel Sheds 'Bective Lane', Tamworth

Size EAD*, µm		Mass/Volume Fraction	
Range	**Mean**	**Cup drinker**	**Nipple drinker**
0 – 4	3	0.139	0.180
5 – 10	7	0.201	0.199
12 – 22	16	0.249	0.257
26 – 49	36	0.212	0.192
58 – 109	79	0.149	0.130
128 – 177	151	0.040	0.033
208 – 364	286	0.010	-
208 – 463		-	0.009

*EAD – equivalent aerodynamic diameter

As far as the authors are aware the size distributions given in Table 9 are the only such measurements taken from broiler sheds. Access to this data will now allow more accurate modelling of (i) dust deposition and (ii) TSP concentration at receptors – allowing for plume depletion due to deposition of the coarse fractions in the intervening space between shed source and the receptor.

Australian DER Measurements – South Australia

An air quality survey of nine naturally ventilated layer buildings, 12 mechanically ventilated broiler buildings and five tunnel ventilated broiler buildings located in South Australia was conducted by Banhazi et al. (2003). The key objectives of the survey were to document dust concentrations and emission rates for poultry houses, and to identify relationships between air quality inside poultry houses and key factors pertaining to housing systems and management practices.

The range of measured dust concentrations and DERs in broiler sheds are reported in Banhazi et al. (2003) in Tables 4 and 5, and extracts of this data are presented below in Tables 11 and 12.

Table 11 Dust concentrations in broiler sheds in South Australia

Fraction	Units	Mean	Minimum	Maximum
Respirable	mg/m^3	0.839	0.298	1.813
Inhalable*	mg/m^3	4.323	2.269	8.575

* Taken to be inspirable fraction

Table 12 Dust emissions outputs from broiler sheds in South Australia

Fraction	Emission rate			
	mg/hr/500kg live weight		mg/s | 1000 birds	
	Mean	Maximum	Mean	Maximum
Respirable dust	879	2490	0.88	2.5
Inhalable* dust	4395	7463	4.4	7.5

* Inspirable fraction

The results in Table 12 suggest that the maximum DER that the maximum DER in South Australian broilers sheds are substantially lower than that measured at Geelong (~1/4) and lower than that measured at Tamworth (~1/2).

The key factors identified to have a significant effect on respirable dust concentrations included shed cleaning practises, biological loading of sheds (stock density), ventilation rates and humidity. The first two of these factors were found to be positively correlated with respirable dust levels and the latter two factors appeared to be negatively correlated.

In the case of inspirable dust levels, the type of ventilation system, bedding material, temperature and shed age were found to have the most significant effects on dust concentrations. Inspirable dust concentrations were reported to be lower in older sheds and in broiler sheds with tunnel ventilation systems. Higher inspirable dust concentrations were reported in sheds using straw litter compared with sheds using litter made of wood shavings.

3.4.2 Layer Sheds

Dust concentrations and DERs are also reported for layer sheds in Tables 6 and 7 of Banhazi et al. (2003) – extracts from these tables are presented in Tables 13 and 14 below.

Table 13 Dust concentrations in layer and broiler buildings

Housing system	Mean - Respirable dust (mg/m^3)	Mean - Inhalable dust (mg/m^3)
Cage (layer)	0.094	0.380
Bedding (layer)	0.863	4.454
Broiler	0.839	4.323

Table 14 Dust emissions rate in layer buildings

Housing system	Mean - Respirable dust		Mean - Inhalable dust	
	mg/hr/500kg live weight	mg/s | 1000 birds	mg/hr/500kg live weight	mg/s | 1000 birds
Cage (layer)	21.9	0.02	85.0	0.09
Bedding (layer)	468.8	0.47	2450.7	2.5

As one would expect, the monitoring results indicated that dust levels measured in layer buildings housing birds in cages are significantly lower than layer sheds using bedding systems. The DER from layer sheds using bedding systems was found to be ~50% of the DER for broiler sheds.

3.5 Odour Component in Dust Emissions

The Cargill review cites an earlier reference *(Carpenter G.A., 1986)* to support the conclusion that by removing dust in broiler shed exhaust, odour emissions can be reduced by up to 60-70%. In turn the Carpenter paper relies on an earlier investigation *(Van Geelam M.A., 1982)*.

A recent review by Banhazi et al. (2003) cites earlier researchers as providing evidence for the claim that dust is largely responsible for facilitating high odour emissions from poultry buildings. However, William (1989) directly tests this hypothesis, and finds that filtering dust from a small scale broiler pen did not significantly reduce odour concentration, although the concentrations of dust were significantly (98% removal) reduced. The mean reduction in odour level when tedlar odour sample bags were used was ~25%.

In Australia, a single odour level measurement on a tunnel shed *(Egis, 2001)* was taken with and without a fine (0.2µm) filter. The measured odour levels for unfiltered and filtered samples were 666 OU and 528 OU respectively – suggesting that for this shed at least the fraction of odour attached to dust was ~ 20%.

In summary there are no direct olfactometry measurements demonstrating that odour emissions are other than in a minor way adsorbed to dust.

Part B
Treatment Technologies

4. Introduction

The recent compilation of poultry data conducted by PAE for RIRDC *(RIRDC 2002)* contains a thorough review of good practise design and management techniques and odour and dust reduction technologies available for the intensive chicken meat intensive industry. The purpose of this review is to provide supplementary information pertaining to control technologies that were hi-lighted in the RIRDC report to be deficient in available information, as well as to present recently emerging control technologies that are applicable to both the chicken meat intensive industry and other poultry operations such as the intensive egg laying industry.

5. Odour Treatment Options

RIRDC Review

The RIRDC *(RIRDC, 2002)* report provides a detailed assessment of eight odour control systems, comparing their installation and running costs and effectiveness to minimise odour emissions. A brief description of each treatment technology and the advantages and disadvantages associated with each system are summarised in Table 15.

Table 15 Summary of Technologies for Odour Control

System	Control	Description	Pros	Cons
Odour Neutralising Agents	Odour	Chemical or biological additives applied to litter or feed to reduce moisture content, inhibit anaerobic microbial activity, or act as a masking agent.	◗ Low cost ◗ Widely available ◗ Potential to reduce ammonia and odour emissions	◗ Products supported by little scientific evidence ◗ No dynamic olfactometry data available
Windbreaks - Vegetative screen	Odour & Dust	Rows of trees or other vegetation planted around buildings and site boundary	◗ Potentially enhance dispersion - reducing odour and dust concentrations ◗ Amenity - Screen sheds from view ◗ Low capital cost, no operational costs	◗ Little available information on odour abatement
Windbreaks - Constructed wall	Odour & Dust	Walls constructed several metres from outlet ventilations fans. Construction material includes tarpaulins, hay bales, wood and steel	◗ Potentially enhance dispersion - reducing odour and dust concentrations ◗ Amenity - Screen sheds from view ◗ Low capital cost, no operational costs	◗ Little available information on odour abatement

System	Control	Description	Pros	Cons
Air scrubber	Odour & Dust	Exhaust air is passed through a film or mist of water and odorous compounds are removed by the process of absorption; chemical or biological additives may be used to enhance odour absorption or destruction	◗ Effectively reduces odour and dust emissions ◗ High odour removal efficiency reported in other processing industries	◗ Removal efficiency shown to decrease as ventilation rates increase ◗ Periodic removal of ammonia and other compounds absorbed in the scrubber is required ◗ High capital and operational costs
Biofilter	Odour & Dust	Exhaust air is passed through a bed of compost and wood chips; microbial activity help to oxidise volatile organic compounds	◗ Can achieve odour reduction efficiencies of over 90% ◗ Readily available technology	◗ Require continuous maintenance ◗ High capital and operational costs ◗ Require reasonably steady conditions to operate efficiently
Short stacks	Odour & Dust	Release of exhaust air from above building height (~5 m) to increase the dispersal of emissions	◗ Reduces ground level concentrations at short range (< 500 m from stack) ◗ Readily available technology ◗ Affordable capital costs ◗ No operational costs if forced ventilation is already in use	◗ Effectiveness dependant on local meteorological conditions and topography ◗ Reduced effectiveness as distance to receptor increases

System	Control	Description	Pros	Cons
Active Oxygen	Odour	The energy level of stable oxygen molecules is increased by passing the molecules over charged electrical sources. This charged oxygen is used to oxidise odorous compounds in the exhaust air before discharge	◗ Odour removal efficiencies are reported between 70 and 80% ◗ Reaction occurs at room temperature	◗ High capital and operational costs
Ozone treatment	Odour	Removal of odours by the oxidation of odorous compounds in the air	◗ Potential to reduce ammonia and odour concentrations in animal sheds	◗ Reduced efficiency in humid conditions ◗ Safety considerations if used at high concentrations ◗ High capital costs
Incineration	Odour & Dust	Removal of odorous by thermal oxidation of odorous compounds	◗ Highly effective means of odour control	◗ High capital and operational costs

A summary of the estimated cost per chicken to implement selected control technologies is provided in Table 16 – as presented in the RIRDC *(RIRDC, 2002)* report.

Table 16 Summary of Odour Control Technology Cost Analysis

Control Technology	Capital Cost	Capital Cost	Operating Cost	Operating Cost	Total Estimated Cost
	($/shed)	($/chicken)	($/shed/annum)	($/chicken)	($/chicken)
Short chimney stacks	10 000 – 26 000	0.006 – 0.014	0	0	0.006 – 0.014
Windbreak walls	1 660 – 14 600	0.001 – 0.008	0	0	0.001 – 0.008
Active oxygen	220 000 – 880 000	0.12 – 0.49	19 000 – 76 000	0.11 – 0.44	0.23 – 0.93
Ozone treatment	60 000 – 300 000	0.033 – 0.17	55 000	0.31	0.34 – 0.48
Biofilter	400 000 – 1 500 000	0.22 – 0.83	106 000 – 800 000	0.59 – 4.44	0.81 – 5.27
ONAs [1]	3 500	0.019	8 125 – 23 200	0.045 – 0.13	0.047 – 0.13

1. Odour neutralising agents

(as presented in RIRDC Environmental Database for the Intensive Meat Chicken Industry, 2002 - Executive Summary, Table 1: Summary of Odour Control Technology Cost Analysis)

Based on the information provided in Tables 15 and 16, it can be seen that of the control technologies assessed, the only commercially feasible options are short stacks, odour neutralising agents and windbreaks. The remaining control technologies evolved as design solutions for industrial emissions, which are typically at high concentration with a relatively low flow rate. Hence, these technologies are less cost effective when applied to high flow rate and low concentration emissions typical of broiler farms and other poultry operations.

Recent Developments in Odour Control Technology

Additional information obtained for each control technology as part of this review is summarised under each section heading below.

Vegetative Screening

The use of vegetation to form "shelterbelts" or windbreaks is considered an emerging odour and dust control technology in the USA *(Malone, 2003)*. Research is being conducted into the physical interception of dust and odour by adsorption and absorption to the cuticle of the plant leaves. It is believed that microorganisms on the leaves can actively metabolise and breakdown the intercepted volatile organic compounds (VOCs) that comprise the odour emission *(Colletti J., Tyndall J., 2002)*.

Odour Neutralising Agents

A recent trial was conducted on a tunnel ventilated broiler shed in Queensland to determine the effectiveness of an odour neutralising agent (ONA) on odour emissions rates determined by olfactometry *(Fleer F.E., Ormerod R., Pollock T., 2002)*. Water mist or a mist containing the selected odour neutralising agent were introduced to the air exhausted during conditions that represent the maximum shed odour emission rate. A polyethylene cylindrical duct was fitted to the exhaust outlet to enable the odour samples to be taken from a well-defined mixing chamber. The addition of the water mist or ONA mist did not result in any significant reduction in odour levels, however, it should be noted that these results are based on only four sets of odour samples.

GHD understands that a trial of proprietary ONA on a tunnel shed broiler farm is scheduled in Victoria this year under the direction of Environmental Odour Control Pty. Ltd. No further information on the intended scope of this trial is publicly available at present.

Chemical additives to poultry litter are an option for odour control at source. In particular, the application of alum (aluminium sulphate) to poultry litter has been reported to provide a 99% reduction in ammonia volatilisation from poultry litter when it is applied at 200 g/Kg (Moore et al., 1995).

6. Dust Treatment Options

The main sources of dust in poultry operations include slough from chickens (feather fragments, dander etc), faecal matter, insect fragments, microorganisms, litter fragments and feed particles. The primary factors influencing dust levels includes animal activity, stock density, shed ventilation rates, litter characteristics and handling practices, as well as environmental parameters such as humidity and temperature (Banhazi, 2003). It has been established that odorous compounds may be adsorbed and transported on dust *(Cargill C., 2001)* and many of the odour control technologies described in the previous section also act to reduce dust emissions and hence, will not be repeated here.

Information, supplementary to the RIRDC report, that relates directly to control technologies designed to reduce dust emissions are described below:

Electrostatic Charge System

An electrostatic space charge system has been developed for reducing airborne dust and pathogens in poultry areas *(Mitchell B., 2000)*. The system operates by transferring a strong negative electrostatic charge to airborne dust and microorganisms within an enclosed area; the charged particles are then collected on grounded plates or surfaces of a room. This system has been applied to chicken hatching cabinets under laboratory conditions and results indicate that the effectiveness of the system to remove airborne dust is comparable to a 95% media filter under similar conditions. Application areas for this technology include breeding and production houses, hatching cabinets, and an egg room, however, no data is currently available for commercial applications of this technology.

Oil Impregnation

An assessment has been made of the efficiency of treating the bedding material used in broiler houses with an oil/water mixture to improve air quality inside the shed (Banhazi et al. 2003). A canola oil and water mixture was applied to chopped straw litter, before stocking the shed, so that the quantity of oil applied represented ~7.5% of the bedding weight. The inspirable and respirable dust concentrations as well as environmental and chicken performance parameters were measured during the study. A statistically significant reduction in dust concentrations was reported, with the greatest level of dust reduction observed during the beginning of the growth cycle. The application of the oil mixture to the litter did not appear to have any significant effects on the performance of the chicken stock in terms of chicken growth and health. The overall cost associated with this trial application was $\$7.40/m^3$ of bedding material.

The application of oil to the bedding material using ultra sonic sprayer units to control dust in experimental poultry houses was investigated by Ikeguchi (2002). The application of a 2% solution of emulsified canola within a floor feeding broiler house was found to decrease dust levels between 40 and 60%.

Vegetation Screening

The use of vegetation to form "shelterbelts" or windbreaks is considered an emerging odour and dust control technology in the USA *(Malone, 2003)*. Research conducted using wind tunnel modelling suggests that the use of vegetation windbreaks to lower the wind speed can reduce the downwind transport of dust from 35 to 56%. Further research is being conducted into the physical interception of dust and odour by adsorption and absorption to the cuticle of the plant leaves *(Colletti J. and Tyndall J., 2002)*.

Air-Scrubber

A preliminary study conducted by Banhazi et al. (2002) demonstrated that a low-cost and self-contained air-scrubber unit could be successfully used to significantly reduce the dust concentration emitted from livestock buildings. Concentrations of inhalable dust were significantly reduced whereas the concentration of respirable particles was not reduced significantly.

It should be noted that this preliminary study was confined to using emissions from a weaner building to "mimic" dust emissions from broiler sheds, however, future trials on broiler sheds are planned to refine the technology as a result of the outcomes of the preliminary study. In addition, no information was provided on the shed ventilation rates associated with air-scrubber trial results. In order for such a system to be commercially viable it would need to maintain its high removal efficiency at peak ventilation rates required for a 40 000 bird shed (i.e. ~90m^3/s).

7. Summary

The results of Part A of this review suggest that Australia is active in the fields of odour modelling and source OER measurements for the poultry industry, and has developed techniques to a higher level of refinement than in other countries.

In the field of treatment technology, there has been more active development in Europe than in Australia – probably reflecting the decreased availability of adequate buffers to residential development

This review of modelling, emission measurement and treatment technologies for poultry farms has hi-lighted areas within these fields that are currently unresolved or omitted from the current knowledge base, the more notable of these areas are reiterated below.

The cost of DER and OER data measurement requirements for new broiler farm proposals in NSW is currently borne by the proponent alone, and there is a consequent reluctance to share it with competitors. If left as is, each new proponent will be forced to replicate DER and OER data already obtained. GHD recommends that an alternate funding scenario be tried, whereby the survey cost is jointly borne by the proponent and RIRDC, on the condition that the survey results are added to the OER/DER data bank and published. Such a system would then have the advantage of removing the need for new surveys – once the robustness of the existing OER/DER database meets EPA requirements.

The characterisation of the relationship between dust concentration and OERs is currently unresolved for commercial poultry shed conditions in Australia. The establishment of this relationship is important in relation to both emission control technology and OER measurement. For instance, if odour levels are found to be positively correlated with the concentration of fine particulates (say, as a result of the greater surface area to mass ratio) then the removal of these fine particulates, to reduce the OER, may be limited by the commercial viability of the control technology required to remove fine particulates at peak shed ventilation rates. If on the other hand, OERs are associated with the larger particulate fractions then there is the possibility of underestimating measured odour levels because odorous molecules, adsorbed to particulate matter, may be removed from the air sample by impingement on the sample line or by electrostatic attraction to the sample bag interior walls during sampling.

The majority of DER data currently available is collected with the primary focus on assessing shed air quality in terms of chicken and employee health. The ventilation rates associated with these DER measurements are typically poorly characterised and documented. Therefore, the collected data is not ideal for use in the application of interest here, namely the assessment of off-site impact of the dust emissions from poultry sheds.

One of the most common forms of odour control technology in commercial use is the application of odour neutralising agents to shed emissions. However, based on the

literature surveyed in this review only one commercial scale validation using a standard olfactometry technique has been made publicly available. Further information is required in this area of odour control so that future resources can be allocated to either enhance the development of this technology or to develop different odour control technologies.

Based on this review, it is recommended that future investigations into poultry shed air emissions and control technologies address the following topics:

- Determine the percentage of OER adsorbed to particulates in the shed exhaust air compared to that in gaseous phase odorants.
- Quantify the buoyant behaviour of the emitted plumes from tunnel fans, and define a stub-stack array that in AUSPLUME replicates the observed behaviour.
- Determine efficiency of emission control technologies on a commercial scale broiler operation to reduce OER, in particular the efficiency of odour neutralising agents.
- Investigate means to part-fund OER/DER surveys for new broiler farms, so as to pool data for the industry.

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