INTRODUCTION - EFFECTS OF AIRBORNE POLLUTANTS AND FACTORS AFFECTING CONCENTRATIONS IN LIVESTOCK BUILDINGS

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Introduction

The main airborne pollutants found in piggery buildings are ammonia, carbon dioxide, dust particles, viable and non-viable microorganisms, and their components. Airborne particles in piggery buildings consist of animal skin, hair, dried urine, faeces, bedding material, microorganisms, grain and other particles. Airborne particles usually act as a vector for pathogenic bacteria, viruses, endotoxins, odorous material, gases (including ammonia) and liquid substances. Viable bacteria and viruses carried by dust particles may have a greater ability to survive and cause infection in animals and transfer infection into neighbouring livestock buildings. Airborne microorganisms attached to airborne particles are often described as 'viable' airborne particles (Hartung and Seedorf 1999). The finer fraction of the biologically active airborne material referred to as 'bioaerosol' and this fraction could remain in suspension in the air for long periods (Hartung and Seedorf 1999). Endotoxins are the cell-wall components of gram-negative bacteria and these compounds are released after the death of the bacteria.

One of the important gaseous pollutants present in livestock buildings is ammonia (Hobbs *et al.* 1999). Most ammonia originates from urine and faecal material produced by the animals and as a result of chemical/biological breakdown of the waste material (Groot Koerkamp *et al.* 1998). Pigs consume a substantial amount of protein and other nitrogen containing material as part of their diet. However, a large percentage of the nitrogen consumed is excreted and ammonia is produced as a result of bacterial breakdown of the dietary nitrogen (Groot Koerkamp *et al.* 1998). Carbon dioxide (CO_2) in piggery buildings is mainly produced by the animals as a result of normal respiration and a smaller amount is produced as a by-product of bacterial breakdown of waste material (Ni *et al.* 1999b).

Previous publications revealed that significant amounts of airborne pollutants can be found in the airspace of piggery buildings (Seedorf *et al.* 1998; Takai *et al.* 1998; Chang *et al.* 2001) (Table 1). Piggery managers, scientists and building engineers are concerned with sub-optimal air quality, as high airborne pollutant concentrations could potentially affect the environment through emission and human and/or animal health via biological effects.

Table 1. Concentrations of different pollutants measured in previous studies.

Pollutant	Range of concentration	Reference
Ammonia	5-18 ppm	(Groot Koerkamp et al. 1998)
Inhalable particles	0.63-5.05 mg/m^3	(Takai et al. 1998)
Respirable particles	0.09-0.46 mg/m^3	(Takai et al. 1998)
Respirable endotoxins	74-189 EU/m^3	(Seedorf et al. 1998)
Total airborne bacteria	Approx. 10^5 cfu/m^3	(Seedorf et al. 1998)

Emission issues

Generally, it is accepted that airborne pollutant emissions have to be reduced from livestock buildings in order to minimise potential damage to the environment (Seedorf *et al.* 1998; Takai *et al.* 1998) and the transmission of pathogenic microorganism between buildings and farms (Hartung *et al.* 1997). It is also well documented that particles, endotoxins and airborne microorganisms emitted from livestock buildings could get into waterways via run-offs and leakage after rain (Barber 2002). In many developed countries, nutrient enrichment and bacterial contamination of waterways is a major concern for the livestock industries, eg. UK (Hooda *et al.* 2000). Particles in livestock ventilation air have been implicated in transporting odour (Hartung *et al.* 1986; Hoff *et al.* 1997; Bottcher 2001). Different odourants are absorbed on particle surface and then desorbed in large local concentrations, potentially creating secondary emission sources around livestock buildings (Takai *et al.* 2002). Additional odorous components might also be produced by bacterial activity within the particles as a result of the different microorganisms breaking down the organic content of the dust particles (Martin *et al.* 1996).

In general, livestock production is heavily implicated in significantly contributing to atmospheric ammonia emissions (Arogo *et al.* 2003). In pig production the major ammonia emission sources are the buildings, effluent lagoons and manure application areas (Aneja *et al.* 2000; Nicholson *et al.* 2002). Some relationship between ammonia and odour emission is also assumed but not proven consistently (Ognink and Groot Koerkamp 2001). Further research on the relationship between ammonia and odour emission is necessary in order to understand the importance of emitted ammonia in odour formation and also to potentially use ammonia measurements as an indication of odour levels. Ammonia emitted from livestock buildings is also implicated in creating opportunities for the formation of very small (PM 2.5) particles, which in turn will have public health consequences (Arogo *et al.* 2003). Excess ammonia deposited in sensitive ecosystems and leached into waterways can cause harmful algal blooms, decrease water quality, change soil pH and directly affect the constitution of native flora (Arogo *et al.* 2003).

Carbon dioxide (together with methane and nitrous oxide) emitted from livestock buildings is considered to be part of 'Greenhouse gas' emission load of the piggery operation (Sommer and Moller 2000). Greenhouse gas emissions from agriculture operations are increasingly scrutinised by environmental authorities.

Human and animal health effects

The quality of working environment within piggery buildings is heavily influenced by the concentration of different pollutants in the air. Epidemiological studies related to the health of farm employees have revealed that workers in piggery buildings might be exposed to pollutant concentrations which could contribute to the development of occupational respiratory diseases (Crook *et al.* 1991; Dutkiewicz 1997). Pig farmers have a high prevalence of wheezing, symptoms of chronic bronchitis and decline in lung function which could be related to exposure to airborne pollutants in livestock buildings (Schwartz *et al.* 1995; Mackiewicz 1998; Laitinen *et al.* 2001).

Studies have demonstrated the effects of sub-optimal air quality on production efficiency (Donham and Leininger 1984; Donham 1991; Urbain *et al.* 1994; Donham 2000). There is evidence that airborne microorganisms, their products and/or components are capable of triggering immune responses and physiological changes in livestock, such as the activation of the immune system (Cargill *et al.* 2002). In turn, this could result in a reduction in feed intake, as well as a diversion of protein and energy away from the development of muscle tissues (Kelley *et al.* 1987; Klasing *et al.* 1987; Klasing and Barnes 1988). Other studies demonstrated the synergic effect of ammonia and other airborne pollutants (such as endotoxins and dust) on animal health and production efficiency (Gustin *et al.* 1994; Urbain *et al.* 1996; Wathes *et al.* 2002a; Demmers *et al.* 2003). Researchers in the UK also demonstrated the behaviour tendency of pigs preferring to avoid high ammonia concentrations, if given a choice (Smith *et al.* 1996; Jones *et al.* 1998; Jones *et al.* 1999; Wathes *et al.* 2002b). Studies conducted in Australia demonstrated that pigs reared in clean environment with better air quality grew faster than pigs living under "normal" commercial conditions (Banhazi and Cargill 1998; Cargill *et al.* 1998; Black *et al.* 2001).

Carbon dioxide levels regularly encountered in piggery buildings do not pose any treat to human or animal health (Banhazi and Cargill 2000). However, CO_2 is of great interest to livestock managers as CO_2 is widely used to estimate ventilation rates of livestock buildings. High CO_2 levels are an indication of reduced ventilation rates in buildings (van't Klooster and Heitleger 1994).

Factors affecting airborne pollutant concentrations

Understanding the factors affecting airborne pollutant concentrations is important, as this knowledge is the first important step in reducing and controlling the internal concentrations of these pollutants. In turn, controlling internal concentrations will enable livestock managers to control emissions. Understanding the factors influencing the internal concentrations of carbon dioxide is also important as such knowledge will enable livestock managers to control ventilation rates of piggery buildings.

Many studies, examining the influence of environmental factors on particle concentration in piggery buildings have demonstrated a circadian dependency. Airborne particle (including viable particle) concentrations are typically higher during the day than night (Pedersen 1993; Seedorf *et al.* 1998; Pedersen *et al.* 2001). The difference in particle concentrations with time of day is related to the higher level of animal activity during daytime (Cargill et al. 1997; Pedersen 1993). Viable particle concentrations within piggery buildings are reportedly influenced by the stocking density and stocking rate of pigs (Cargill and Banhazi 1996). Air humidity strongly influences the condition of the air and therefore the density and the size of the suspended particle concentrations inside piggery buildings. Several studies in piggery buildings have demonstrated a relationship between respirable particle concentration and relative humidity (Butera *et al.* 1991; Ellen *et al.* 2000). Ventilation also has a complex effect on the concentration of air pollutants. The ventilation system is designed to facilitate the elimination and transportation of particles outside the building via exhausted air (Duchaine *et al.* 2000; Wang *et al.* 2000). However, the turbulence associated with increased ventilation favours the re-suspension of settled particles. The ability for ventilation systems to resuspend particles is influenced greatly by the hygienic conditions encountered within livestock units (Gustafsson 1999). The bedding is a major source of particles in livestock buildings and its characteristics would affect particle concentrations (Ellen *et al.* 2000; Barnett *et al.* 2001).

A number of studies concerning the influence of environmental and management factors on ammonia concentrations in piggery buildings have demonstrated an effect of pen hygiene. Ammonia concentrations are typically increasing with increased level of pen floor contamination (Aarnink *et al.* 1996; Aarnink *et al.* 1997; Ni *et al.* 1999a). Ammonia concentrations within piggery buildings are reportedly influenced by the characteristics and management of the effluent system as well as the pH of the slurry (Hörnig *et al.* 1999; Jensen 2002). Turbulence associated with increased ventilation favours the volatilisation of ammonia from exposed sources, such as manure pits and contaminated pen floors (Ni *et al.* 1999a). However, improved pen cleanliness will limit the opportunities for volatilisation and will therefore greatly improve the effectiveness of the ventilation system. It was reported that it is more likely to find high gas concentrations (both CO_2 and ammonia) in buildings housing younger animals as those buildings usually have reduced ventilation levels to save heating cost (Donham and Popendorf 1985). Investigations undertaken in Sweden revealed that ammonia concentrations in pig and poultry houses are influenced by location of air inlets and outlets, stocking rate of the animals, air flow rate and time intervals between manure removals (Gustafsson

1997). While the effects of air in/outlet locations will have little implications for typically naturally ventilated Australian piggery buildings, the other factors identified will likely to have consequences for ammonia levels even under the hot/dry Southern Australian climatic conditions.

Discussion

Based on the results of previous studies, it is evident that improving air quality in livestock buildings could produce significant benefits, including reduced environmental damage, improved production efficiency and better working environment for farm employees. A number of management, environmental and housing factors have been demonstrated in separate studies to interact and influence the concentrations of airborne pollutants within and emission from piggery buildings. However, these factors have not been evaluated considering all factors simultaneously. In addition, most of the studies conducted in relation to airborne pollutants in livestock buildings were mainly concerned with the concentrations and/or emissions measured (Wathes *et al.* 1998). Very few studies have attempted to model and therefore explain the variation observed in concentrations. Therefore, a comprehensive study was needed to investigate the interaction between different air quality parameters and housing/management features in order to determine the key factors affecting the internal concentrations of airborne pollutants in piggery buildings, to predict and ultimately reduce the concentrations and emissions of these airborne pollutants. A number of articles published as part of this series report on the outcomes of such an investigation (Banhazi *et al.* 2004c; Banhazi *et al.* 2004a; Banhazi *et al.* 2004b).

Conclusion

1. Improving air quality could reduce environmental damage, improve production efficiency and workers health.
2. A number of factors have been identified in previous studies to affect the concentration of airborne pollutants.
3. Few studies have attempted to model the variation observed in pollutant concentration.

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