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– Review of "add-on" technologies –

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by Mark Dunlop

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Foreword

The Australian chicken meat industry grows approximately 500 million chickens producing 800,000 tonnes of meat annually. Meat chicken farms are often built close to feed supply and meat processing infrastructure, with associated markets and labour force. Positioning poultry farms close to essential infrastructure usually means that the farms are located close to urban and rural-residential developments. Close proximity of neighbours to poultry farms can result in adverse impacts, primarily due to odour. Odour impacts are recognised as an issue for intensive animal industries worldwide, and have become a significant issue for the Australian chicken meat industry. Consequently, technologies and techniques are being developed to minimise these impacts.

There are numerous technologies that are promoted as being able to reduce the impacts of odour and dust emissions from mechanically ventilated poultry production. In general, there is insufficient information regarding the performance of these products as well as uncertainty about the costs of these technologies and the method by which they should be applied for maximum benefit. For this reason, RIRDC commissioned DPI&F, Queensland, to investigate the current range of add-on technologies that could be integrated into odour and dust control strategies for tunnel ventilated meat chicken sheds.

Results from this investigation will be useful for poultry producers, the chicken meat industry, environmental regulators, government agencies, consultants and the research community. Information presented in this report will enable better decision making for those considering or recommending the use of add-on technologies to reduce odour and dust impacts.

Technologies investigated in this report include dry dust filters, wet scrubbers, fogging systems, odour neutralising agents, electrostatic dust precipitation systems, dust control structures, litter aeration and dispersion altering structures.

This project was funded from industry revenue which was matched by funds provided by the Australian Government.

This report, an addition to RIRDC's diverse range of over 1800 research publications, forms part of our Chicken Meat R&D program, which aims to support increased sustainability and profitability in the chicken meat industry through carefully focussed research and development.
Most of our publications are available for viewing, downloading or purchasing online through our website: www.rirdc.gov.au.

Peter O'Brien
Managing Director
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Contents

Executive Summary

What the report is about

Odour and dust impacts from tunnel ventilated sheds have been identified as a significant issue for the Australian chicken meat industry. Meat chicken producers are under pressure to reduce these impacts, and need cost-effective solutions. Add-on technologies, designed to control odour and/or dust, may offer solutions to this problem. These technologies include dry dust filters, wet scrubbers, electrostatic de-dusters, odour neutralising fogging/spray systems and litter aeration, to name just a few. Unfortunately, there is little scientifically valid evidence to support the claims associated with many of these technologies. There is also a lack of readily available information regarding the costs, maintenance requirements and practical issues associated with these technologies. This report summarises the available information on a selection of add-on technologies.

This review of add-on technologies will be an important reference for anyone requiring information about add-on technologies to control odour and dust from meat chicken sheds. It will also assist the industry to identify which of these, based on further detailed investigation, may have the greatest potential to provide affordable and effective control of odour and dust.

Who is the report targeted at?

This report was written for:

- poultry producers, who may be considering installation of add-on technologies;
- the chicken meat industry, which is under pressure to reduce odour and dust impacts and needs to know whether or not the use of an add-on technology will provide an appropriate odour reduction strategy;
- environmental regulators/government agencies, who require information when making decisions on how to resolve odour impacts; and
- consultants, who require additional information on add-on technologies so that they can advise poultry producers, environmental regulators and community groups on information about odour reduction strategies.

Background

Increasing pressure from regulators and the community to control odour and dust from meat chicken farms is forcing some producers to consider new odour and dust control solutions. Early odour control technologies have previously been reviewed and evaluated; however, recent developments with respect to new and existing technologies have meant that previously reported information is now out-dated. Up-to-date information is therefore required to ensure that the performance, costs, operational requirements, benefits and limitations of these technologies is clearly understood. Information contained in the report will assist in the decision making process for applying odour and dust control technologies to meat chicken farms.

Aims/Objectives

The objectives of this review were to:

- identify potential add-on technologies for air quality improvement based on scientific and practical validity as well as cost-benefit performance;
- define the benefits and short-comings of the selected technologies in terms of comparative and objective information on costs, production performance, environmental performance, amenity factors and workplace health and safety; and
- develop a guide for producers, integrators and regulators defining the benefits/limitations of these technologies.

Methods used

Research literature, industry literature, product catalogues and the internet were searched to identify a variety of potential technologies that could be used to control odour and dust from meat chicken sheds.

Information was sought from the developers and distributors of these technologies regarding costs, operational requirements and expected performance. Where possible, technologies were inspected if they were installed in meat chicken sheds or other intensive animal housing. Pertinent information was collated and compiled into this report.

Results/Key findings

A significant amount of information has been collated regarding a selection of add-on technologies. Cost analyses have shown that for the technologies included in this report, costs ranged from 0.5 cents per bird to 8.4 cents per bird (technology lifespan costs calculated over ten years). Affordability, cost effectiveness and suitability of each technology will be different for each farming operation, and will be influenced by many factors, especially external pressures to control odour and dust emissions. For some of the technologies, it would not be possible to treat all of the exhaust air due to practical, physical or cost limitations. In these cases, treating a percentage of this air may be sufficient to provide adequate odour or dust control while improving affordability. Before deciding to install an add-on technology, producers first need to consider their own circumstances, thoroughly understand exactly why odour or dust nuisance is occurring and ensure that all measures have been taken to control these first. If an add-on technology is required, producers should choose one that is affordable and has a proven track record.

Implications for relevant stakeholders

A number of odour and dust control technologies were identified as compatible for installation in broiler sheds. However, odour and dust control performance, especially under Australia conditions, has not been tested. In addition, affordability of these technologies has not been clearly defined for Australian operating conditions. Consequently, it is difficult to recommend which, if any, of these technologies are the most suitable and affordable for Australian meat chicken producers. Future consultation with industry, technology suppliers and regulators will be required to identify which technologies should undergo further testing and evaluation.

Recommendations

1. Farm managers must understand why, when and how odour and dust impacts are occurring in their particular circumstance and, if possible, address these issues first before considering the installation of an add-on technology. However, if impacts are occurring regularly, and are due to normal farming operations that cannot be altered to reduce emissions, an add-on technology to control odour or dust emissions may be required. If this is the case, there are a number of options available, but, no option is perfect. Regardless of which technology is chosen, there will be costs associated with purchasing, installing, operating and maintaining the technology. Additionally, complete and reliable control of odour or dust emissions is not possible.

2. The Australian poultry industry should undertake independent evaluations of the technologies that will be most suitable to the majority of the industry, especially dry dust filtration, wet scrubbing, electrostatic particulate ionisation and odour neutralising technologies. Litter aeration could also be researched.

3. To minimise operating costs and maximise the useful life of add-on technologies, treating a portion of the exhaust air or intermittent/cyclic treatment of exhaust air, at times when odour impacts at receptors are most likely, should be investigated.

4. Producers need to consider their own circumstances and select an add-on technology that is affordable, compatible with their infrastructure and operations, and will reliably provide the level of control required to address odour or dust issues.

Introduction

Background

Odour impacts from meat chicken farms have been identified as an issue for the Australian chicken meat industry. Concern about odour impacts may prevent the establishment of new poultry farms or limit the expansion of existing ones, thus restricting development of the industry. Poultry facilities operate under a regulatory framework that imposes conditions designed to minimise odour nuisance as well as other environmental impacts. Odour nuisance will occur when a receptor is repeatedly subjected to odours that are considered offensive. Frequent exposure to offensive odours may encourage an affected receptor to make a formal odour complaint. Complaints and regulatory attention may require producers to take remedial action to reduce odour impacts.

Generation of odour is an unavoidable part of poultry production. The most effective method to prevent odour impacts is through adequate planning, including the requirement for buffer distances between the poultry sheds and nearby residences (McGahan and Tucker, 2003). These buffer distances provide an opportunity for odours to disperse and be diluted into the atmosphere, ideally to the point that nearby receptors cannot detect the odour. However, due to the influences of highly dynamic, variable odour emission rates, weather and uncertainties surrounding the techniques used to calculate buffer distances, this planning approach may not provide complete protection against odour impacts. Odour impacts may also begin to occur if new residences are built near existing broiler farms.

Agricultural odours are non-hazardous and generally do not constitute an environmental problem unless they are detected (i.e. smelt) by a receptor. Therefore, it is not necessarily essential to stop odours from being generated or released from poultry farms, as long as measures are taken to minimise the frequency with which they reach neighbours at a level that can be detected. If the emission of odour from a poultry farm can be reduced in a reliable and affordable manner, the potential for odour impacts will be reduced and, consequently, the requirement for buffer distances will also be reduced. As a result, there is significant interest in identifying or developing technologies to reduce the emission of odours from intensive meat chicken production.

Odour and dust emissions from meat chicken production

Kolominskas *et al.* (2002) reported that odours in intensive meat chicken buildings are generated by the decomposition of waste products such as faeces, urine, feathers, dust and bedding. There are primarily two oxygen conditions in which this decomposition occurs, namely aerobic and anaerobic. Anaerobic decomposition occurs in oxygen free conditions, such as wet, compacted or caked litter (Jiang and Sands, 2000), and is known to cause the production of offensive and highly odorous compounds such as volatile fatty acids, mercaptans, amines and sulphides (American Society of Agricultural and Biological Engineers, 2007). Aerobic decomposition occurs in an oxygen rich environment and is generally accepted to produce fewer odorous compounds than anaerobic decomposition (Kolominskas *et al.*, 2002).

Dust in broiler house emissions consists of feather fragments, faecal material, dander (skin debris), feed particles, biological materials (mould, bacteria, fungi) and litter material (Ministry of Agriculture and Food, 1999). Dust is generally considered a lesser issue than odour, especially regarding the potential to cause impacts and complaints, because a large proportion of the dust settles within a reasonably short distance of the fans. However, dust has been implicated in the emission and transport of odours. This occurs due to odorous compounds and odour producing micro-organisms being adsorbed onto dust particles (Cai *et al.*, 2006; Cargill, 2001; Heber *et al.*, 1988; McGahan and Tucker, 2003; Van Wicklen and Czarick, 1997). Significant quantities of odorants can absorb onto dust particles, which can produce a strong and long-lasting olfactory response (Hammond *et al.*, 1981). Unfortunately, the exact contribution of dust to odour impacts is complicated and not well understood.

Measuring the exact contribution of dust to odour strength is equally challenging, especially using olfactometry, because odour laden particulates are removed from the sample air by filtration or electrostatic attraction to plastic sampling equipment (Williams, 1989). Cargill (2001) reported that odour levels in exhaust air can be reduced by up to 60%–70% by removing dust. Consequently, dust control technologies have been included in this review because they may have a positive effect on reducing odour emissions.

Odour control practices and technologies

There are three categories of odour control technologies (Schmidt and Jacobson, 1995):

1. *Technologies to prevent or reduce odours from being generated*

   Preventing or reducing odours and dust from being generated is the ultimate solution and would reduce the need for the other categories of odour control technologies. Preventing the generation of odours could be potentially achieved through dietary manipulation or by altering conditions to reduce the activity of malodour producing microbes (by using litter/feed additives or controlling moisture, temperature, pH or aeration of the litter).

2. *Technologies that capture and destroy odours before they are released to the atmosphere*

   Technologies that capture, contain or treat odours and dust before being released to the atmosphere operate using the principles of biological, chemical or physical treatment. *Biological* processes are used in technologies such as biofilters and bio-scrubbers where microbial action converts odorous compounds into less odorous compounds (Nicolai and Janni, 2001). *Chemical* processes are used in technologies such as chemical scrubbers or ozone treatment systems where chemicals in the scrubbing liquid remove or convert odorous compounds from the air stream. *Physical* processes include thermal or catalytic incineration (Environment Agency, 2002), UV treatment (Environment Agency, 2002), active oxygen (Kolominskas *et al.*, 2002) non-thermal plasma (Snell *et al.*, 2003), dry filtration or wet filtration (for dust). These processes either remove the contaminant or use energy to destroy or convert contaminants.

   The ventilation requirements in meat chicken sheds can require large treatment systems in order to provide adequate treatment capacity. Also, if the treatment system is external to the broiler shed, exhaust air needs to be constrained and delivered to the treatment system using ducts. These two factors have numerous practical constraints and can lead to high costs.

3. *Technologies that enhance dispersion or disguise the odours to prevent odour impacts or nuisance*

   Technologies that enhance dispersion or disguise odours include windbreak walls, short stacks, proprietary odour neutralising sprays or masking agents. Windbreak walls and short stacks operate by intercepting the exhausted air and directing it in an upward direction which theoretically will help it to disperse (Bottcher *et al.*, 2001). Reliance on dispersion to reduce perceived odours downwind can be unreliable if atmospheric and weather conditions are not conducive to dispersion (Bottcher *et al.*, 2001; Dunlop and Galvin, 2006).

   Proprietary odour neutralisers and masking agents can be used to change the odour strength or character of odorous exhaust air. They either react with odorous compounds to neutralise them, or add a scent to change the character of the odour. There is very little scientific evidence to support the claims associated with many of these products with relation to odour control. Other issues with these products include ensuring that the neutralising agent completely mixes with the odorous air and that sufficient time is allowed for ‘treatment’. Because these agents are usually applied with high pressure fogging or spray systems, mixing of the odour neutralising agent with the odorous air can be random and inconsistent. Additionally, if a new scent is added to the poultry air (e.g. lemon, bubblegum or floral), the odour concentration may increase or the poultry air may become more identifiable (as a lemon, bubblegum or floral scent etc.), which could potentially lead to greater opportunity for complaints.

Regardless of the type of odour control being considered, site specific needs will dictate whether odour and dust control needs to be continuous or intermittent (so that odour and dust control is activated only during periods when impacts are most likely). Costs, physical and practical limitations, and performance of the control technology will also influence the selection of an add-on technology. Compatibility with the ventilation system in particular, will be required to ensure that ventilation requirements are maintained. Only a few of the technologies that are available to control odour and dust have been specifically designed for application in meat chicken buildings or are capable of being adapted for this application. The following chapters provide information on a variety of add-on technologies, which will assist broiler farm managers to select the technology most suitable for them. The chosen treatment system will need to compatible with the building design and ventilation system, cost effective and provide reliable performance.

About this report

This review does not intend to report on all possible odour and dust control technologies or techniques. Previous reports by Kolominskas *et al.* (2002), McGahan *et al.* (2002), Briggs (2004) and Pollock and Anderson (2004) provide details of a selection of odour control technologies. These authors found that technologies such as biofilters, air scrubbers, ozone treatment, active oxygen and incineration were prohibitively expensive for poultry applications. On the other hand, windbreak walls, short stacks and odour neutralising agents were found to be affordable technologies. Of these, windbreak walls and short stacks were evaluated by Dunlop and Galvin (2006) and were found to offer inconsistent performance for improving odour dispersion due to reliance on weather conditions. Simons (2006) trialled two odour neutralising products and concluded that these technologies were not effective in reducing total odour emissions from broiler sheds. However, a post-trial survey indicated that the products changed the character of the odour, which may have improved the way that the odour was perceived. This evaluation also revealed that olfactometry may not be an effective tool for evaluating odour neutralisers due to their own inherent odour. While there is insufficient supporting evidence for odour neutralising produces, Kolominskas *et al.* (2002) commented that further evaluation of these products may demonstrate their suitability for controlling odours. With the exception of odour neutralising sprays/foggers and new generation wet scrubbers, the technologies listed above will not be re-visited in this report.

The aim of this report is to provide information about recently developed odour and dust control technologies. Technologies evaluated in this report include:

- dry dust filtration;
- wet scrubbing (recently developed products);
- odour neutralising spray/fogging systems;
- electrostatic dust precipitation
- dust control structures; and
- litter aeration.

These technologies have the potential to minimise odour or dust impacts from meat chicken sheds. Evaluations of the costs, performance, reliability and practicality of these technologies for use in poultry applications are provided.

Methodology

The technologies reported in the following sections have evolved or become available during recent times. Each was assessed for its practicality, costs, maintenance, and efficacy to control odour and/or dust from tunnel ventilated meat chicken sheds. Information was sourced directly from the developers and suppliers of these technologies as well as independent sources whenever possible. Unfortunately, comprehensive information was not available for all of the mentioned technologies, especially for application in meat chicken sheds. The following sections summarise the information that was available at the time of preparing this report.

Cost analysis assumptions

The analysis of capital and operating costs is based on the parameters as shown in Table 1. These are considered to be representative of the average broiler farm nationally.

Table 1 Basis for cost estimates expressed on a per chicken basis

Capital Cost ($ / chicken)	Operating Cost ($ / chicken)
• 35,000 meat chickens produced per shed per batch • 5.5 batches of meat chickens per shed per year • Capital cost is borne over a period of 10 years (i.e. 1.925 million chickens per shed)	• 35,000 meat chickens per shed per batch • 5.5 batches of meat chickens per shed per year (192,500 chickens per shed per year)

One important consideration associated with operating costs is the increase in fan running costs if a filter system increases the static pressure across the fans. It is estimated that the cost of running ventilation fans is approximately $1,500 per batch (on average throughout the year, calculated at a meat chicken shed in south-east Queensland with approximately 35,000 bird being grown for 51–58 days and was fitted with 14 fans, including 12 tunnel ventilation fans and 2 side wall fans for minimum ventilation). This value will be adopted throughout this report as typical fan operating costs. Consequently, if a filter system increases running costs by 10% ($150 per batch), annual power costs for ventilation will increase by $825 per year (assuming 5.5 batches per year).

Another important consideration is the loss of production space if the technology is installed inside the broiler shed and floor space is converted to accommodate the technology. To enable calculation of this lost production, it will be assumed that birds are grown at a density of 19 birds per square metre (with 96% liveability) with a gross production value of $0.62 per bird. This equates to lost production of $11.31 per square metre. For a shed with 35,000 birds, the gross cost of lost production for different amounts of converted floor space is show in Table 2.

Table 2 Costs of lost production due to conversion of floor space to accommodate an add-on technology (based on a shed with 35,000 birds at a density of 19 birds per square metre)

Converted floor space (% of whole shed)	Lost value in gross production per shed per batch ($)	Average gross cost of lost production ($/bird)
1%	$ 208	$ 0.0060
3%	$ 625	$ 0.0179
5%	$ 1042	$ 0.0298

All prices are expressed in Australian Dollars (AU$), and exclude GST unless specified.

Results and discussion

There are numerous products and technologies that have been developed to reduce odour impacts from meat chicken farms. For the purpose of this review, the selected technologies were grouped into the following categories:

- dry dust filtration;
- wet scrubbing (recently developed products);
- odour neutralising spray/fogging systems;
- electrostatic dust precipitation;
- dust control structures; and
- litter aeration.

Dry dust filtration - One product, *StuffNix* (manufactured by *Big Dutchman*, Germany) was selected. The *StuffNix* dry dust filter system has been specifically designed for use in mechanically ventilated poultry buildings. It has been evaluated by the manufacturer and independent researchers, and dust removal rates ranged from 40% to 70%. Limited olfactometry data indicated that StuffNix reduced layer shed odour concentration by 30%. It is a simple technology with no moving parts; however, it increases static pressure on fans and requires regular cleaning. StuffNix is a modular system and can be installed on a minimal number of exhaust fans (to minimise costs, but provides only limited treatment) or on all fans (higher cost but more complete treatment). It is likely that a level of treatment between these minimum and maximum levels will be required to balance cost effectiveness and affordability while still providing adequate treatment. StuffNix is available in Australia (through Big Dutchman agents). Further details of this technology are included in Error! Reference source not found..

Wet scrubbing technologies - two products were selected. *MagixX* (manufactured by *Big Dutchman*, Germany) is a wet scrubbing system specifically designed to remove ammonia and dust from poultry shed emissions. It is expected to reduce odour emissions by 50%; however results of odour testing are not currently available. The system can be installed into broiler sheds (and has been installed into broiler sheds in Germany). Complexity of the MagixX system makes it more expensive when compared with other products. However, it is one of the only technologies that resembles a traditional air treatment system with definable treatment processes. Treatment of all exhaust air will not be possible if installed into Australian broiler sheds, due to the high ventilation rates that are required. However, treatment of a percentage of the airflow may prove adequate to resolve odour impacts at an affordable cost. The efficacy of partial treatment requires further evaluation. The second wet scrubber was designed by researchers at the *USDA-ARS*. This air scrubber offers a low-cost alternative to more expensive scrubbers. However, the small size of the scrubbing unit restricts its use to small fans and is really only a worthwhile option during low ventilation conditions when ammonia concentration within the building is quite high. Consequently, it is unlikely to be a viable technology for controlling odour or dust impacts from Australian broiler farms and will not be given any further consideration in this review. Details of these wet scrubbing technologies are included in **Appendix** .

Odour neutralising products – These products provide a flexible option for odour control. Fogging or spray systems, with or without odour neutralising agents, can be switched on or off as demands on odour control change. There are many odour neutralising agents available, and an infinite number of fogging/spray system configurations, which makes it difficult to know which combination (if any) will prove to be effective. A basic fogging system can be installed for a very low cost; however, the effectiveness of such a basic system is questionable. Installation of a more comprehensive fogging system may prove to be more effective but will also be more expensive. Distributors of odour neutralising agents do not always know exactly how their products react with odours, nor do some of them understand the constraints of applying these products in broiler sheds. Mixing and reaction between odour neutralising agents and odorants is often quite random (with fogging/spray systems), which can make it very difficult to accurately assess the ability of odour neutralising agents to control poultry odours. Therefore, poultry producers who are considering the installation of an odour neutralising system, particularly those who require reliable and consistent odour control, need to be very cautious, especially considering that most of these products haven't been rigorously or scientifically assessed. Recent trials of two odour neutralising products (different products from those included in this review) by Simons (2006) demonstrated the difficulties in evaluating these products. Details of four odour neutralising products are included in **Appendix** .

Electrostatic dust precipitation – Only one product, *Electrostatic Particulate Ionisation (EPI)* (distributed by *Baumgartner Environics Inc*, USA), has been proven by independent research to reduce dust (by 40-61%) and ammonia levels in intensive animal housing, including broiler sheds. This not only reduces emissions, but also improves internal air quality (for animals and workers). It is one of the least costly technologies that have been reviewed in this report. It is unobtrusive, low maintenance and does not interfere with the ventilation system. It is suitable for application in breeding houses, hatchery facilities, broiler and layer sheds. Details of this technology are included in **Appendix** .

Dust control structures – These products include fan hoods, windbreak walls and commercially available products such as BioCurtain®. They do not provide reliable odour or dust control. Any collection of dust or improved dispersion of odours occurs randomly and in an unreliable fashion. Changes in weather or shed operating conditions will affect the performance of these structures. These structures do, however, offer some advantages such as light control and protection of fans from strong winds. They also have low installation cost with virtually no operating or ongoing costs. A combined system incorporating the BioCurtain® and EPI technology has a greater potential for dust (and some odour) control, and is worthy of being considered for installation as a control technology. Details of these technologies are included in **Appendix** .

Litter aeration – Litter aeration, achieved through disturbance of the litter, is a technology that requires further research and development. The purpose of litter aeration would be the prevention of anaerobic conditions, which lead to increased odour generation. A few meat chicken farmers are currently using hand operated tilling machines to aerate caked litter in sheds. Litter aeration is summarised in **Appendix** , however, this technique is only at a conceptual stage.

Each technology requires individual assessment due to differences in physical attributes, operational requirements, and performance characteristics. Costs and expected performance for these technologies are summarised in Table 3. Costs ranged from 0.5 cents per bird to 8.4 cents per bird (based on the 10 year lifespan cost assumptions). While every attempt has been made to estimate costs based on 'typical' scenarios, potential users of these technologies must carefully consider their own circumstances and calculate costs accordingly.

There are a number of factors that will influence the suitability of different add-on technologies, including:

- frequency of requirement for odour control (is continuous control of 'normal' levels of emissions required, or is control only required during 'upset' events or adverse weather?);
- required level of odour control (is significant reduction of all emissions required, or is only slight reduction required?);
- available money to cover the costs of an adopted add-on technology;
- farm configuration (number of sheds as well as shed dimensions and design); and
- proven performance and cost effectiveness of the available technologies.

Given the range of these variables and a shortage of relevant information, it is extremely difficult to make recommendations as to which, if any, technologies should be given further consideration. However, an attempt to provide an order of preference for which of these add-on technologies should be further evaluated is provided in Table 3. The order is different for both odour and dust control, as some of the technologies will only target one of these emissions. This order has been constructed as a guide only, and is based on performance (or expected performance based on the available information), costs and practicality.

Table 3 Summary of costs and expected performance as well as order of recommendation for further investigation for all reviewed add-on technologies (continued over page)

Technology		Estimated *total* 10 year lifespan costs (¢/bird)	10 year lifespan costs (breakdown of the total costs)			Performance comments	Recommendation for further investigation / demonstration (order of preference[**])	
			Capital (¢/bird)	Operating & maintenance (¢/bird)	Cost of reduced bird numbers (¢/bird)		Odour Control	Dust Control
Dry dust filtration *Big Dutchman StuffNix*		0.5 (minimal treatment) – 4.6 (partial treatment) – 7.6 ¢ (full treatment)	0.2–3.3 ¢ ($ 4,000–63,500)	0.2–2.2 ¢	0.1–2.1 ¢	*Odour* - 30% reduction in odour emission [AB] *Dust* – 47%[B]-70%[A] dust reduction [AB] of filtered air *General* - fan performance is reduced and regular cleaning is required – full shed treatment unlikely to be affordable, so partial treatment requires investigation	1	2
Wet scrubbing *Big Dutchman MagixX*		8.4 ¢	3.6 ¢ ($ 69,500)	2.8 ¢	1.9 ¢	*Odour* - expected 50% reduction in odour emissions [C] *Dust* - >70% dust reduction[A], captured dust remains trapped in liquid solution *General* - system is complex, relatively expensive and unable to treat all exhaust air	5	4
Odour Neutralising products	*Neutraliser-2*	1.6 – 2.8 ¢	0.21 ¢ ($4,000)	1.4 – 2.6 ¢	-	*Odour* - reported 80% reduction [A] *Dust* – higher volume sprays may intercept dust and cause deposition *General* - treatment mechanisms between odours and the neutralising agent are random. Therefore, no guarantees for odour control. *Odour Eliminator* product claims to improve productivity, which could offset some costs	4	6
	Odour Kill	0.7 ¢	0.05 ¢ ($1,000)	0.7 ¢	-			
	Odour Eliminator	3.5 – 4.5 ¢	1.0 ($20,000)	2.5 – 3.5	-			
	OEC sprays	0.6 – 0.8 ¢	0.1 ¢ ($1,750)	0.5 – 0.7 ¢	-			
Electrostatic dust control *Electrostatic particulate ionisation (EPI)*		0.87 – 0.93 ¢	0.81 ¢	0.06–0.012 ¢	-	*Odour* [C] – untested, (30-40% possible assuming 60% dust reduction and 60% contribution of dust to odour (Cargill, 2001)) *Dust* - 40% to 61% dust reduction *General* - improved internal air quality, low cost, low maintenance, no effect on ventilation	3	1

Notes: [**] 1 = first preference, 7 = last preference; [A] data provided by manufacturer; [B] independently tested; [C] no test data; n/r – not recommended

Table 3 (continued) Summary of costs and expected performance as well as order of recommendation for further investigation for all reviewed add-on technologies

Technology		**Estimated *total* 10 year lifespan costs (¢/bird)**	**10 year lifespan costs (breakdown of the total costs)**			**Performance comments**	**Recommendation for further investigation / demonstration (order of preference**)**	
			Capital (¢/bird)	**Operating & maintenance (¢/bird)**	**Cost of reduced bird numbers (¢/bird)**		**Odour Control**	**Dust Control**
Dust Control Structures	Individual fan hoods (for 10 fans)	0.4 ¢	0.15 ¢ ($ 2,900)	0.21 ¢	-	*Odour* – no data *Dust* – no data *General* – improved dispersion and dust deposition may provide some odour and dust control under certain conditions	7	5
	Group fan hood	0.4 ¢	0.21 ¢ ($ 4,000)	0.21 ¢	-			
	Windbreak Wall	1.0 ¢	0.83 ¢ ($ 15,000)	0.17 ¢	-			
	BioCurtain®	0.6 ¢	0.36 ¢ ($ 7,000)	0.26 ¢	-			
	BioCurtain® with EPI	0.8 ¢	0.42 ¢ ($ 8,100)	0.36 ¢	-	*Odour* – no data *Dust* –Claimed 60-80% [A], 67% reduction [B] *General* – manufacturer recommend full *EPI* over *BioCurtain®* with *EPI*	6	3
Litter Aeration	Manual tiller	0.8 ¢	0.06 ¢ ($ 1200)	0.8 ¢	-	*Odour* - Requires research, development and testing but has the potential to control odour generation *Dust* – not recommended for dust control	2	n/r

Notes: ** 1 = first preference, 7 = last preference; [A] data provided by manufacturer; [B] independently tested; [C] no test data; n/r – not recommended;

The majority of the technologies included in this report have been trialled in poultry buildings or other intensive animal housing either in Australia or overseas, in one way or another. Unfortunately, evidence of meaningful, scientifically valid odour or dust control is not readily available in most cases. The electrostatic particulate ionisation (EPI) system has been independently tested with results published in peer-reviewed scientific papers and at conferences. The dry dust filter, wet scrubber and some of the odour neutralising agents have been tested by the manufacturer, or independently, for dust, ammonia or odour control. Evidence of dust or ammonia control does not automatically infer odour control as well. Independent odour testing for all of these technologies is required to demonstrate odour control.

If constant control of odour or dust is required, treatment systems such as a dry dust filter or wet scrubber should be considered because contact between the exhaust air and the filter system is controlled and the treatment process is clearly defined and manageable. The electrostatic particulate ionisation and litter aeration systems may also be suitable in this case. Technologies such as the odour neutralising agents and dust control structures should not be considered because the treatment process is random and reliability cannot be guaranteed. On the other hand, if short term reduction of peak emissions (or erratic emissions due to infrequent 'upset' events) is all that is required, the ongoing costs and reduction of ventilation performance associated with full time filter systems will result in unnecessarily high costs. In these situations, odour neutralising agents, dust control structures, litter aeration (as-required manual operation) or electrostatic particulate ionisation may be sufficient to relieve the problem during these irregular events. This is of course assuming that these technologies provide adequate control of the emissions.

Because of the variety of add-on technologies (and different configurations for each), different farm configurations and unavailability of performance data and cost estimates, it is difficult to make recommendations about the suitability of these technologies to control odour or dust emissions from meat chicken farms. Recommendations ideally need to be based on the results of full-scale trials and independently tested, peer-reviewed, scientifically assessed performance data rather than manufacturer's data.

Recommendations

1. **Farm managers must understand why, when and how odour and dust impacts are arising from their farm and, if possible, address these issues first before considering the installation of an add-on technology.** However, if impacts are occurring regularly, and are due to normal farming operations, an add-on technology to control odour or dust emissions may be required. If this is the case, there are several options for add-on technologies to address odour and dust related issues on broiler farms; however, no option is perfect. Regardless of which technology is chosen, there will be costs associated with purchasing, installing, operating and maintaining the technology. Additionally, complete and reliable control of odour or dust emissions is not possible.

2. **The Australian chicken meat industry should undertake independent evaluations of the technologies that will be most suitable for the majority of the industry, especially dry dust filtration, wet scrubbing, electrostatic particulate ionisation and odour neutralising technologies. Litter aeration could also be researched and developed as a technique to reduce the generation of odour within the shed.** Most of the technologies included in this report are untested, or have only been evaluated overseas, which is why independent, local assessment is required. Future evaluation of odour neutralising agents would be complex due to the large range of products, application rates and configurations of application systems. Testing of these agents should be considered; however, development of an appropriate testing methodology will be required in order to generate meaningful results. Simple dust control structures should not undergo scientific evaluation because the variety of designs (and no design standards), reliance on external conditions (atmospheric stability, weather etc.) and poorly defined 'treatment' principles would mean that testing results would not be widely applicable.

3. **To minimise operating costs and maximise the useful life of add-on technologies, treating a portion of the exhaust air or intermittent/cyclic treatment of exhaust air, at times when odour impacts at receptors are most likely, should be investigated.** This will optimise cost-effectiveness while offering adequate odour and dust control. For technologies, such as the dry dust filter, wet scrubber and odour neutralising agents, this approach will be essential if these technologies are to be applied to broiler sheds in an affordable manner. Further research and individual assessment of farms where these technologies will be installed, will be required to determine exactly what proportion of exhaust air needs to be treated (or what times odour and dust need to be controlled) in order to avoid impacts.

4. **Producers need to consider their own circumstances and select an add-on technology that is affordable, compatible with their infrastructure and operations, and will reliably provide the level of control required to address odour or dust issues.** Table 3 provides a concise summary of the technologies included in this review. The order of preference listed in this table should be considered a guide only. Details of costs and expected performance of the technologies in this table, combined with other details in this review, will allow potential users to assess which technologies will be most suitable for their particular situation

Appendix 1. Dry dust filtrations

Big Dutchman *StuffNix*

Technology description

Big Dutchman (Vechta, Germany, http://www.bigdutchman.com) have designed a dry dust filter, called *StuffNix* (see Figure 1 and Figure 2). This filter is manufactured from a blend of poly-propylene and poly-ethylene plastics. It is supplied in 3.0 m wide by 1.4 m high panels, which makes it suitable for modular construction. Modular construction allows the filter system to be adapted to individual farm installations depending on the ventilation and space requirements of each shed.

Figure 1 StuffNix filter system installed in a poultry shed (original, superseded, paper filter panels were used in this installation, *source:* http://www.bigdutchman.de/bd_images/fotoseiten/Stuffnix.jpg)

Figure 2 Display of the plastic StuffNix filter panel mounted in a frame with dust collection tray fitted below.

The filter panels are constructed in two layers (see Figure 3). Each layer is concertinaed and has evenly spaced 25 mm diameter holes. The holes on the front layer are not aligned with the holes on the back layer. The misaligned holes cause the air to rapidly change direction, forcing dust particles to be removed from the air stream and accumulate between the two layers (see Figure 4). Eventually, the build-up of particulate matter dislodges from the plastic material and drops into a collection basin at the bottom of the filter panel or onto the floor. Dust can also be dislodged from within the filter by striking the filter panel. Dust collected in the accumulation basin is easily removed as a part of the cleaning process. Because the filter panels are manufactured with durable plastic material, the filter can be washed with water and cleaning agents. Due to the relatively large diameter holes (25 mm), the filter system resists clogging, and flow restriction will not increase as dust accumulates in the filter.

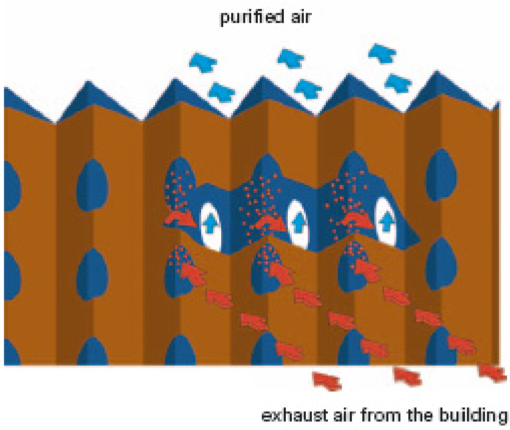

Figure 3 StuffNix concertinaed construction with non-aligned holes (Big Dutchman, 2005)

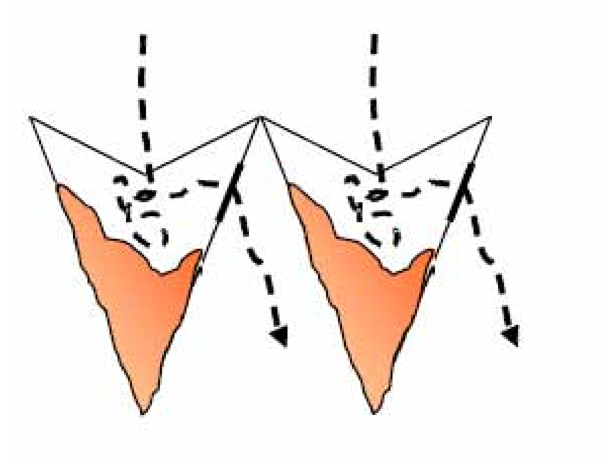

Figure 4 Accumulation of dust between the two layers of StuffNix (looking vertically downward) (Heyer and Kalkhoff, 2006)

Design considerations in tunnel ventilated meat chicken sheds

One of the primary design considerations for installing StuffNix is to match the flow rate and pressure drop through the technology with the fan performance and ventilation requirements of the shed. The recommended flow velocity through the StuffNix, for optimum dust removal, is 0.65 m/s. At this flow velocity, pressure drop through the filter is approximately 40 Pa. Taking into account that tunnel ventilated sheds usually operate at approximately 20 Pa, the total static pressure across the fans would be approximately 60 Pa. This additional static pressure is likely to reduce fan performance by 15%–40% depending on the specifications of the individual fan. Big Dutchman recommends the use of the *Big Dutchman, Air Master V130-5* fan (Big Dutchman, 2006) as an integrated part of the StuffNix dust control system; however, this is not essential. Big Dutchman designed the V130-5 fan for operation with higher than normal static pressures and improved efficiency.

The amount of StuffNix panels required per fan needs to be calculated at the expected flow rate (according to fan performance at 60 Pa static pressure). At the recommended flow velocity (0.65 m/s), volumetric flow rates through a single filter panel (3 m wide by 1.4 m tall) will be approximately 2.73 m^3/s (9828 m^3/h). Considering that 1220–1270 mm (48" to 50") diameter fans, which are commonly used in tunnel ventilated meat chicken sheds, operate at a flow rate of approximately 7.5 m^3/s (27,000 m^3/h) to 10.8 m^3/s (39,000 m^3/h) at 60 Pa, approximately 2.7 to 4.0 StuffNix panels will be required per fan. When using the Big Dutchman V130-5 fan, it is recommended to install three panels of StuffNix for each fan.

Correspondence with Big Dutchman representatives indicates that dust collection performance decreases if the flow velocity falls below 0.65 m/s. Consequently, installation of additional StuffNix panels (which would reduce the static pressure by reducing the average flow velocity) is not recommended.

Costs
Purchase cost for a 3 m wide by 1.4 m tall panel of StuffNix is approximately $850 (500 Euro). These can be purchased in Australia through Big Dutchman agents.

StuffNix operating and maintenance costs are extremely low. Additional fan operating costs (due to reduced performance at higher static pressure) will be expected. Cleaning of the filter panels will be required at the end of each batch as part of regular shed cleaning and sanitising. This will incur an additional small cost for extra cleaning water and cleaning agents. De-dusting of the filter panels will be required weekly or fortnightly. This is expected to take just a few minutes for a single fan installation or up to an hour for a full shed installation. The combined cost of these is difficult to estimate. For the purpose of including some value to represent these operating and maintenance costs, it will be assumed that operating and maintenance costs will be approximately $300 per filtered fan per year (fan, filter and ventilation requirements will be specified in the case studies detailed below).

Performance data
StuffNix has been evaluated for both odour and dust reduction efficiency.

Dust removal efficiency is stated to be 70% (Big Dutchman, 2005). Lim *et al.* (2005) evaluated the performance of an earlier version of StuffNix on a high-rise layer barn and found that PM_{10} (particulate materials finer than 10 μm) removal efficiency was 41% and removal of TSP (total suspended particulates) was 47.4%. These values are lower than those stated by the manufacturer; however, the integrity of the filter was not maintained throughout the trial. Consequently, lower performance could be expected. Additionally, improved filter design and the use of more suitable materials will ensure greater dust control compared to the earlier versions of the product which were tested by Lim *et al.*

Odour removal efficiency of StuffNix has been measured. Three pairs of odour samples were analysed using dynamic olfactometry. It was reported that StuffNix reduced odour concentration on a layer house by an average of 30% (Schneider and Kresse, 2006).

Maintenance requirements
The main requirement for maintenance of the StuffNix technology is removal of dust from the filter panels and collection trays. Dust can be dislodged from the StuffNix filter by striking the filter material. This cleaning operation would be expected to be required on a weekly to monthly basis, depending on the quantity of dust collected.

In order to prevent trapped dust being re-suspended and then emitted from the shed, ventilation through the filter may need to be reduced or ceased during cleaning operations.

Removal of dust from the exhaust air by StuffNix should reduce de-dusting requirements on the ventilation fans.

Conceptual design case studies
A wide range of options for installing StuffNix into a tunnel ventilated meat chicken shed are available, largely due to its modular design. Decisions about which configuration of StuffNix will provide the most benefit will differ between each shed and each farm and will be dependent on many factors including:

- the need to reduce dust emissions;
- orientation of the sheds in relation to receptors;
- existing shed design (or new shed design);
- the existing ventilation system; and
- affordability.

In an effort to simplify the number of possible configurations for installing StuffNix, three conceptual designs have been selected for analysis in this report. These include:

1. a minimalist approach that only treats the air from side fans (or timed fans);
2. a balanced approach to treat the air exhausted from the side fans and a percentage of the tunnel ventilation fans (to balance affordability with acceptable performance); and
3. comprehensive treatment of all air exhausted from the building.

1. Treatment of air from side fans only

StuffNix could be applied to side wall mounted ventilation fans (see Figure 5). Depending on the performance of individual fans, approximately three to four panels of StuffNix would be required for each fan. StuffNix panels could be installed on the inside of the existing shed structure. StuffNix material cost would be approximately $2,550–$3,400 per fan. An additional access door would be required to allow entry into the area enclosed by the filter to enable removal of dust, shed washing and servicing of the fan. Installation cost is estimated to be approximately $1,000. For the purpose of the cost analysis, it will be assumed that 3.5 StuffNix panels are required at a cost of $3,000 (plus installation).

Operating and maintenance requirements and costs are expected to be minimal. A few minutes per week will be required to clean the dust collected in the StuffNix (for each fan). Washing and sanitising at the end of each batch will be required. Fan operating costs will also increase by an estimated 10% to 20%. The total operating and maintenance cost is estimated at $300 per year per fan.

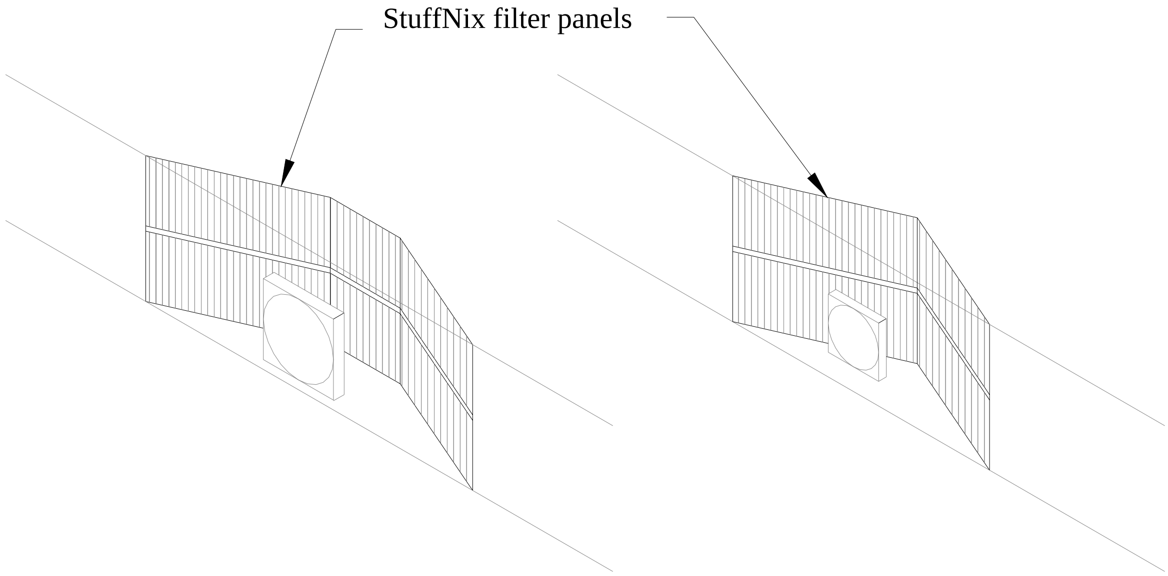

Figure 5 Using StuffNix on side-wall mounted fans

2. Treatment of air from side fans and half of the tunnel ventilation fans

StuffNix could be applied to side wall fans and a percentage of tunnel ventilation fans (see Figure 6). This percentage should be chosen according to cost and ventilation requirements as well as necessity to reduce dust emissions. The principle behind this idea is that not all of the fans are active all of the time. Therefore, the side fans and half of the tunnel ventilation fans may actually account for 65% to 85% of the total amount of air ventilated from the building on average throughout the year. Consequently, treating the air emitted from the side fans and half of the tunnel ventilation fans may actually treat 65% to 85% of the total amount of air emitted from the shed. This may enable dust reduction goals to be achieved at reduced cost (when compared to treating the air from all ventilation fans).

For the example displayed in Figure 6, StuffNix has been applied to two side fans and five (of ten) tunnel ventilation fans. The remaining five tunnel ventilation fans have been repositioned to each side of the shed upwind of the StuffNix filter. The cost for this application is approximately $20,400 for the filter that is servicing the tunnel ventilation fans plus an additional $8,000 for the side mounted fans, producing a total cost of $28,400. Installation cost per shed is estimated to be approximately $7,000. In this situation, it will be assumed that one additional tunnel ventilation fan will need to be installed to maintain the correct ventilation rate and tunnel ventilation velocity. This additional fan can be installed at a cost of $1,500. Therefore, total cost for installing the StuffNix on two side fans and half the tunnel ventilation fans would be approximately $36,900. Annual operating costs will be estimated at $2,400 ($300 per fan x 8 fans).

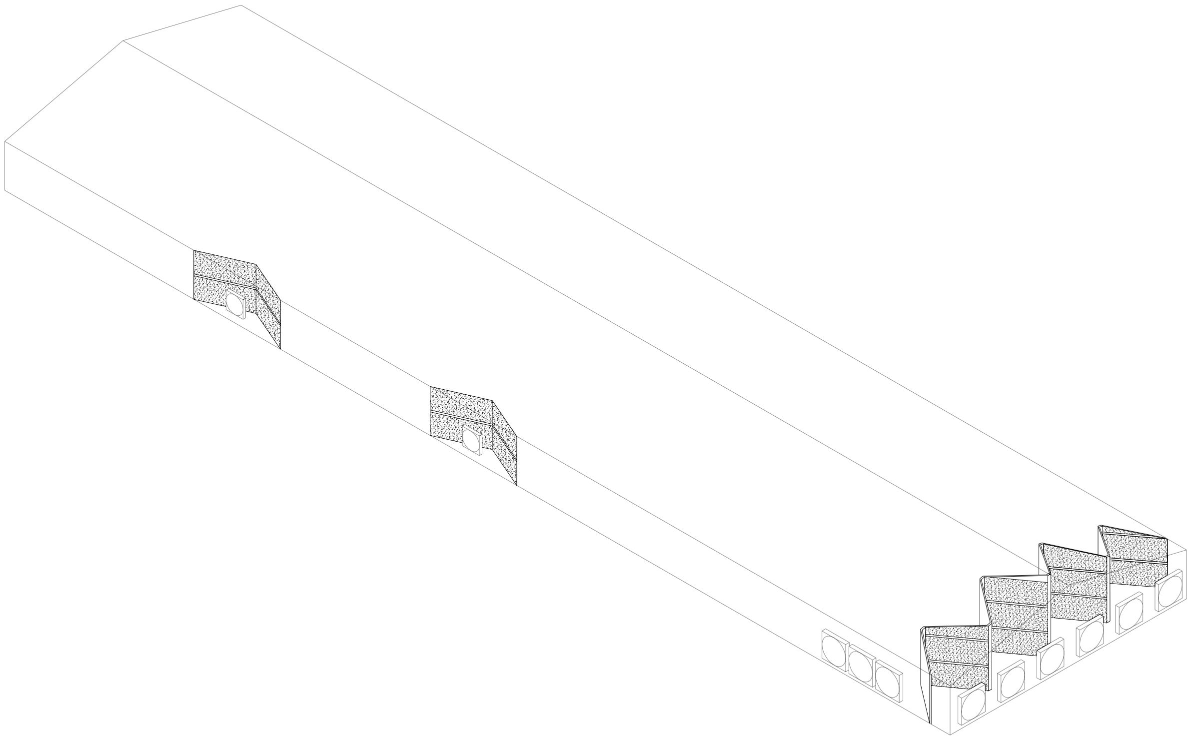

Figure 6 Using StuffNix on side mounted fans and half of the tunnel ventilation fans (note: the length of the long axis has been halved for improved presentation)

One advantage of this type of installation is that some of the fans (in this example, half) will not be affected by the StuffNix filter. Consequently under full tunnel ventilation conditions, there will only be a partial reduction in fan efficiency on average throughout the shed.

3. Treatment of all exhaust air from side and tunnel ventilation fans

StuffNix could be applied to all side and tunnel fans (see Figure 7). This would ensure that all air exhausted from the building would be treated by the filter system.

For the example displayed in Figure 7, StuffNix has been applied to two side fans and all tunnel ventilation fans. In this case, it might be necessary to fit one or more additional fans to the shed in order to maintain adequate ventilation rates. The exact number of fans would depend on the performance of the fans. It will be assumed in this case that two additional fans will be installed at an approximate cost of $3,000. The cost for StuffNix filter is approximately $42,500 for the tunnel ventilation fans plus an additional $8,000 for the side mounted fans, producing a total of $53,500. An estimated installation cost is $10,000. Total installation cost (StuffNix, additional fans and installation) would therefore be approximately $63,500.

Annual operating costs are estimated to be approximately $4,200 ($300 per fan x 14 fans total).

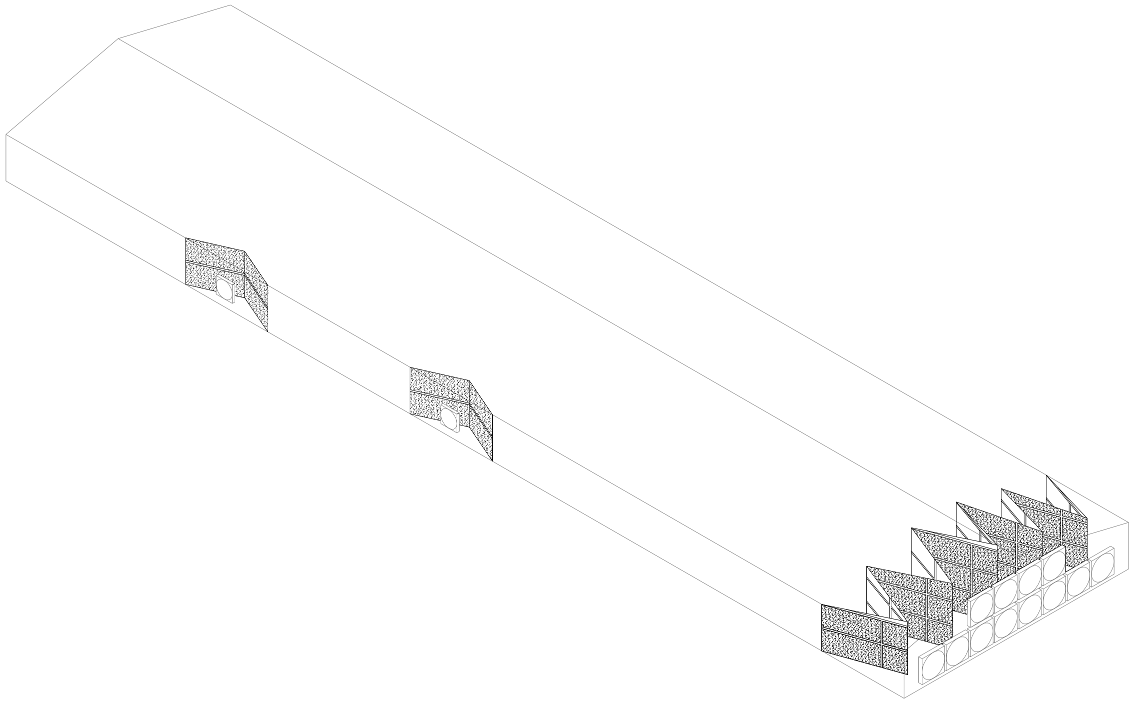

Figure 7 Using StuffNix on side mounted and all tunnel ventilation fans (note: the length of the long axis has been halved for improved presentation)

Cost analysis

The following costs on a per chicken basis have been calculated according to the cost analysis assumptions (costs over ten years) and estimated costs for the technology (specified for the three configurations detailed above). Estimated ten year lifespan cost for the three described installations configurations is displayed in Table 4.

In all cases, the shed is assumed to be 14.7 m wide, 125 m long and contain 35,000 birds. Maximum ventilation rate is assumed to be 458,000 m^3/h in tunnel ventilation (unfiltered flow rate, side fan ventilation extra). This ventilation rate is required in order to achieve a minimum tunnel ventilation velocity of 3 m/s underneath ceiling baffles. Each tunnel ventilation fan has an assumed flow rate of 39,000 m^3/h when filtered and 46,000 m^3/h when unfiltered (the differences in flow rate are due to reduction in fan performance with additional pressure drop caused by StuffNix). Side fans have an assumed flow rate of 38,000 m^3/h when filtered and 41,000 m^3/h when unfiltered. It will be assumed that ten tunnel ventilation fans and two side wall fans (for minimum ventilation) will be required to meet the ventilation requirement prior to installing the StuffNix filter.

Some of the production space will be converted to accommodate the StuffNix. It will be estimate that 0.2% of the floor space will be required for each side fan, 2.4% required for two side fans and half of the tunnel fans and 3.5% required for all side and tunnel fans. These costs have been incorporated into Table 4.

Table 4 Costs of installing and operating StuffNix for three different installation configurations

Installation configuration		**Each side fan (3.5 StuffNix panels)**	**Side fans and half tunnel fans**	**Side fans and all tunnel fans**
Capital cost ($)		$ 4,000	$ 36,900	$ 63,500
10 year lifespan capital cost ($/bird)		$ 0.0021	$ 0.0192	$ 0.0330
10 year operating cost ($)		$ 3,000	$ 24,000	$ 42,000
10 year lifespan operating cost ($/bird)		$ 0.0016	$ 0.0125	$ 0.0218
Gross cost of lost production ($/bird)		$ 0.0012	$ 0.0143	$ 0.0208
Total 10 year lifespan costs	**($/bird)**	**$ 0.0048**	**$ 0.0459**	**$ 0.0756**
	(¢/bird)	**0.48 ¢**	**4.59 ¢**	**7.56 ¢**

Inspection of StuffNix technology

StuffNix was inspected at a layer farm in Germany during October, 2007 (see Figure 8, image taken after de-dusting of the filter). The StuffNix was installed across two ventilation fans mounted on the side wall of the building. StuffNix was not installed across all of the ventilation fans. Ventilation fans for warm weather were left untreated. Figure 10 displays the accumulation of dust on the front and inside of the filter structure. At this installation shown in Figure 9 and Figure 10, maintenance had been completely neglected. No cleaning or dust removal had occurred since installation of the filter. Dust should have been removed more frequently. Consequently, excessive amounts of dust had accumulated on the filter.

Figure 8 StuffNix installation in a barn layer shed in Germany after filter de-dusting

Figure 9 Front face of StuffNix filter. The dust collection tray, covered by a stainless steel flap is visible at the bottom of the filter panel (*Note:* filter maintenance had been neglected and required de-dusting)

Figure 10 The front face of StuffNix showing accumulation of dust on the inside of the filter (*Note:* filter maintenance had been neglected and required de-dusting)

Summary of StuffNix technology

The StuffNix technology was designed for application in mechanically ventilated animal housing. The examples provided in the above sections demonstrate the potential for StuffNix to be installed in tunnel ventilated meat chicken sheds. The most economical option would be to install the StuffNix so that only a percentage of the full ventilation capacity of the shed would be treated. StuffNix installed in this manner could potentially stop the emission of a reasonable proportion of the dust currently emitted from meat chicken sheds.

Limited data exists to support the performance of StuffNix. The data that is available suggests that it is capable of trapping a large proportion of the dust, which in turn slightly reduces odour emissions.

The following points summarise some of the features and considerations for installing the StuffNix system:

- Capital and operating costs are reasonable when the shed is partially treated (0.5 ¢/bird to treat each side fan, 4.6 ¢/bird to treat two side fans plus half of tunnel fans and 7.6 ¢/bird to treat all side and tunnel ventilation fans). The only maintenance required is to dislodge dust in the panels and empty the dust collection trays (maintenance required weekly to monthly).
- Reasonably low pressure drop (approx 40 Pa, but this is likely to reduce fan performance by 15% to 40%, increasing fan running costs and possibly noise as well). Additional fans may be required to maintain adequate ventilation rates and tunnel ventilation velocities.
- Simple technology with no moving parts.
- Dust deposition on fans should be reduced.
- Manufacturer reports 70% dust removal and 30% odour reduction.
- Collected dust will need to be disposed.
- Because the StuffNix is installed inside the shed, some of the floor space (0.2% to 3.5%) will be converted from production space to accommodate the treatment system. Bird numbers may need to be adjusted.

Appendix 2. Wet scrubber technologies

Wet scrubbers have evolved since being reviewed previously by Kolominskas *et al.* (2002).

One such wet scrubber is the single stage *MagixX* system. This technology has been designed by Big Dutchman (Vechta, Germany, http://www.bigdutchman.com) specifically for application in poultry buildings, where high ventilation rates and low pressure losses are required.

An air washer system has also been developed by researchers of the USDA-ARS, Arkansas, USA. This air washer system has been designed specifically to trap ammonia from the fans that are used during minimum ventilation conditions.

Big Dutchman *MagixX* exhaust air washer

Technology description

The single stage MagixX system is primarily designed to remove particulate matter and ammonia from the exhaust air, but not specifically odour. Particulates are trapped on the wet scrubbing wall and are washed into a water basin. Ammonia is scrubbed from the air stream using water, however, removal of ammonia can be maximised by reducing the pH of the scrubbing liquid with the use of acid. To remove odour, a three stage system is available and comprises a dust removal stage (water washing wall), an ammonia scrubbing stage (acidified washing wall) and a biofiltration stage (vertical biofilter wall). This three stage system has been designed for use on pig houses in Europe; however large pressure losses through the three stages make this system prohibitive for application in poultry houses, which have significantly higher ventilation requirements.

The single stage MagixX system (see Figure 11) is comprised of a vertical filter panel (constructed using a specially designed plastic packing media), a water bath, spray nozzles, water circulation pump and an optional dosing system (for adding acid or other solutions to the washing water). While operating, water is pumped to the top of the filter bed and trickles down through the filter bank. Spray nozzles are activated intermittently on the front face of the filter bank to dislodge particulate matter, ensuring long service life of the filter bank. Operation of the spray nozzles also improves performance of the scrubbing system. Acid can be added to the washing water using an automatic dosing system to improve ammonia trapping.

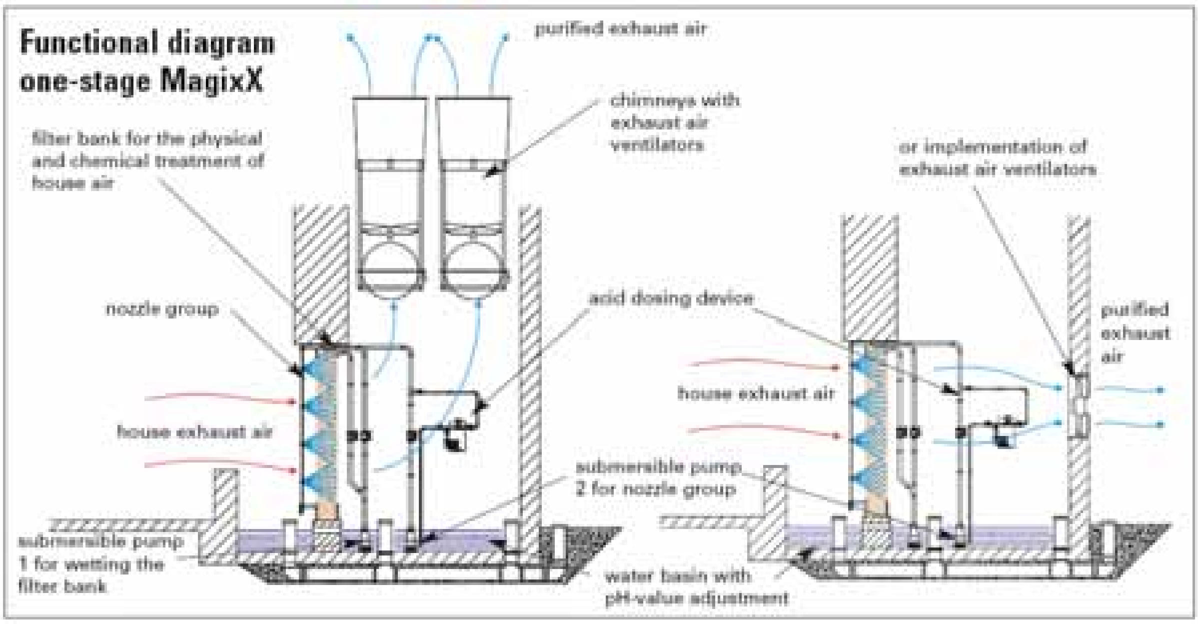

Figure 11 Functional diagram of the single stage MagixX (Big Dutchman, 2005)

The filter bank is installed across the entire width of the shed, just upwind from the ventilation fans (see Figure 12). Figure 13 demonstrates how close the filter bank can be installed to the back wall of the poultry shed (where tunnel ventilation fans are traditionally mounted in Australian poultry sheds). Figure 14 demonstrates the placement of the spray nozzles, the proximity of the filter bank to the chicken production space and ventilation fans on the far side wall of the shed (which are operated during warm weather conditions, when ventilation requirements increase). The water basin is approximately 20–30 cm deep, and is separated from the production area by a concrete wall.

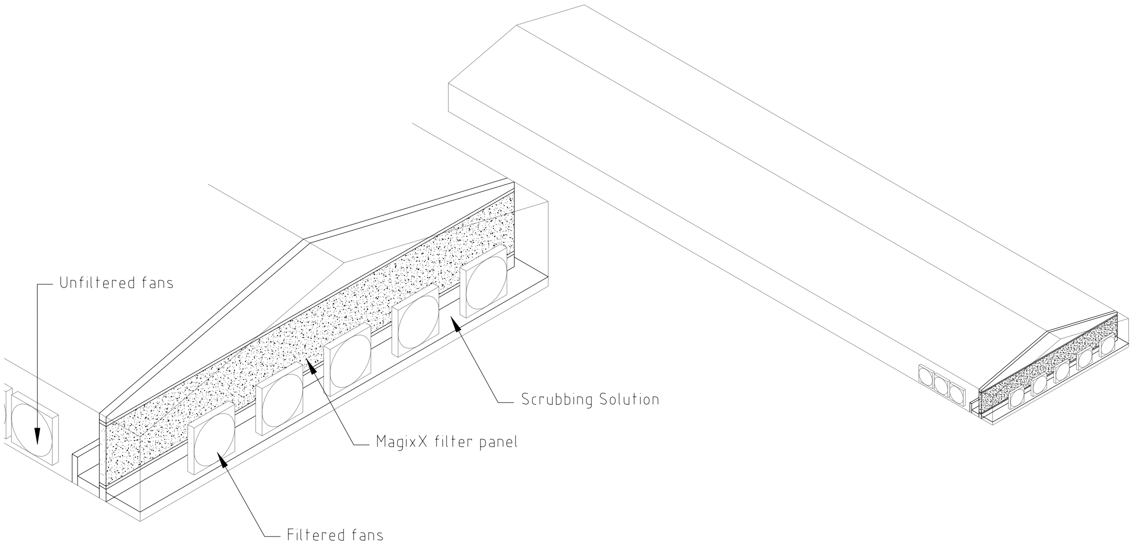

Figure 12 Conceptual installation of MagixX on an existing tunnel ventilated poultry shed

Figure 13 MagixX system installed in a poultry house in Germany - rear view of filter bank showing proximity to the rear wall and roof mounted ventilation fans

Figure 14 MagixX system installed in a poultry house in Germany - front view of the filter bank showing spray nozzles, proximity to chickens and warm weather ventilation fans on far side wall

Design considerations in tunnel ventilated meat chicken sheds

The MagixX water washing system is a more complex system than the StuffNix system described earlier. It has pumps, spray nozzles, piping and an automatic dosing system. Consequently, the MagixX system is more expensive, and has greater operating and maintenance costs.

Pressure losses across the filter bank are expected to be in the order of 20–40 Pa, which will reduce the performance of existing ventilation fans, possibly requiring additional fans to be fitted in order to maintain suitable levels of ventilation.

MagixX is a centralised treatment system. Fans installed on the side of a meat chicken shed would be left untreated (without installing an entire MagixX system on each fan, or cluster of fans). To be an effective treatment system, all air exhausted during low ventilation conditions would need to be drawn through the treatment system.

A 20 m wide MagixX system is designed to treat 200,000 m³/hour (118,000 cfm) of ventilation air. A concertinaed design (see Figure 15) is required in order to fit the 20 m wide wall within a conventional tunnel ventilated shed. Because maximum ventilation requirements in Australian tunnel ventilated buildings are usually 300,000–450,000 m³/h (to generate 2.5–3.0 m/s wind speed), additional ventilation fans required for times of higher ventilation would need to be positioned upstream of the MagixX treatment system. For the MagixX system displayed in Figure 14, additional ventilation fans are visible on the far wall.

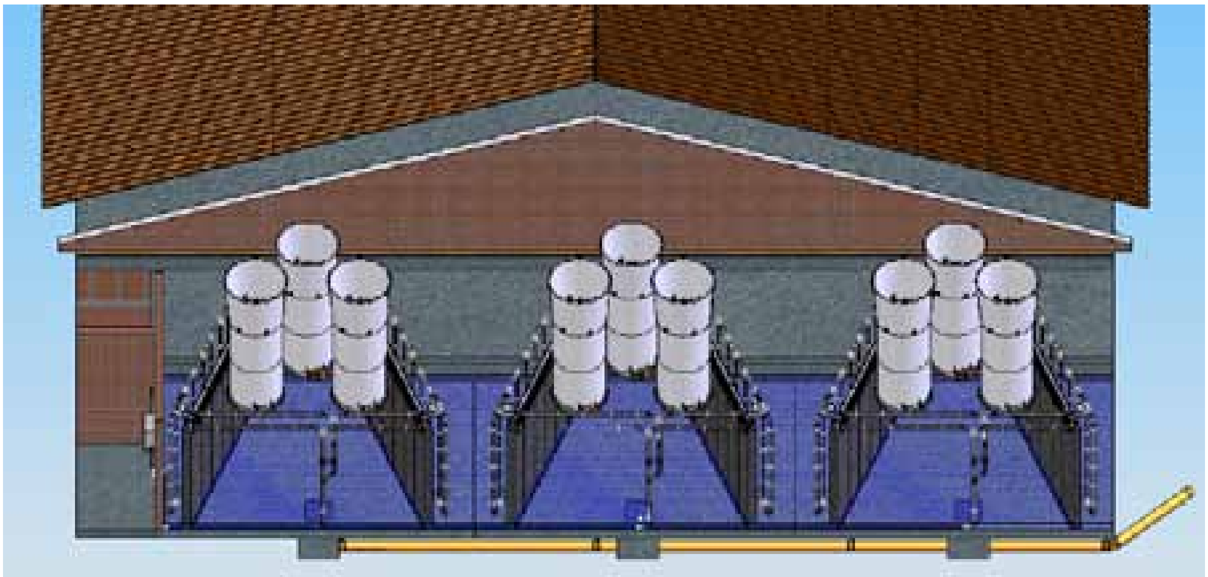

Figure 15 Concertinaed, modular MagixX installation for poultry, designed to improve airflow and efficiency compared to a straight wall

Performance data

Odour, dust and ammonia reduction performance data are not currently available for this technology. Due to the design of the filter system, it would be expected that particulate removal should be greater than 70%. Odour reduction would be dependent on the additives used in the washing solution, the concentration of odorants in the washing solution, and the presence of microbes in the filter structure (effectively producing a bio-scrubber). The manufacturer expects that 50% odour reduction would be possible. Testing using olfactometry would be necessary to confirm the performance of this scrubbing system.

Maintenance requirements

The MagixX system will require some maintenance in order for it to operate at peak performance. Some essential maintenance will include:

- emptying and re-filling the water basin with every batch (approximately 15,000 litres);
- removal of accumulated particles from the water basin;
- regular cleaning the filters on the recirculation and spray nozzle pumps;
- occasional cleaning of the filter bank to prevent long-term clogging, although the spray nozzles should prevent excessive amounts of particulates from sticking to the wall; and
- inspection, maintenance or calibration of the acid and/or odour neutralising agent dosing systems.

The Magixx system may reduce de-dusting requirements for ventilation fans because it will remove particulates from the air before reaching the fans.

Costs

The cost of a single stage MagixX system to suit meat chicken shed applications and treat 200,000 m^3/h of air is estimated to be approximately \$66,500 (based on a cost of 41,000 Euros for a similar installation in Germany, and including freight to Australia and installation).

Additional fans may be required to be installed to overcome lost performance due to higher static pressures. However, with moderate pressure losses in the order of 20 Pa, total static pressures across ventilation fans are moderate (approximately 40 Pa) and only minimal reduction in fan performance would be expected.

Detailed operational costs for MagixX were not available. The manufacturer has advised that fan operating costs (only the fans being treated by MagixX) are expected to increase by about 10%–20%. The water circulation pump (2.8 kW), if operated 24 hours a day for 40 days of the batch (and assuming electricity costs 15.45 cents per kilowatt-hour) would cost approximately \$2,500 per year. Acid, or other scrubbing liquid additives, would add additional cost. While the exact operating and maintenance costs are not know, it is expected that operating costs would be more than for the StuffNix dry dust filter. In the absence of actual operating costs, annual operating costs for the MagixX system (for a design flow rate of 200,000 m^3/h) will be approximated by the following values:

Table 5 Estimates of annual operating costs for MagixX

Additional fan running costs	\$ 1,200
Pump running costs	\$ 2,500
Acid/scrubbing liquid	\$ 520
Cleaning	\$ 120
General maintenance	\$ 500
Water	\$ 500
TOTAL	**\$ 5,500**

Example MagixX installation in a broiler shed

Only one approach to installing MagixX into a tunnel ventilated poultry shed will be considered in this section. The system will be installed to treat approximately half of the full shed ventilation rate (approximately 200,000 m^3/h).

It will be assumed that the shed is 14.7 m wide, 125 m long, has 2.7 m high side walls and was originally fitted with 10 tunnel ventilation fans (46,000 m^3/h each) and two side wall fans.

A concertinaed MagixX system will be installed just a few meters upwind from the tunnel ventilation fans. The divider that separated the chickens from the filter is located approximately 4 m from the rear wall (corresponding to a 3.2% loss of production space). Additional fans, required for higher levels of ventilation, will need to be mounted on the side wall, just upwind from the filter bank (and will therefore not be treated by the MagixX system).

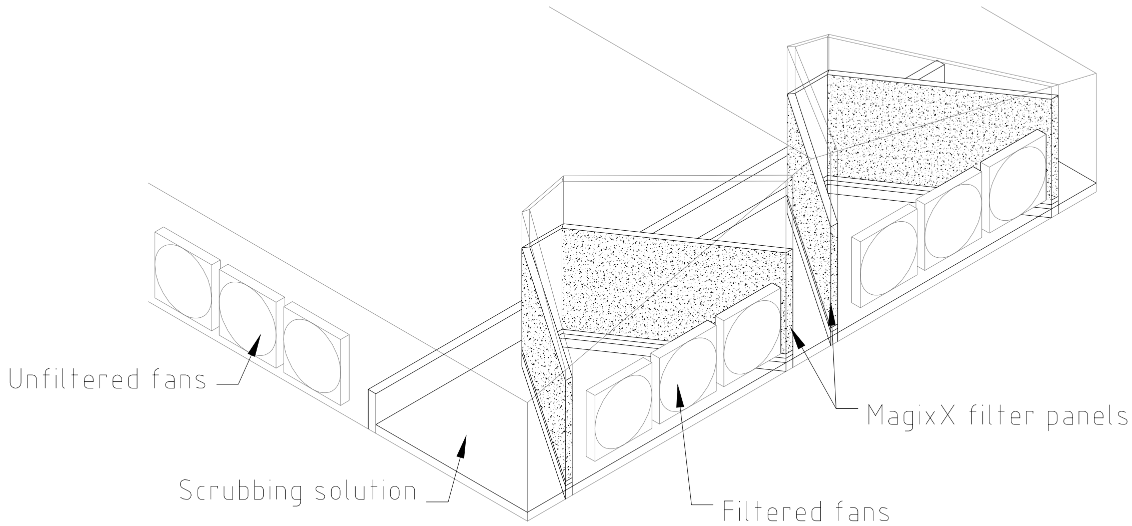

Figure 16 Concertinaed MagixX installation in a broiler shed

With this installation configuration, consideration would need to be given to:

- the possible reduction in fan performance while drawing air through the MagixX filter system. Pressure drop would be approximately 20–40 Pa greater than standard operating pressures, which would reduce fan performance, and increase fan operating costs. Extra fans may be required to compensate for lost performance;
- removing (or deactivating) any side wall fans that are operated during very low ventilation conditions;
- ensuring that maximum tunnel ventilation velocities meet production requirements;
- increased maintenance to empty the water basin and replenish additives to the water bath (eg. acid or odour neutralising agents);
- increased water use and evaporation due to the filter panel (15,000 litres required to fill the basin, plus replenishment of evaporation losses); and
- a liquid waste stream containing dust, feathers, soluble odours and possibly acid will be generated by the scrubber. (This liquid may be land applied as fertiliser; however, to guarantee compliance with regulations and environmental management guidelines, testing would first be required to confirm this. Testing and disposal may add to the operating costs.)

Cost analysis

The following costs on a per chicken basis have been calculated according to the cost analysis assumptions (costs over ten years) and estimated costs for the technology. The estimated ten year lifespan costs for the installation of the MagixX as described above are displayed in Table 6.

In this case, it is assumed that the poultry building is 14.7 m wide, 125 m long, houses 35,000 birds and has a maximum ventilation rate of 458,000 m^3/h. In this case, the MagixX filter system will treat approximately 200,000 m^3/hr of exhaust air. Additional ventilation air will be exhausted without treatment. Approximately 3.2% of the floor space will be needed to accommodate the filter system. Costs associated with this are included in Table 6.

Table 6 Costs of installing and operating MagixX (with a treatment capacity of 200,000 m³/h)

Capital cost ($) (including $3000 for extra fans and moving existing fans)		$ 69,500
10 year lifespan capital cost ($/bird)		$ 0.0361
10 year operating cost ($)		$ 55,000
10 year lifespan operating cost ($/bird)		$ 0.0286
Gross cost of lost production by reduced bird numbers ($/bird)		$0.0191
Total 10 year lifespan cost	**($/bird)**	**$ 0.0837**
	(¢/bird)	**8.37 ¢**

Given that this cost analysis has shown that treating only part of the full ventilation air in the shed will cost approximately 8.4 ¢/bird, it is unlikely that increasing the size of the system to accommodate treatment of 100% of the ventilation air will be affordable.

Inspection of MagixX technology

A MagixX system was inspected at a meat chicken farm in Germany during October, 2007 (see Figure 13). The MagixX was installed just upwind from the back wall of the poultry shed. Roof mounted fans were used to draw air through the filter system. Additional fans, required to provide higher amounts of ventilation, were installed upwind of the filter panel and were therefore untreated by the filter system.

Some of the spray nozzles were blocked and required cleaning (see Figure 14). The washing water appeared to be relatively clean and some dust was visible floating on the liquid surface. Reduction of odour through the system was not able to be assessed during the inspection because air was exhausted through the roof mounted fans.

Overall, the system appeared to be functioning and the filter panel appeared to be relatively clean.

Figure 17 MagixX: close-up image of the filter bed structure

Figure 18 MagixX: dust floating on the liquid surface

Summary of MagixX technology

The single stage MagixX air washing system appears to be a well designed technology that could be adapted for use in tunnel ventilated meat chicken farms in Australia. It is unlikely that the system, as shown, will be able to treat all tunnel ventilated exhaust air economically. The affordability of even partial air treatment, as demonstrated in the ten year lifespan cost analysis, requires careful consideration. Because it is a relatively new technology, and not yet being used under Australian conditions, maintenance requirements, equipment longevity and operating costs are yet to be accurately determined.

There is minimal evidence currently available to demonstrate the dust, odour and ammonia removal efficiencies of the treatment system under commercial operating conditions. Consequently, performance testing of the treatment system will be required to demonstrate the odour and dust reducing capabilities of the system under Australian production conditions.

The following points summarise some of the features and considerations associated with the MagixX system:

- particulate removal should be significant;
- additives can be used in the washing water to trap ammonia and potentially scrub odours from the air-stream;
- additional water requirements to operate the system;
- capital and operating costs will be more than dry dust filters (e.g. StuffNix);
- additional maintenance or specialist servicing may be required;
- due to pressure losses, additional fans may be required, and some existing fans will need to be relocated;
- washing water will create an additional waste stream requiring treatment or disposal. This liquid may be suitable for application as a fertiliser;
- washing water may become another source of odour and ammonia emission if stored or treated on-farm.

USDA-ARS ammonia scrubber

Technology description

Researchers of the United States Department of Agriculture, Agricultural Research Service (USDA-ARS) Fayetteville, Arkansas, USA have developed a low cost ammonia scrubber to remove gaseous ammonia from air exhausted from intensive animal housing ((Moore *et al.*, 2006), see Figure 19). Removal of ammonia is not directly related to odour control, rather it is designed to address environmental concerns relating to ammonia emissions, which are regulated in the USA.

The scrubber uses a liquid solution of alum (aluminium sulphate) or aluminium chloride to trap ammonia as it is exhausted from the shed. The scrubber has been designed to operate under minimum ventilation conditions during cool weather or between batches (when stockpiling or composting litter for reuse as a floor covering). Under these conditions, ammonia conditions are higher, and the effectiveness of the scrubber to recover ammonia is greatest.

The scrubbing solution is stored in a 380 litre reservoir at the bottom of the scrubber. The solution is pumped to the top of the scrubber where it cascades down a bank of alternately aligned slats. Turbulence within the scrubber provides contact between the scrubbing solution and the ammonia laden air.

The scrubber pictured in Figure 19 is a prototype and was manufactured using timber. The scrubber is patented (US patent 7,194,979). Currently, the scrubber is designed only for smaller diameter minimum ventilation fans, and is not suitable for 1220 mm to 1270 mm (48” to 50”) axial fans.

Figure 19 USDA-ARS ammonia scrubber installed on a broiler shed ventilation fan, *from* (Moore *et al.*, 2006))

Accumulation of ammonia in the scrubbing solution reduces the effectiveness of the scrubbing system and requires regular replacement. Once the solution becomes saturated with ammonia, it can be land applied as a nitrogen fertiliser. When used as a fertiliser, the solution has an additional benefit that it reduces the solubility of phosphorus, preventing phosphorus runoff (Moore *et al.*, 2006).

Costs

The USDA-ARS is a simple scrubber system, but will have costs associated with:

- initial purchase of the scrubber;
- installation the scrubber on a fan;
- supplying and replenishing the scrubber solution;
- operating the solution circulation pump;
- additional fan operating costs (due to increased static pressure); as well as
- cleaning and maintenance

The prototype scrubber costs $1,100 (based on US$1,000).

Operating costs associated with scrubber solution replenishment are difficult to estimate because it will depend on the frequency and duration of operation of the ventilation fan and scrubber, as well as the ammonia concentration within the building. It is assumed that the scrubber liquid would be replaced with every batch (for cleaning and sanitation) and would require 400 litres per batch. The scrubber will require an additional 90–180 litres of scrubbing liquid on a weekly basis to replace evaporation and droplet losses (based on estimations for use in USA). Consequently, an estimate of 1,000 litres of alum solution per batch is reasonable. An Australian supplier for liquid alum solution was not found; however, liquid alum solution can be made by dissolving dry, granular alum into water. Alum dissolves in water to form a solution of up to 5% alum concentration. Bulk, granular alum is available at a price of $700 per tonne. Consequently, when dissolved in water to produce a 5% solution, the cost of liquid alum is approximately $0.035 per litre. For 1,000 litres per batch of chickens, this equates to $35 ($210 per year for 5.5 batches).

The scrubber reduces fan performance by approximately 30%. Consequently, fan operating costs will increase.

With the above costs as well as powering and servicing of the recirculation pump, cleaning of the scrubber, annual operating and maintenance costs will be estimated at $1,500 per year per scrubber.

Performance

The performance of the scrubber has only been evaluated with regard to ammonia collection. During ideal operating conditions, the scrubber has been shown to trap 1.1–4.5 kg of ammonia per day (Moore *et al.*, 2006). With several scrubbers on each shed, there is potential to recover hundreds of kilograms of nitrogen per shed per year, to be used as fertiliser. It is unlikely that the scrubber, in its current form, would be effective in reducing odour concentration. The scrubber should, however, effectively trap dust particles.

Cost analysis

The following costs on a per chicken basis have been calculated according to the cost analysis assumptions (costs over ten years) and estimated costs for the technology. Estimated lifespan costs for the USDA-ARS scrubber system as described above are displayed in Table 7.

Table 7 Costs of installing and operating the USDA-ARS wet scrubbing system on a single, small diameter minimum ventilation fan

Capital cost ($)		$ 1,100
10 year lifespan capital cost ($/bird)		$ 0.0006
10 year operating cost ($)		$ 15,000
Operating cost ($/bird)		$ 0.0078
Total 10 year lifespan cost	**($/bird)**	**$ 0.0084**
	(¢/bird)	**0.84 ¢**

Assessment of the USDA-ARS scrubber for use on Australian broiler farms

The USDA-ARS scrubber has been designed to trap and reduce ammonia emissions during minimum ventilation conditions. Differences in production systems between the USA and Australia will reduce the applicability of this scrubber for use in Australia. In the USA, reuse of poultry litter within the shed results in periods of high ammonia concentration and low ventilation during the periods between batches and early growth stages. These are ideal conditions for efficient and effective trapping of ammonia in the scrubber. In Australia, however, litter reuse is not as widespread and consequently, ammonia concentrations within sheds are typically low between batches and during the early growth stages when ventilation is also low. By the time that significant quantities of ammonia are generated, ventilation also increases to maintain optimum temperature conditions within the shed. Consequently the ammonia concentrations within the sheds are usually relatively low, and the effectiveness of the scrubber to trap ammonia would be marginal. Additionally, it is only suitable for application on small diameter fans (less than 750 mm diameter). Therefore, it is unlikely that this scrubber would be suited to use on broiler production sheds in Australia.

This scrubber has not been designed or evaluated for the reduction of odour or dust emissions. It is expected that the scrubber could be used to reduce dust emissions. If this were the only goal, the alum scrubbing solution could be replaced with water, and the system could be operated at lower cost.

Appendix 3. Odour neutralising spray/ fogging systems

Technology description

Odour neutralisers are products which aim to eliminate offensive odours. Kolominskas *et al.* (2002) reviewed odour neutralisers and found them to be cost effective; however, there was insufficient evidence to prove the performance of the odour neutralisers to actually control odour emissions from broiler sheds. Simons (2006) trialled two odour neutralising products and concluded that these technologies were not effective in reducing total odour emissions from broiler sheds; however, a post-trial survey indicated that the products changed the character of the odour, which may have improved the way that the odour was perceived. This evaluation also revealed that olfactometry may not be an effective tool for evaluating odour neutralisers due to their own inherent odour.

The trials conducted by Simons (2006) appear to be the only publically available evaluation of odour neutralisers using olfactometry. No independent or scientifically valid evidence was found to support the odour neutralising claims of these products for use on broiler farms.

There are numerous odour neutralising products available in Australia. The odour neutralising products displayed in Table 8 were selected for inclusion in this review because they have already been installed into broiler sheds or are promoted as being suitable for installation into broiler sheds.

Table 8 Odour neutralising products reviewed in this report

Odour neutralising product	Supplier/ distributor	Type of product	Application method
Neutraliser-2 (N-2)	Odour Technologies Pty Ltd	Proprietary odour neutralising mixture with optional scent (not essential oils based)	High pressure fogging, inside shed just upwind from ventilation fans
Odour Kill	Your Earth Queensland (YEQ) Pty Ltd	Mixture of vegetable oil extracts	High pressure fogging on the external face of ventilation fans
Odour Eliminator (TS-2)	New Health Technology Australia Pty Ltd (NHTA)	Mixture of essential oils	High pressure fogging, inside shed
Water sprays (with optional scent)	Outback Environmental Controls Pty Ltd (OEC)	Water (with optional scent)	Medium pressure spray nozzles on the external face of each fan

Odour neutralising products need to be delivered into the broiler shed or into the exhaust air in an effective manner (depending on the product and manufacturer's recommendations). For the products identified during this review, the method of application is through spray or fogging nozzles. Configurations of these spray/fogging systems vary depending on the manufacturer. Figure 20 displays schematic drawings of different configurations of spray/fogging nozzles adopted by the different manufacturers.

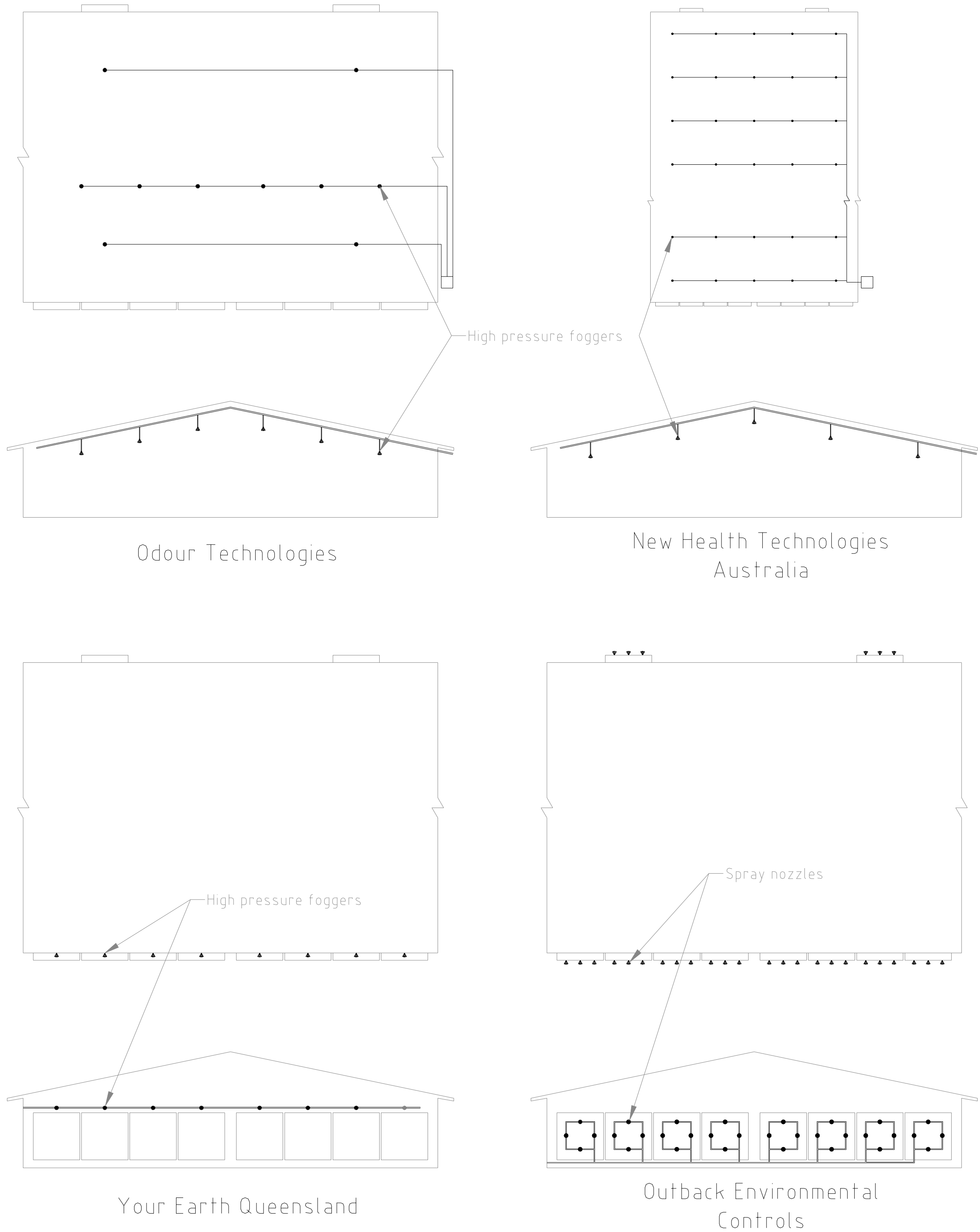

Figure 20 Configurations of spray/fogging systems for odour neutralising products as recommended by various manufacturers/distributors

Odour neutralising systems descriptions and costs

Neutraliser-2 by Odour Technologies Pty Ltd

Neutraliser-2 (N-2) is an odour neutralising product distributed by Odour Technologies Pty Ltd, Queensland. The N-2 odour control system has been installed on a meat chicken farm in south-east Queensland. N-2 is sold as a liquid solution and contains an active ingredient that reacts with odour molecules. According to the manufacturer, it breaks down the offending odour molecules leaving a slightly musty smell. A re-odorant is added to 'improve' the smell of the treated air by creating a mild bubblegum, lemon or floral scent. This re-odorant is used to reduce the amount of the active ingredient required (because it would be difficult to completely remove all odours) and assists users of the product to regulate the amount of the odour neutraliser that is required. It is recommended to increase the concentration of the N-2 until the re-odorant is just detectable. For this product to be effective, it is recommended that a high pressure fogging system is used (to create a very fine mist) and it is essential that the odour neutralising mist completely mixes with the odorous air.

The recommended high pressure fogging system is comprised of groups of high pressure fogging nozzles (see Figure 20). All nozzles are installed inside the broiler shed and are suspended from the ceiling approximately 2–5 m from the fans. Each nozzle has a flow rate of 4 L/h (litres per hour) and is operated at approximately 3.5 MPa (500 psi). The nozzles are placed inside the shed to enable adequate mixing of the odour neutraliser with the exhaust air. The groups of fogging nozzles are operated in stages depending on the number of active ventilation fans and the need to control odour emissions. During minimum ventilation conditions, one fogging nozzle can be operated to correspond with each active fan (up to four nozzles per shed). When the number of ventilation fans increase, a group of foggers (approximately six) are activated. The 'fog' from each nozzle is drawn out through the active ventilation fans (see Figure 21). The system can be installed in such a way that the fogging operation is manually controlled. Ideally, automatic solenoids, connected to the ventilation system, should be used so that foggers are activated to correspond with fan activity.

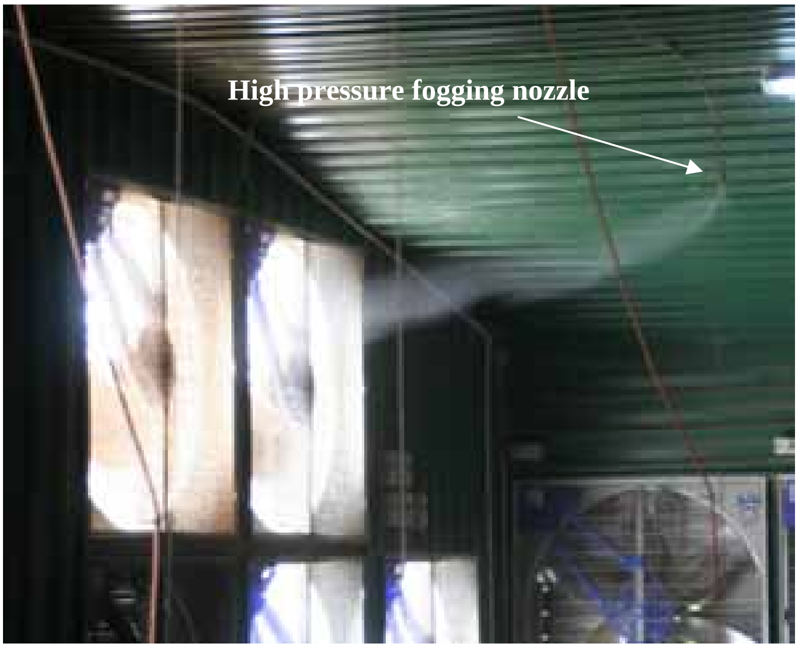

Figure 21 High pressure fogging nozzle with odour neutraliser being released through ventilation fan

Concentrated odour neutraliser solution (including the re-odorant) is diluted using an automatic dosing machine. The concentrate is diluted to form a 1% solution. This dilution rate can be adjusted depending on odour levels and odour control by the system. The diluted solution is then pumped using a high pressure pump. One pump has sufficient capacity to service more than one shed (at least four sheds can be serviced by one pump).

Capital costs vary depending on the size of the sheds, complexity of the system and the level of automation. The first shed will cost approximately $10,000, including the pump, dosing machine, filters and all plumbing and wiring. Additional sheds can be fitted out for approximately $2,000 per shed. If the system is installed across four sheds, the cost per shed is reduced to approximately $4,000.

Operating costs will vary depending on the amount of time that the odour neutraliser fogging system is required to operate throughout the batch. The concentrated odour neutralising solution costs approximately $10 per litre. It is applied into the shed at a 1% concentration, therefore, the cost of the fogging solution is about $10 per 100 litres. At a flow rate of 4 L/h per nozzle, the cost to run six nozzles (the maximum required to operate at any one time) is $2.40 per hour.

To calculate approximately how much it will cost to operate per batch, it will be assumed that the odour neutralising system would not be required before day 21 during a production cycle (due to low odour potential). It will be assumed that the system will only be required on average 12 hours per day with an average of five nozzles operating. This equates to a total volume of 240 litres and a cost of $24 per day. For a batch of 35,000 birds grown to 51 days, this equates to a cost of 2.1 cents per bird. This should be considered a worst case scenario. In reality, the producer will be able to turn off the system at all times when odour control is not required (e.g. when the wind is blowing away from sensitive receptors or during unstable atmospheric conditions when odour dispersion is greatest).

Maintenance costs will vary depending on water quality and operating time for the fogging system. It is expected that the fogging nozzles may need cleaning or replacement every six months (replacement cost $9 per nozzle), and the pump may need servicing annually at a cost of $500.

The ten year lifespan costs for this odour neutralising system are shown in Table 9.

Table 9 Lifespan costs (over ten years) for *Neutraliser-2* and fogging system

Installation scenario	**4 sheds, operating 12 hours a day for days 21 to 51**		**4 sheds, operating 8 hours a day for days 25 to 45 of the batch**	
	$ (per shed)	**$/bird 10 year lifespan cost**	**$ (per shed)**	**$/bird 10 year lifespan cost**
Capital costs	$ 4,000	$ 0.0021	$ 4,000	$ 0.0021
10 year operating costs	$ 43,200	$ 0.0224	$ 19,200	$ 0.0100
10 year maintenance costs	$ 6,800	$ 0.0035	$ 6,800	$ 0.0035
Total 10 year lifespan	$ 54,000	**$ 0.0281**	$ 30,000	**$ 0.0156**
(¢/bird)		**2.8 ¢**		**1.6 ¢**

From these costs estimates, the major cost is associated with supply of the odour neutralising agent. Consequently, in order to keep costs down, the grower could choose to deactivate the system whenever odour control is not required. If the system was operated 24 hours a day for 35 days of a batch, costs could increase to 6.6 cents per bird.

Odour Kill by Your Earth Queensland Pty Ltd

Odour Kill (OK) is an odour neutralising product distributed by Your Earth Queensland Pty Ltd. The OK odour control system has been installed on a meat chicken farm in south-east Queensland. OK is sold as a liquid solution and contains an active ingredient based on vegetable oil extracts. It was developed in Perth specifically for hydrogen sulphide control at sewage treatment plants but has also been used to control phenolic odours found at foundries. For poultry applications, it is recommended that OK is delivered at a 0.5% concentration. The concentrated liquid is valued at approximately $36 per litres.

It is recommended that OK is administered on the outside of the ventilation fans using high pressure foggers (see Figure 20). At the broiler farm where the system has been installed, eight fogging nozzles (standard cooling foggers) have been installed on a high pressure pipe line just above the tunnel ventilation fans (see Figure 22). The system is manually operated by the producer. Diluted OK is stored in a 1000 L module. High water pressure has been provided using an economically priced high pressure cleaner (as a substitute for a high pressure pump), and is controlled using a pressure release system. The system has seldom been used because odour nuisance has not occurred at this farm. A timer has been installed to operate the system intermittently when required.

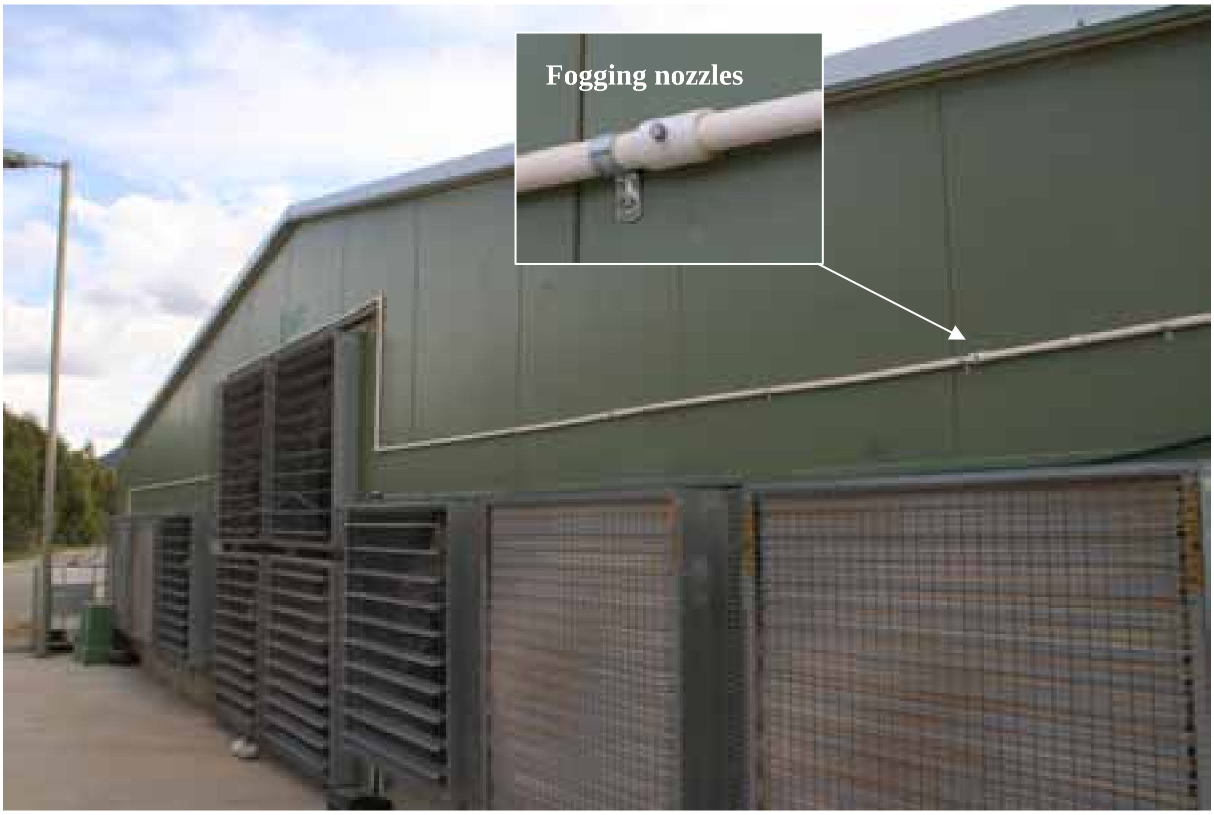

Figure 22 Installation of the *Odour Kill* system on a SE Queensland broiler farm

The fogging system was designed and installed by the producer for a cost of approximately $1,000 per shed. The producer estimated that approximately 1,000 litres of the diluted solution would be required per batch if the system were frequently used, equating to a cost of $200.

The ten year lifespan costs for the *Odour Kill* odour control system are shown in Table 10.

Table 10 Lifespan costs (calculated over ten years) for *Odour Kill* odour control and fogging system

Installation scenario	Single shed operated intermittently	
	$	**$/bird 10 year lifespan cost**
Capital costs	$ 1,000	$ 0.0005
10 year Operating costs	$ 12,000	$ 0.0062
10 year Maintenance costs	$ 1,000	$ 0.0005
Total 10 year lifespan	$ 14,000	**$ 0.0072**
(¢/bird)		**0.72 ¢**

Assessment of odour control has been undertaken by *Airlabs Australia* on a single occasion using dynamic olfactometry. The data was not available at the time of writing this report, however, the distributor reported an odour reduction of 80% after 30 minutes of operation.

Odour Eliminator (TS-2) by New Health Technology Australia Pty Ltd

Odour Eliminator is an odour neutralising product distributed by New Health Technology Australia Pty Ltd. It is sold in a liquid solution and contains active ingredients based on essential oils (including clove, cypress, eucalyptus, mint, pine, rosemary, savoury and thyme). It has a natural eucalyptus/menthol scent. According to the manufacturer, *Odour Eliminator* controls odours by destroying offensive odour molecules as well as controlling the bacteria which create the offensive odours.

The distributor recommends that the product is applied within the meat chicken shed using a grid of high pressure fogging nozzles (see Figure 20). New Health Technology Australia Pty Ltd engages specialist fogging system distributors to design and install the fogging system. Each fogging nozzle covers an area of 3 m by 3 m. Consequently, fogging nozzles are placed at 3 m intervals (1.5 m from walls). A high pressure pump and automatic dosing system is used to supply diluted product (variable rate 0.5%–1.0%) at 5–7 MPa pressure. The odour neutralising agent is applied throughout the production cycle according to Table 11. It is estimated that a typical meat chicken shed installation will cost between $10,000 and $30,000.

Table 11 Application program for *Odour Eliminator* in broiler sheds

Batch Age	Application strength	Application timing
0 to 2 weeks	0.5%	15 seconds every hour
2 to 4 weeks	1.0%	20 seconds every hour
4 weeks to end	1.0%	30 seconds every hour

Odour Eliminator concentrate retails for approximately $54 per litre. By adopting the application program in Table 11, and assuming that the chickens are grown to 56 days, approximately 1,900 litres of diluted *Odour Eliminator* (including 18 litres of the concentrate) will be required per batch. This equates to a value of $950 per batch. If the chickens are only grown to 42 days, this cost is reduced to approximately $630 per batch.

The lifespan costs (calculated over ten years) for *Odour Eliminator* are shown in Table 12.

Table 12 Lifespan costs (calculated over ten years) for *Odour Eliminator* odour control and fogging system

Installation scenario	**Single shed operated intermittently (batch age 56 days)**		**Single shed operated intermittently (batch age 42 days)**	
	$	**$/bird 10 year lifespan cost**	**$**	**$/bird 10 year lifespan cost**
Capital costs	$ 20,000	$ 0.0104	$ 20,000	$ 0.0104
10 year Operating costs	$ 57,000	$ 0.0296	$ 37,800	$ 0.0196
10 year Maintenance costs (estimated)	$ 10,000	$ 0.0052	$ 10,000	$ 0.0052
Total 10 year lifespan	$ 87,000	**$ 0.0452**	$ 67,800	**$ 0.0352**
(¢/bird)		**4.5 ¢**		**3.5 ¢**

Testing in Australia and Europe has indicated that *Odour Eliminator* can reduce ammonia levels in sheds, eliminate poultry mites (a problem mainly for laying hens, tests conducted in Germany), and improve feed conversion and bird health. *Odour Eliminator* is currently being evaluated for odour control and improved feed conversion at a broiler farm in New South Wales. If improved feed conversion can be proven under Australian conditions, some of the costs to operate the system would be offset by improved production efficiency and profits.

Water Sprays by Outback Environmental Controls Pty Ltd

Outback Environmental Controls Pty Ltd have developed a spray system that can be used to control odour and dust emissions from tunnel ventilated broiler sheds. The spray nozzles are arranged so that four nozzles are mounted on the outside of each ventilation fan (see Figure 20 and Figure 23). Clean water, or water with an added lemon scent, are sprayed from each nozzle. This system has been installed at several broiler farms in south-east Queensland.

The spray nozzles operate at 500–1,400 kPa (80–200 psi) pressure. Each nozzle delivers approximately 4 L/h, which equates to 16 L/h per fan. Each fan has its own solenoid valve, which activates the spray nozzles only when the corresponding fan is active.

Figure 23 OEC water sprays mounted on the outside of a ventilation fan

Costs for this system are minimal. A pump and filter costs approximately $300. The spray nozzles, plumbing and solenoid valve cost approximately $120 installed.

Water use is one consideration with this system. If a batch of chickens requires 7,000 fan hours (which is approximately five fans active throughout a 56 day batch cycle) approximately 110,000 litres will be required per batch. The exact cost of this water is difficult to calculate, as it will be dependent on where the farm sources water (town supply or bore). It will be assumed that water is worth $1,150 per ML (for town water supply). At this rate, water would cost approximately $125 per batch. It would be expected, however, that the actual operating time will be less than this because odour suppression would not normally be required all of the time (especially early in the batch or during favourable weather conditions). Consequently, the actual volume of water required would be much less.

The ten year lifespan costs for the OEC water spray system are provided in Table 13.

Table 13 Lifespan costs (calculated over ten years) for *OEC* spray system

Installation scenario	**Single shed (12 fans) operated continuously (batch age 56 days)**		**Single shed (12 fans) operated for half the batch (batch age 56 days)**	
	$	**$/bird lifespan cost**	**$**	**$/bird lifespan cost**
Capital costs	$ 1,750	$ 0.0009	$ 1,750	$ 0.0009
10 year operating costs	$ 8,000	$ 0.0042	$ 4,000	$ 0.0021
10 year maintenance costs (estimated)	$ 5,000	$ 0.0026	$ 5,000	$ 0.0026
Total 10 year lifespan	$ 14,750	**$ 0.0077**	$ 10,750	**$ 0.0056**
(¢/bird)		**0.77 ¢**		**0.56 ¢**

No formal testing has been undertaken to quantify odour and dust reduction as a result of these sprays. It would be expected that some dust would be intercepted by the spray droplets and fall out of the airstream.

Summary of costs for odour neutralising agents

Lifespan costs (calculated over ten years) for assorted odour neutralising agents and application systems are summarised in Table 14. It can be seen that costs vary from 0.6 ¢/bird to 4.8 ¢/bird. In most cases, the majority of these costs are associated with supply of the active odour neutralising agent.

Table 14 Ten year lifespan costs for odour neutralising products reviewed in this report

Odour neutralising product	Supplier/ distributor	Estimated 10 year lifespan costs (¢/bird)
Neutraliser-2 (N-2)	Odour Technologies Pty Ltd	1.6 to 2.8
Odour Kill	Your Earth Queensland (YEQ) Pty Ltd	0.7
Odour Eliminator (TS-2)	New Health Technology Australia Pty Ltd (NHTA)	3.5 to 4.5
Water sprays (with optional scent)	Outback Environmental Controls Pty Ltd (OEC)	0.6 to 0.8

Summary of odour neutralising agent

Odour control systems, which use odour neutralising agents, offer an on-demand style of air treatment. With most of these systems, treatment can be halted and then resumed at the flick of a switch. This flexibility allows cost savings when odour impacts are unlikely, and the option to re-activate the system at times when odour impacts are likely.

The majority of the costs associated with odour neutralising agent treatment systems are related to the supply of the odour neutralising agent. Capital costs are generally only a fairly small proportion of the overall lifespan cost. Consequently, if such a system is to be installed, careful consideration should be given to automating the system as much as possible. Potentially, an outlay of a few hundred or thousand dollars for solenoids and programmable spray controllers may be recovered if the amount of odour neutralising agent required for adequate treatment is reduced.

Assuming that the odour neutralising agents actually eliminate offensive odours, it is essential that the correct amount of the odour neutralising agent is able to mix with the odorous air. This may require site specific adjustments to get the correct number and position of fogging nozzles as well as the correct dilution of the odour neutralising agent, in order to achieve adequate odour control. There are significant differences in the recommended designs of fogging and spray systems, even for similar styles of products (e.g. essential oils). This raises questions as to which is the most appropriate way to apply the product, and how important is it to get the application exactly as recommended by the manufacturer. If considering the installation of an odour neutralising fogging system, producers should ensure that the system has been used previously in broiler farms, and shown to be effective.

Unfortunately, there is very limited evidence to support the claims of odour reduction being made by distributors of the odour neutralising agents. This was also found by Kolominskas *et al.* (2002). Trials by Simons (2006) were unable to demonstrate a reduction in odour emissions using two commercially available odour neutralisers (the products trialled were different from those included in this report). The assessment of these products is challenging because reactions with the odorous ventilation air are poorly controlled and because of the neutralising agents add their own baseline odour to the odour concentration being measured using olfactometry (Simons, 2006). Before investing in these products, producers need to be provided with evidence that odour neutralising agents will actually reduce odour emissions from their farm, or will treat the odour emissions to prevent odour nuisance occurring at sensitive receptors.

Appendix 4. Electrostatic dust precipitation

BEI Electrostatic Particulate Ionisation (EPI) system

Technology description

The use of electrostatic technology to control dustiness in animal housing was developed during the 1990s and has been described by Mitchell (1997), Mitchell and Baumgartner (2007), Mitchell *et al.* (2004; 2003) and Ritz *et al.* (2006). This system has been made available by *Baumgarter Environics Inc.* (BEI, Olivia, Minnesota, USA, http://www.beiagsolutions.com). It will be referred to as the *Electrostatic Particulate Ionisation system (EPI)*. Recent business arrangements should make this system available in Australia shortly through local suppliers.

The EPI system operates by using high negative voltage (-30,000 V) and low current (up to 2 mA) to ionise particles in the air. Negative ionisation polarises the charge on particulates, which causes them to be attracted to 'grounded' surfaces like the floor, walls, ceilings or specially installed ground planes. The process is analogous to the forces between a magnet and a metal surface. Ionised particles will become attached to the surface and will not be re-suspended unless the ionising charge is turned off, or other forces exceed the force of attraction between the ionised particles and the grounded surface (e.g. gravitational forces on a large clump of dust, or friction force with strong winds). By attracting dust particles to the walls, ceiling and ground, fewer dust particles are airborne. This reduces the amount of dust available to be breathed in by workers or animals, and reduces the amount of dust available to be exhausted from the shed. If particles are resuspended by chicken activity, they are immediately re-ionised and attracted back to the ground (Hagen, 2007).

The EPI system is composed of a high voltage, low current power supply (see Figure 24) and stainless steel wires with sharp pointed electrodes (see Figure 25). The high voltage, low current power supply has a power lead that can be plugged into any standard power outlet. This enables the unit to be easily installed (if a power point is conveniently located) and can be easily turned on and off at the flick of a switch. Continuous power consumption is approximately 100 W for a broiler shed. The stainless steel electrodes are suspended from the ceiling using insulators. In previously reported installations in broiler houses (Mitchell and Baumgartner, 2007; Mitchell *et al.*, 2003), two rows of electrodes, running the entire length of the shed, were installed 2.1 m above the ground.

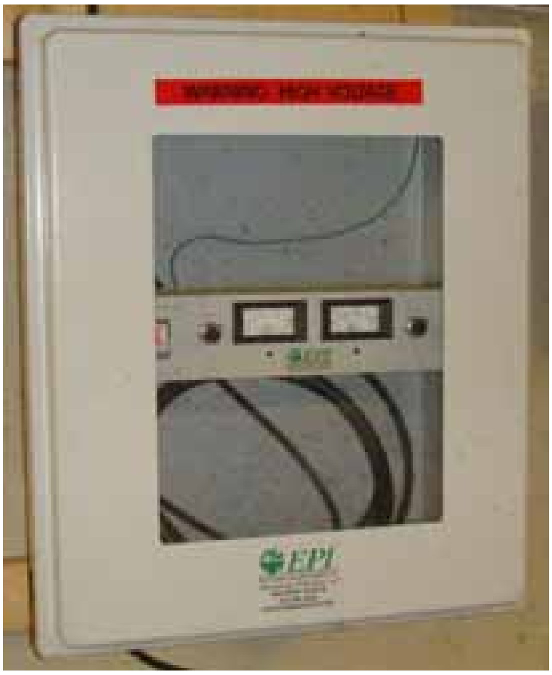

Figure 24 EPI system high voltage, low current power supply

Figure 25 Stainless steel ionization wires with sharp pointed electrodes (insulator on the top left side of photo)

Design considerations in tunnel ventilated meat chicken sheds

The EPI system is well suited to installation in broiler houses. Typically, two rows of the ion generating wires are run the entire length of the shed. A ground plane, in the form of a metal pipe, can be suspended, if required, just above the ionising wire to maximise collection of dust particles. It is likely, however, that the ceiling and walls will provide an adequate grounding surface.

The EPI system currently available in the US is warranted for a period of five years. Life expectancy is greater than ten years.

Costs

Price for the system is estimated at $8.50 per square metre of floor space (US$0.75 per sq foot) fully installed. Consequently installation costs would range from $10,200 for a 12 m wide by 100 m long shed to $19,125 for a shed 15 m wide by 150 m long.

Operating costs are approximately equal to 100 W (Mitchell and Baumgartner, 2007; Ritz *et al.*, 2006). Electricity costs are estimated at 16 cents per kilowatt hour (cents/kW.h). Consequently, the system will cost $0.41 per day or $149 to operate 365 days a year.

Cost analysis

The following costs on a per chicken basis have been calculated according to the cost analysis assumptions (costs over ten years) and estimated costs for the technology. This technology is costed on a per square metre of floor basis, consequently, the costs increase with larger sheds, but the per bird price is approximately similar assuming bird density is similar. The costs have been calculated for three different size sheds, each with a density of 19 birds per square metre. Estimated lifespan costs for installations of the EPI system, as described above, are displayed in Table 15. It can be seen that the cost per bird is approximately 0.87–0.93¢/bird.

Table 15 Costs of installing and operating the EPI system (calculated over ten years, 5.5 batches per year))

Installation scenario	For a 12 m wide by 100 m long shed		For a 14.7 m wide by 125 m long shed		For a 15 m wide by 150 m long shed	
	$	$/bird	$	$/bird	$	$/bird
Number of birds/batch	**22,800**		**35,000**		**42,750**	
Capital costs ($)	$ 10,200	$ 0.0081	$ 15,620	$ 0.0081	$ 19,125	$ 0.0081
10 year operating Costs ($) (Maximum)	$ 1,500	$ 0.0012	$ 1,500	$ 0.0008	$ 1,500	$ 0.0006
Total 10 year lifespan costs	**$ 11,700**	**$ 0.0093**	**$ 17,120**	**$ 0.0089**	**$ 20,625**	**$ 0.0087**
(¢/bird)	**0.93 ¢**		**0.89 ¢**		**0.87 ¢**	

Performance data

The EPI system has been tested in broiler houses, broiler and turkey breeding houses, hatcheries, layer sheds and piggeries. Testing of the EPI in a number of intensive animal production systems has been reported (Heber *et al.*, 2006; Mitchell, 1997; Mitchell *et al.*, 2004; Mitchell and Baumgartner, 2007; Mitchell *et al.*, 2003; Ritz *et al.*, 2006).

The EPI system has been evaluated for reducing airborne dust (PM_{10} concentration), ammonia and bacterial concentrations. Ritz *et al.* (2006) found that the EPI system reduced airborne dust concentration by 43% and ammonia by 13% in a broiler production house. Mitchell *et al.* (2004) found that the EPI system reduced airborne dust by 61%, ammonia by 56% and airborne bacteria by 67%.

Because the EPI system is installed inside the broiler shed, air quality inside the shed is improved. This is in comparison with ‘end-of-shed’ dust filters, which do not have any influence on indoor air quality. Consequently, the EPI system can reduce the impacts of dust, ammonia and pathogens on animals, farm workers and researchers (Mitchell *et al.*, 2003).

Maintenance requirements

Earlier versions of the EPI system required cleaning weekly, or fortnightly. Cleaning takes about an hour per shed and requires brushing the dust off the insulators that suspend the ionising wire with a long handled brush (Mitchell *et al.*, 2003; Ritz *et al.*, 2006). Recent improvements in the design of the system may reduce the frequency of cleaning, or the length of time required for each clean (Mitchell and Baumgartner, 2007).

Complete cleaning of the entire system at the end of each batch would be achieved during normal shed washing. The system is completely sealed and can be washed using high pressure water.

There are no moving or sacrificial parts. Consequently, no specialist or regular maintenance other than cleaning is expected.

Inspection of the EPI system

The EPI system was inspected during September 2007 at a piggery, a turkey breeder house and in a turkey hatching room. In both the piggery and the turkey farms, the production buildings were separated into two rooms. The EPI system was installed in only one of the rooms, allowing a comparison between the EPI treatment and a control.

In the piggery, dust had accumulated on the ceiling, directly above the EPI ionising wires. In the treated room (compared to the control), the air appeared to be less dusty, and may have been slightly less odorous as well. Figure 26 shows the accumulation of dust on the ceiling directly above the EPI ionising wires.

Figure 26 Accumulation of dust on the ceiling directly above the EPI system (left and right)

The turkey breeder house had a litter floor, much the same as the floor material used in broiler sheds in Australia. The building was divided into two separate rooms. One of these had the EPI system installed (Figure 27, right) and the other was left untreated (Figure 27, left) (note that different coloured lights were used in each room and the variation in colour in the two photos was not due to the EPI system). In the EPI treated room, dust accumulation was visible on the ceiling immediately above the two ionising wires (see Figure 28). Ammonia and dust concentrations in the two rooms were noticeably different. In the untreated room, the concentration of ammonia was sufficient to cause eye and throat irritation whereas in the EPI treated room, it was barely detectible. Also, in the untreated room, the air was noticeably hazy and felt gritty whereas in the EPI treated room, the air seemed cleaner.

Figure 27 Turkey breeder house: *Left* – room without EPI system and *Right* – room with EPI system (note accumulation of dust on ceiling where the EPI system is installed; also, lighting was different in both rooms)

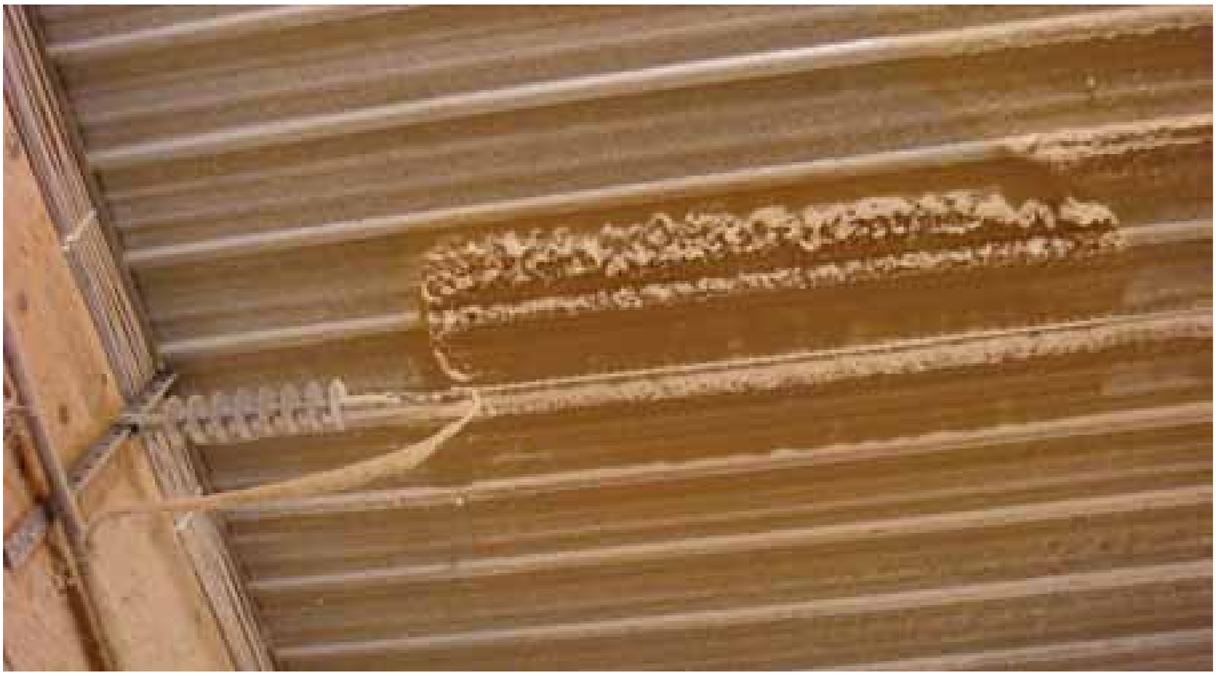

Figure 28 Accumulation of dust on the ceiling directly above the EPI ionising wires

While inspecting the EPI system at the turkey farm, the system was turned off for a few minutes in order to demonstrate what would happen. Within a few moments, clumps of dust detached from the ceiling and began falling (see Figure 29). When the system was turned on again, the smaller clumps of dust were again attracted to the ceiling. The larger clumps continued to fall to the ground.

Figure 29 Clumps of particulates detached from the ceiling when the EPI system was turned off

The EPI system was also inspected in a turkey hatching room (see Figure 30). In this room, machinery was used to separate the turkey hatchlings from the shells. Upon arrival, the air in the hatching room was filled with particulates resembling the small feathers on the hatchlings. It was discovered that the EPI system had not been switched back on after cleaning on the previous day (the hatching room was pressure cleaned every afternoon once all of the hatchlings had been processed).

Figure 30 Turkey hatching room where the EPI system was installed (EPI ionising wires are visible above the machinery

Once the system was turned back on, the feather and dust particles began attaching to the EPI system ground plane (which was installed above the ionising wires, see Figure 31) and to other grounded equipment (see Figure 32). For this EPI installation, some sections of the ionising wire were shielded to prevent dust from accumulating on certain parts of the machinery.

Figure 31 **Dust and feather particles attracting to the ground plane**

Figure 32 **Feather particles attracting to hydraulic hoses (grounded surface). Also breaks in the ionising wire can be used to prevent dust precipitation in places where dust accumulation is not wanted.**

Summary of the EPI system

The *Electrostatic Particulate Ionisation* (EPI) system offers a unique way to improve indoor air quality within the broiler building, which will lead to reduced dust emissions from the building. The system operates by polarising dust particles, which makes them attract to 'grounded' surfaces like the floor, walls, ceilings and specially installed ground planes. The efficacy of the system to reduce airborne concentrations of dust, ammonia and bacteria has been evaluated in broiler farms, layer farms, poultry breeding farms and piggeries. The results of these evaluations have been documented in scientific journals. The improvement of indoor air quality could have a beneficial effect on bird health and productivity as well as improve working conditions for poultry farm workers.

The EPI system is simple, easy to install and has very low operating costs. The system will not interfere with the ventilation systems used in tunnel ventilated broiler sheds (as, for example, filters will). Management practices need to be refined to prevent accumulated dust being released suddenly by de-activation of the EPI system. Frequency of cleaning intervals for Australian broiler sheds needs to be determined.

The following points summarise some of the features and considerations associated with the EPI system:

- Independent research has demonstrated the reduction in airborne dust and ammonia levels in broiler sheds.
- Reduction in airborne dust, ammonia and bacteria improve the indoor environment for animals and workers.
- The system will not impede ventilation or airflow within the shed.
- Low power consumption.
- High voltage power source is powered from a standard power outlet.
- Minimal maintenance and cleaning.
- The presence of high voltage lines in the poultry shed constitutes a minor electrical risk (current limited to 2 mA is insufficient to cause any injury). This risk can be managed with the use of appropriate clothing and equipment or by switching off the system when there is potential to contact the ionising lines (e.g. during cleaning, but not required when entering the shed for normal activities).
- Dust attracted to grounded surfaces is released and may become resuspended when the power is switched off.

Appendix 5. Dust control structures

Simple Structures

Technology description

There are many structures that are available to control dust. These range from simple hoods, which are designed to direct dust and feathers to the ground (Ministry of Agriculture and Food, 1999) and windbreak walls to structures specially designed to settle and collect dust particles by altering the aerodynamics of the exhaust air stream (see the section on BioCurtain® below).

Hoods can be installed on individual minimum or tunnel ventilation fans (see Figure 33, 900mm (36”) fans) or on groups of tunnel ventilation fans (see Figure 34, hereafter referred to as *grouped fan hoods*).

Figure 33 Hoods placed over 915 mm (36”) fans to direct dust and feathers downward

When dust particles are directed downward by a hood, a proportion of the dust becomes lodged on the ground surface (see Figure 34), on ground covers (eg grass) and on the inside of the hood itself (see Figure 35 and Figure 36).

Bolla (2002) made reference to fan hoods as a technology to improve light control, reduce noise, reduce dust dispersion and reduce air blast and dust while walking past fans. He also mentioned that fan hoods could help to maintain fan performance by protecting fans from buffeting winds. It was suggested that boxed fan housings (as shown in Figure 34) may provide adequate control of odour and dust.

Figure 34 Grouped fan hoods placed over tunnel ventilation fans to direct dust and feathers downward

Figure 35 The hood shown in Figure 34 with access flap raised to show visible accumulation of dust

Figure 36 Interior view of the dust hood shown in Figure 34 showing the visible accumulation of dust

As an alternative to the fan hoods, construction of a windbreak wall (see Figure 37) might provide similar dust control. Kolominskas *et al.* (2002) reported that improved dispersion and deposition of particulates due to the windbreak wall will reduce ground level concentrations of particulate matter.

The operation of hoods and windbreak walls are completely opposite. The hood shown in Figure 34 exhausts air at ground level, so that dust, not settled in the hood itself, will be more likely to settle nearby. The windbreak wall, on the other hand, exhausts air in an upward direction. Therefore, dust not settled within the wall will be exhausted in a vertical direction where it will either disperse into the atmosphere or will settle some distance further away.


Figure 37 Windbreak wall constructed at a broiler farm

In a recent evaluation of windbreak walls (Dunlop and Galvin, 2006), a windbreak wall was constructed on a broiler shed. The wall was constructed using steel framework and corrugated iron sheeting. Construction of this wall was completed when the birds were approximately 28 days old. Five days following installation of the windbreak wall, a thin layer of dust was visible on the inside surface of the wall, with most of the dust concentrated directly in front of the minimum ventilation fan (see Figure 38). Fifteen days following installation of the windbreak wall, significantly more dust was attached to the inside surface of the windbreak wall (see Figure 39).

Accumulation of dust appeared greatest on the corrugated iron directly above each of the horizontal purlins. It is assumed that turbulent eddies and lower velocities in these areas allowed dust particles to become detached from the general airflow and settle on the wall. It may be possible to take full advantage of this by changing the conditions within the windbreak wall to maximise turbulence and stagnation zones. It was observed at this windbreak wall installation, that when low numbers of fans were active, air tended to swirl inside the windbreak wall, providing an opportunity for dust particles to settle or become attached to the wall. Therefore, to optimise dust and feather containment, the windbreak wall should be constructed with side walls (as shown) and extending as far as possible away from the ventilation fans in order to minimise the velocity of air being exhausted over the wall.

Figure 38 Dust on the windbreak wall 5 days after construction (birds aged 28 to 33 days during this period)

Figure 39 Dust on the windbreak wall 15 days after construction (birds aged 28 to 43 days during this period)

Design considerations in tunnel ventilated meat chicken sheds

If installing simple fan hoods, it is necessary to consider the potential for reduced fan performance due to pressure losses (due to rapid changes in airflow direction and flow restrictions). For the farm shown in Figure 33, hoods had been installed on the tunnel ventilation fans (1220 mm (48”) diameter fans). The ground was excavated beneath these larger fans in an attempt to improve fan performance while the hoods were fitted (see Figure 40). The hoods have since been removed from the fans (and can be seen to the right of the fans in Figure 40). For the hoods displayed in Figure 34, velocity measurements inside the shed confirmed that adequate tunnel ventilation velocities were still being achieved, therefore any reduction in fan performance attributable by the hoods was not considered to be significant.

Figure 40 Excavation under fans to improve fan performance when hoods were fitted

Costs

Individual fan hoods can be manufactured by any sheet metal manufacturer. Prices for individual fan hoods was found to be $245 for hoods to suit 1,220 mm (48”) diameter fans and $225 for hoods to suit 915 mm (36”) diameter fans. As examples of how much this would cost per shed, for the purpose of the lifespan cost analysis, it will be assumed that a typical shed has ten tunnel ventilation fans (1,220 mm) and two side ventilation fans (915 mm). The cost of hoods per shed in this case will be $2,900.

Grouped fan hoods (as installed at the farm displayed in Figure 34) were installed in the year 2000 at a cost of $2,500 per shed. With large increases in steel prices since then, it is estimated that the materials alone would now cost this amount. Once labour costs are included, overall costs to manufacture and install these hoods would be expected to cost $3,500 to $4,000 per shed.

Operating and maintenance costs are very difficult to estimate for fan hoods. Fan hoods would require cleaning between batches (with associated labour and cleaning agent costs). The hood would also increase fan running costs (due to flow restrictions), which would increase the operating costs. Taking all of this into account, it is estimated that additional operating and maintenance costs would amount to $4,000 over the ten year lifespan. While it has been assumed that these hoods would last ten years, it is expected that the actual serviceable life would be much greater.

The windbreak wall constructed in Figure 37 cost less than $5,000 in materials and was constructed by two workers within four days. Kolominskas *et al.* (2002) provided a total construction cost for a steel framed windbreak wall at $15,000. For the purpose of undertaking a cost analysis, this value will be adopted as it should be sufficient to cover engineering design, construction and building approval costs.

Operating costs for a windbreak wall will be negligible, especially if the wall is constructed sufficiently far away from the fans (approximately four to five fan diameters away from the fans). Some additional costs will be incurred during cleaning, as extra water, time and cleaning agents will be required. These costs are estimated at $300 per year.

Performance data

No performance data could be found to support the efficacy of simple hoods as a dust control technology. Their use, however, is recommended by the Ministry of Agriculture and Food, British Columbia (1999) on 600 mm and 900 mm (24" and 36") fans as one method to reduce complaints about dust by directing dust and feathers to the ground.

Maintenance requirements

The simple fan hoods require virtually no maintenance apart from washing at the end of each growing cycle. This washing would be undertaken at the same time that fans are washed down.

BioCurtain®

Technology description

BioCurtain® (see Figure 41) is a technology that was developed by Baumgartner Environics Inc. (Olivia, Minnesota, USA, http://www.beiagsolutions.com). It is comprised of a metal frame structure, covered with a woven geotextile fabric. This structure is used to enclose a group of ventilation fans.

Figure 41 BioCurtain® installed on a pig shed in Minnesota, USA

The BioCurtain® operates by altering the aerodynamics of the air being exhausted from the building. Figure 42 illustrates how the air, exhausted through the fans, is directed toward the geo-textile and then down into the bottom corner of the structure, where dust settles out of the air stream. The 'de-dusted' air is then exhausted in a vertical direction. Some air will also diffuse through the geotextile material.

The addition of an electrostatic particulate ionisation system (described above in Appendix , as EPI) in the BioCurtain® can improve dust collection within the structure. If the EPI is installed, the BioCurtain® design can be modified so that air is exhausted along the ground. This takes full advantage of the ionized dust particles being attracted to the ground surface.

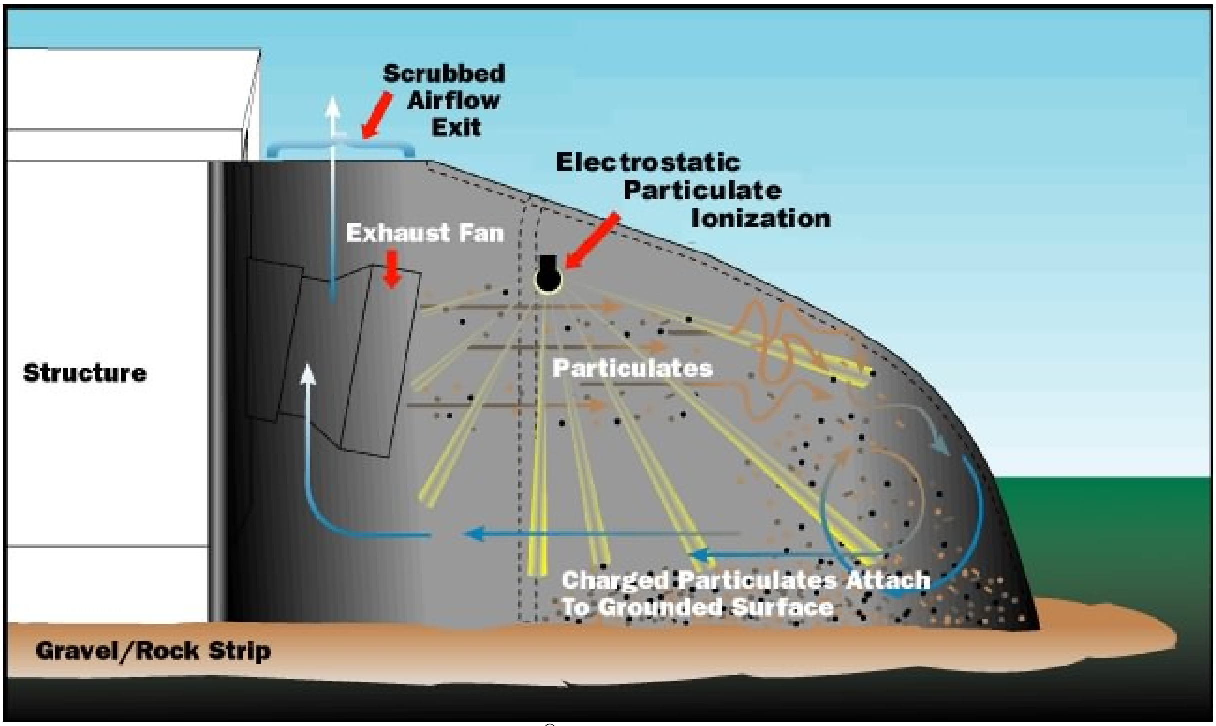

Figure 42 Schematic operation of a BioCurtain® (fitted with optional Electrostatic Particulate Ionisation system) displaying how air moves within the technology (http://www.beiagsolutions.com/bio-curtain.htm)

Design considerations in tunnel ventilated meat chicken sheds

The BioCurtain® is suited to application on tunnel ventilated poultry farms because it can enclose all of the tunnel ventilation fans (assuming they are not positioned on the sides of the shed). The design of the BioCurtain® provides an effective distance of three to four fan diameters between the fans and the geotextile surface. According to the guidelines recommended by Ford and Riskowski (2003), this should not impose any significant back pressure on the fans. Additionally, the slightly porous nature of the geotextile material will allow some airflow to pass through it. Consequently, decline of fan performance would not be expected with the use of a BioCurtain®.

The geotextile material of the BioCurtain® has been found to be self-cleaning (during rain), however, some consideration would need to be given to removing the accumulated dust particles at appropriate intervals.

In order for the BioCurtain® to treat air exhausted from side wall fans, separate BioCurtains® units can be installed on each of these fans.

Costs

The cost of the BioCurtain® is estimated at $7,000 (US$6,500). The geotextile material is expected to last approximately ten years. The BioCurtain® displayed in Figure 41 was approximately eight years old when the photo was taken. Some deterioration of the geotextile is visible, but overall performance would not be greatly affected.

Operating costs for the BioCurtain® would be minimal. Fan operating costs should not increase and minimal maintenance would be required to clean the BioCurtain® structure. Some costs could be expected for cleaning accumulated dust from inside the structure. Ongoing costs associated with the BioCurtain® are conservatively estimated at $500 per annum.

Installation of electrostatic particulate ionisation inside the Biocurtain® (EPI, BEI, Minnesota, USA) costs approximately $1,100 (US$1,000). Cleaning and maintenance costs of this unit would be negligible, however, electricity costs would be approximately $150 per annum if run continuously.

Cost analysis for simple structures and BioCurtain®

The following costs on a per chicken basis have been calculated according to the cost analysis assumptions (costs over ten years) and estimated costs for the technology. Estimated lifespan costs for dust control structures are displayed in Table 16.

Table 16 Costs of installing and operating dust control structures

Installation scenario		**Individual fan hoods**	**Fan hood covering multiple fans**	**BioCurtain® on all tunnel ventilation fans**	**BioCurtain® plus EPI system**	**Windbreak Wall**
Capital cost ($)		$ 2,900	$ 4,000	$ 7,000	$ 8,100	$ 15,000
10 year lifespan capital cost ($/bird)		$ 0.0015	$ 0.0021	$ 0.0036	$ 0.0042	$ 0.0078
10 year Operating costs ($)		$ 4,000	$ 4,000	$ 5,000	$7,000	$ 3,000
Operating cost ($/bird)		$ 0.0021	$ 0.0021	$ 0.0026	$ 0.0036	$ 0.0016
Total 10 year cost	**($/bird)**	**$ 0.0036**	**$ 0.0042**	**$ 0.0062**	**$ 0.0078**	**$ 0.009**
	(¢/bird)	**0.4 ¢**	**0.4 ¢**	**0.6 ¢**	**0.8 ¢**	**0.9¢**

Performance data

Efficacy of the BioCurtain®, without an electrostatic particulate ionisation system, to reduce dust emissions has been measured on poultry and piggery applications (Appleford *et al.*, 2005; Heber *et al.*, 2005; USEPA, 2004). Results from these trials suggest that the BioCurtain® was not able to significantly reduce particulate emissions. However, Funk *et al.* (2007) report that the BioCurtain®, when fitted with electrostatic particulate ionisation system, reduced particulate emissions by 67% from mechanically ventilated pig sheds. The manufacturer estimates that the combined BioCurtain® and Electrostatic Particulate Ionisation unit (EPI) achieves 60%–80% dust reduction (Baumgartner Environics Inc, 2008).

Maintenance requirements

Maintenance requirements for the BioCurtain® are minimal. The geotextile material is usually self cleaning. Occasional removal of accumulated dust is all that is required.

Positive and negative aspects of dust control structures

Positive aspects of installing dust control structures

Simple structures

- Simple construction and minimal maintenance
- Improved light control (hoods)
- Long life expectancy
- Hood displayed in Figure 34, that span multiple fans, would have an improved opportunity for dust settling with few fans active, because air mixing would be greater and exit velocities lower
- Hoods and windbreak walls would offer a suitable structure to improve mixing with odour neutralising agents
- Provide a visual barrier to the fans

BioCurtain®

- Simple structure
- Majority of air is exhausted vertically, so BioCurtain® functions like a windbreak wall, which may improve odour and dust dispersion under some conditions (Dunlop and Galvin, 2006)
- Minimal reduction in fan performance
- 10 year life expectancy
- Enclosure structures, like the BioCurtain®, would suit the use of odour neutralising agents due to increased air mixing and opportunity for these agents to mix with odorous air. Addition of other systems would, however, increase the costs of the system
- Fans readily accessible through access doors
- Provide a visual barrier to the fans

Negative aspects of installing dust control structures

Simple structures	*BioCurtain®*
• No data to quantify dust or odour control • No reduction in actual dust emission from fan ie. Dust control is dependant on ground conditions and hood configuration • Potential for reduction in fan performance • Hood may need to be removed to service fans • Odour reduction is not the primary function of the hood. Any odour reduction will be a consequence of settled dust	• Dust washed from the system during rain or maintenance cleaning may generate another waste stream or odour source • Odour reduction is not the primary function of the hood. Any odour reduction will be a consequence of settled dust • Dust may accumulate on the wall and under the roof of the shed, requiring cleaning to prevent corrosion • Potential for reduction in fan performance

Inspection of dust control structures

The dust hoods shown in Figure 33 and Figure 34 were inspected on broiler farms located in central and northern New South Wales during 2006 and 2007. The hoods in Figure 34 were installed to reduce dust travelling to a neighbouring small crops farm and also for light control.

At both farms, dust was visible on the ground and grass directly beneath the hood and extended several metres from the hood. Additionally, a layer of dust had accumulated on the inside surface of the hood. The grouped fan hood displayed in Figure 34 had the advantage of a hinged flap, which when raised (as shown in Figure 35 and Figure 36), provided much easier access to the fans and back-draft prevention shutters for maintenance and cleaning operations.

The BioCurtain® was inspected at a piggery in Minnesota, USA, during September 2007. This installation did not have the electrostatic precipitation unit installed. This BioCurtain® was eight years old and was beginning to show signs of deterioration (e.g. torn and frayed geotextile). Figure 44 shows a close up of the geotextile material used on the BioCurtain®. Through a tear in the geotextile material, dust accumulation was visible on the ground inside the BioCurtain® (see Figure 43). Overall, there generally appeared to be very little dust accumulation on the fans, walls or geotextile material

While standing in front of the BioCurtain®, odour from the piggery was barely perceptible, probably because the exhaust air was being directed upward through the vent in the top of the BioCurtain®.

Figure 43 Dust accumulation on the ground inside the BioCurtain®

Figure 44 Close up of the woven geotextile material used on the BioCurtain®

Summary of dust control structures

Fan hoods, windbreak walls and other dust control structures like the BioCurtain® (without additional technologies such as an electrostatic particulate ionisation unit) will have minimal effect on dust and odour emissions from broiler sheds. However, improved settling, dispersion or deposition within these structures may reduce downwind ground level concentrations of particulate matter, and consequently may be sufficient to alleviate impacts on nearby receptors. Available data suggests that installation of electrostatic precipitation technology will assist dust particles to settle out of the air stream (testing conducted on the BioCurtain®). The supplier of the BioCurtain® recommends installation of the electrostatic particulate ionisation (EPI) system in the production building as a first preference compared to installation of a BioCurtain®.

All of these dust control structures will provide a visible barrier to the fans, which might improve the perceptions of neighbours that emissions are being controlled. Technologies that exhaust air upward, for example the windbreak wall and BioCurtain® (with vertical exhaust and no electrostatic particulate ionisation system), may assist with odour dispersion under certain conditions, however, they should not be solely relied upon as an odour control strategy (Dunlop and Galvin, 2006).

Appendix 6. Litter aeration

Introduction to litter aeration

The process of aerating animal manures is one technique that can be used to reduce odour generation by reducing anaerobic decomposition (American Society of Agricultural and Biological Engineers, 2007; Barth *et al.*, 1984). Kolominskas *et al.* (2002), McGahan and Tucker (2003) and Jiang and Sands (2000) reported that anaerobic conditions occur in chicken shed litter that is excessively moist, compacted or caked. These anaerobic conditions can increase the formation of odours. Litter aeration is proposed in this section as a technology that could potentially reduce odour generation, and consequently reduce odour emissions.

Litter aeration has previously been investigated and reported by van Middelkoop (1994; 1995) and Allen *et al.* (1998). In all previous research, investigations were aimed at reducing gaseous ammonia concentration within the chicken shed to improve animal production.

Allen *et al.* (1998) found that aerating poultry litter in-situ using a negative pressure sub-floor plenum successfully reduced ammonia emissions. While the researchers observed a noticeable reduction in odour concentration, they found no significant difference in odour reduction between ventilated and standard (unventilated) litter floors using olfactometry analysis.
Allen *et al.* (1998) and van Middelkoop (1995) identified an issue that litter aeration using a raised, permeable floor is cost restrictive and has numerous practical implications. The raised permeable floor also appeared to reduce growth rate during the early production stages due to reduced heat control and the creation of drafts down through the litter.

The available information indicates that significant odour is generated by anaerobic decomposition within broiler litter, and that aeration could reduce the amount of odour produced. The challenge is to develop an affordable system that can effectively aerate litter in-situ, to reduce the possibility of anaerobic conditions.

Consultation with several broiler growers in south-east Queensland revealed that some growers actively break up caked litter in their shed in order to prevent excessive odour generation. For some growers, this is a regular weekly or fortnightly activity, while for others, it is only carried out as required if litter conditions deteriorate and there is significant caking. Equipment used to break up the caked litter ranges from tractor mounted rotary hoes to hand operated garden tillers (similar to Figure 45). Generally, only the litter identified to be cakey is disturbed. Anecdotally, the farmers undertaking this activity comment that odour emissions are reduced.

An alternative approach could be to use an automated plough or rotary tiller to disturb the litter. This technology, however, requires further research and development. Further research is also required to confirm that aerating litter will reduce odour emissions

Figure 45 Hand operated power garden tiller used to break-up and aerate caked litter (image from www.stihl.com.au)

Figure 46 Caked litter in a broiler shed

There are a few drawbacks with manually disturbing the litter including:

- it can be time consuming (which prevents this activity from being done frequently and can take time away from other activities);
- when the crusted litter is disturbed, odorous gases will be released (but this can be managed by scheduling these activities when odour impacts are least likely to occur, e.g. on fine, warm days when winds are blowing away from sensitive receptors);
- high speed blades of a rotary hoe or garden tiller could increase dust generation; and
- associated noise, movement and lifting drinking and feeding lines to access caked litter disturbs the birds.

Costs

Hand propelled garden tillers (seen in Figure 45) can be purchased for approximately \$700 to \$1500. Replacement blades cost \$100 to \$250, and would be expected to need replacing annually. There will be additional costs for fuel and scheduled servicing. The hand propelled tiller requires labour for operation of the unit. Farmers who use garden tillers report that it takes about an hour to aerate the caked sections within a shed. If it is assumed that the aerating operation is performed weekly from weeks three to eight of the batch, and that the farmer (or farm staff) is paid \$30/hour, labour costs amount to approximately \$180 per batch.

Cost Analysis

The following costs on a per chicken basis for aerating litter have been calculated according to the cost analysis assumptions (costs over ten years) and estimated costs for the technology. Estimated lifespan costs for litter aerating/disturbing technologies are displayed in Table 17.

Table 17 Costs of installing and operating litter aeration/disturbance technologies

Installation scenario		Aeration with hand propelled garden tiller (operated once weekly)
Capital cost (\$)		\$ 1,200
10 year lifespan capital cost (\$/bird)		\$ 0.0006
10 year Operating cost (\$)		\$ 15,000
10 year lifespan operating cost (\$/bird)		\$ 0.0078
Total 10 year lifespan cost	**(\$/bird)**	**\$ 0.0084**
	(¢/bird)	**0.8 ¢**

Summary of litter aeration

Aeration of litter is proposed as a way to possible reduce odour generation within broiler sheds. This technology represents a different approach to odour control than many of the other technologies discussed in this report, because it is aimed at reducing odours at the source, rather than attempting to recapture and treat them before being released to the atmosphere (when they are diluted by high volumes of ventilation air and mixed with particulates, which can block filter systems).

Trials using ventilated floors systems have demonstrated that ammonia (and probably odour) emissions could potentially be reduced by maintaining aerobic conditions within the litter. However, Further research is required to:

- quantify the reduction in odour generation by regularly aerating litter;
- identify the changes in litter microbial population by regular aeration (and the implications of these changes on emissions, e.g. odour and greenhouse gases);
- assess whether litter disturbance using plough or rotary tiller is sufficient to maintain aerobic conditions;
- assess how suitable the plough and rotary tiller methodology will be for use in commercial broiler sheds; and
- identify other techniques for aerating litter.

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Control of Odour and Dust from Chicken Sheds

– Review of "add-on" technologies –

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Odour and dust from tunnel ventilated sheds have been identified as a significant issue for the Australian chicken meat industry. Meat chicken producers are under pressure to reduce their impact, and need cost-effective solutions. Add-on technologies, designed to control odour and/or dust, may offer solutions to this problem. These technologies include dry dust filters, wet scrubbers, electrostatic de-dusters, odour neutralising fogging/spray systems and litter aeration, to name just a few.

Unfortunately, there is little scientifically valid evidence to support the claims associated with many of these technologies. There is also a lack of readily available information regarding the costs, maintenance requirements and practical issues associated with these technologies. This report summarises the available information on a selection of add-on technologies.

This review of add-on technologies will be an important reference for anyone requiring information about add-on technologies to control odour and dust from meat chicken sheds. It will also assist the industry to identify which of these, based on further detailed investigation, may have the greatest potential to provide affordable and effective control of odour and dust.

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