Risks caused by bio-aerosols in poultry houses

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SUMMARY

Aerial pollutants in confined animal houses are widely recognized as detrimental to the respiratory health of animals kept in these facilities. Primary and opportunistic microbial pathogens may directly cause infectious and allergic diseases in farm animals, and chronic exposure to some types of aerial pollutants may exacerbate multi-factorial environmental diseases. There are, however, few international field surveys paying attention to the health of the farmers and the farm personnel working in such atmospheres, and to the spread of pathogens from farm buildings. Studies reveal that up to 20 percent of farmers and farm workers report work-related symptoms of respiratory affections, such as coughing, sputum and wheezing. Some develop asthma, others develop diseases that are described as ODTS (organic dust toxic syndrome). There are indications that various pathogens can survive in ambient air for several minutes and can be distributed over long distances, (e.g. foot-and-mouth disease (FMD) virus more than 50 km, and staphylococcae up to 500 m).

This paper describes the complex nature and composition of the aerial pollutants, such as gases, dust, micro-organisms and other compounds, present in the air of farm animal houses, their potential role in the development of respiratory diseases in humans and animals, and their distribution in the surroundings of farms. Future-oriented sustainable farm animal production should (in addition to improving animal welfare, consumer protection, economy and occupational health) enhance standards aimed at preventing or reducing the aerial spread of pathogens.

Key words: air pollutants, bio-aerosols, poultry farming, disease transmission, occupational health, dust, gases, bacteria

1 INTRODUCTION

The air in modern poultry production systems contains a large variety of air pollutants, such as gases like ammonia and carbon dioxide, dust, micro-organisms and endotoxins. These pollutants, also referred to as bio-aerosols, are increasingly regarded as both aggravating and environmentally harmful. The pollutants give cause for concern for several reasons.

Animal respiratory health may be compromised by pollutants such as gases, dust, micro-organisms and endotoxins (Baekbo, 1990; Hamilton *et al.*, 1993; Hartung, 1994).

It is well documented that livestock buildings, manure storage facilities, manure spreading and even free range systems are major sources of gaseous pollutants such as ammonia, methane and nitrous oxide, which contribute to soil acidification and global warming (Jarvis and Pain, 1990; Hartung *et al*., 1990; Ecetoc, 1994).

There is epidemiological evidence that the health of farmers working in animal houses may be harmed by regular exposure to air pollutants such as ammonia, dust, micro-organisms and endotoxins (Donham, 1987; Whyte *et al*., 1994; Donham *et al*., 1995; Radon *et al*., 2002; Hartung, 2005). Providing a safe and healthy work environment for employees is an important objective for any industry – including animal farming (Cargill and Hartung, 2001).

A major reason for concern are bio-aerosol emissions, such as dust and micro-organisms, from farm buildings, which are believed to play a role in respiratory affections in people living in the vicinity of animal enterprises (Müller and Wieser, 1987; Hartung, 1995; Seedorf, 2004), and which can be transmitted between poultry houses and farms via the air (Schulz *et al*., 2005). Scientific assessment of the risk of aerial transmission of pathogens between flocks is hampered by the fact that there is still little knowledge about the nature and composition of bio-aerosols, the tenacity (resistance) of bacteria and viruses in an airborne state, and their survival times in ambient air.

This paper briefly defines the term bio-aerosol, gives some quantitative data on air pollutants in poultry houses, presents examples of the health effects of this pollution on humans and animals, discusses the survival times of bacteria and viruses in air and the possible extent of their spread in the surroundings of farms, and reflects on "safe distances" between flocks.

2 COMMON POLLUTANTS FOUND IN FARM ANIMAL HOUSES, AND DEFINITION OF "BIO-AEROSOL"

The key pollutants recognized in the airspace of livestock buildings are particles including dust, micro-organisms and their toxins, and gases such as ammonia, carbon dioxide and more than 100 trace gases such as volatile fatty acids (Table 1). Under commercial production conditions the airborne particles will contain a mixture of biological material from a range of sources, with bacteria, toxins, gases and volatile organic compounds adsorbed to them. Hence, a more descriptive term for these airborne particles is bio-aerosol (Cargill and Banhazi, 1998). The typical character of bio-aerosols is that they may affect living things through infectivity, allergenicity, toxicity, pharmacological or other processes. Their sizes can range from aerodynamic diameters of 0.5 to 100 µm (Hirst, 1995).

TABLE 1
Common air pollutants in poultry houses

Type of pollutant	Examples
Gases	Ammonia, hydrogen sulphide, carbon monoxide, carbon dioxide, 136 trace gases, osmogens
Bacteria/fungi	100 to 1 000 colony-forming units (CFU)/litre air 80 percent staphylococcaceae/streptocococcaceae
Dust	inhalable dust can reach levels of 10 mg/m³; approximately 90% is organic matter; particles can carry antibiotic residues
Endotoxin	339 to 860 ng/m³ inhalable endotoxin in poultry houses

TABLE 2
Bio-aerosol concentrations in livestock buildings

	Cattle	Pigs	Chickens
Inhalable dust (mg m^{-3})	0.38	2.19	3.60
Respirable dust (mg m^{-3})	0.07	0.23	0.45
Total bacteria (log CFU m^{-3})	4.4	5.2	5.8
Total fungi (log CFU m^{-3})	3.8	3.8	4.1
Inhalable ETOX (ng m^{-3})	23.2	118.9	660.4
Respirable ETOX (ng m^{-3})	2.6	12.0	47.5

ETOX = endotoxin; 1 ng = approx. 10 EU (endotoxin units); CFU = colony forming unit.
Sources: Seedorf *et al.* (1998): Takai *et al.* (1998).

Several studies have recorded the concentrations of key components of bio-aerosols in farm animal buildings, with particular high levels recorded in poultry production (e.g. Seedorf *et al*., 1998).

Table 2 summarizes the results of a broad European Union-wide study on bio-aerosols in pig, cattle and poultry farms. The results show that the lowest concentrations were found in cattle production and the highest in poultry houses (ibid.). However, there are considerable differences between production systems within a given species. The highest dust concentrations regularly occur in houses for laying hens. These concentrations often exceed the occupational health limit for the workplace (in Germany) of 4 mg/m^3, particularly at times of high animal activities (Saleh, 2006). These pollutants are emitted into the environment by way of the exhaust air through the ventilation system.

3 WORK-PLACE HEALTH EFFECTS OF BIOAEROSOLS IN FARM ANIMAL HOUSES

Complaints about respiratory symptoms during and after work in animal houses have risen among farmers and employees in recent years. The number of employees who were granted an insurance pension because of work-related obstructive airway diseases caused by allergic compounds rose from about 90 in 1981 to approximately 700 in 1994, a slightly smaller increase from 8 to 50 was observed for obstructive diseases caused by chemical irritants or toxic compounds (according to the statistic of the German occupational health board in agriculture, 1996). In a study comprising 1 861 farmers in northern Germany, about 22 percent of the pig farmers, 17 percent of the cattle farmers and 13 percent of the poultry farmers admitted airway problems (Nowak, 1998). The data are detailed in Table 3. Although the causes of the relatively high incidence of health problems, associated particularly with pig farming are not yet completely understood, it seems that factors such as high concentrations of air pollutants, the composition of pig house bio-aerosols, insufficient ventilation, and poor system management may play a role. The results may also be biased by the fact that most pig farmers in Germany work on their own farms, which they do not easily abandon even in the event of health problems, while poultry farm workers can more easily change their workplace or profession.

Numerous studies have demonstrated links between dust and human ill-health in a number of livestock-related industries (Donham *et al*., 1995). A survey of 69 full-time poultry stockpersons in the United Kingdom found that although occupational health and safety guidelines were adhered to, 20 percent were exposed to levels of dust 2.5 times higher than the 10 mg/m3 recommended under occupational health and safety guidelines (Whyte *et al*., 1994). Findings such as these have led to the introduction of strict codes to protect people involved in the intensive livestock industries in several countries including Denmark and Sweden. Guidelines have also been recommended to the Australian pig industry (Jackson and Mahon, 1995).

The first reports indicating health hazards for humans working in intensive livestock production systems were published over 20 years ago (Donham *et al*., 1977). A number of syndromes have been recognized in workers in the intensive animal industries. They range from an acute syndrome, which develops within a few hours to days of exposure to animal sheds, and which is accompanied by a variety of clinical signs including lethargy, a mild febrile reaction, headaches, joint and muscle aches, and general malaise, to more chronic responses. In some cases, the initial attack is so severe that the employee terminates his or her employment within a matter of days. In general, episodes last 12 to 48 hours, with chronic fatigue and congested respiratory passages being reported as the most common clinical signs. The condition has been referred to as organic dust toxic syndrome (ODTS) or toxic alveolitis. The prevalence of ODTS has been quoted as ranging from 10 to 30 percent of workers, depending on the type of intensive animal production and the facilities used (Donham, 1995).

A range of acute respiratory symptoms, described by employees following contact with their work environment, but not necessarily associated with a generalized clinical syndrome, have also been documented (Brouwer *et al*., 1986). The more common clinical signs include an acute cough, excess sputum or phlegm, a scratchy throat, discharging or runny nose, and burning or watery eyes. Other more generalized clinical signs that may or may not be present include headaches, tightness of the chest, shortness of breath, wheez-

TABLE 3
Frequency of workplace-related respiratory symptoms in livestock farmers/employees in Lower Saxony, Germany

Animal species		Number of persons surveyed	Percentage of persons with complaints
Pigs	Sow	619	22.7
	Fattening	799	21.9
	Weaner	551	23.0
Cattle	Cow	1 245	17.4
	Beef	895	17.2
	Calf	1 190	17.8
Chickens	Laying hens	279	14.7
	Broilers	47	12.8

Source: Nowak (1998).

ing and muscle aches. In several studies in North America, and Sweden, the prevalence of acute symptoms was found to be 1.5 to 2 times higher than chronic symptoms. However, in a similar study in the Netherlands, the prevalence of chronic and acute symptoms was reported to be similar (ibid.).

Exposure to dust produces a variety of clinical responses in individuals. These include occupational asthma due to sensitization to allergens in the airspace, chronic bronchitis, chronic airways obstructive syndrome, allergic alveolitis and ODTS (Iversen, 1999).

The suggestion that the primary clinical problem is an obstruction of the airways is supported by various studies in which workers have been subjected to lung function tests. Although the forced expiratory volume-in-one-second (FEV1) was not changed in most people studied, decreases in the FEV1/forced vital capacity (FVC) ratio and flow rates support this hypothesis. In a series of studies of workers over a period of time, the greatest decrease (4 to 12 percent) occurred in forced expiratory flow rates (Hagland and Rylander, 1987). In both Swedish and American workers, significant changes were also recorded in FEV1 and flow rates. Although the changes reported in these studies were modest on a population basis, a significant clinical reduction in FVC was recorded in 14 percent of Canadian workers (Dosman *et al*., 1988) and 20 percent of Dutch workers (Brouwer *et al*., 1986).

Exposure to bio-aerosols has also been shown to cause broncho-constriction, hyper-responsiveness and increased inflammatory cells in bronchial alveolar lavage fluids in naïve subjects (Malberg and Larsson, 1992). It is assumed that broncho-constriction followed by reduced ventilation of the lungs can be caused by inhaled endotoxin. Experiments using nasal lavage show that pig-house dust containing different concentrations of endotoxins increases the inflammatory reaction of the nasal mucous membranes of humans, distinctly (Nowak *et al*., 1994). The broncho-constrictive effects of bio-aerosols have also been demonstrated in guinea pigs (Zuskin *et al*., 1991) as well as in stockpersons in Sweden and North America (Donham, 1995).

Further studies are needed to improve understanding of the building features and animal husbandry practices that increase the concentration of airborne pollutants in buildings housing animals, and to determine the key pollutants involved. The evidence collected in farm animal buildings suggests that issues such as hygiene and stocking density (kg biomass/m^3) are key factors, but that the composition of pollutants or bio-aerosols may vary significantly from shed to shed depending on a range of factors (Banhazi *et al*., 2000); these factors include hygiene, dietary composition, as well as the type of bedding and effluent disposal system used. The severity of specific occupational health problems might be more affected by the composition of bio-aerosols within an animal-house atmosphere than just by the concentration of airborne particles.

4 TRANSMISSION DISTANCES OF BIO-AEROSOLS

There are few experimental data available on transmission distances of bio-aerosols from animal houses. From epidemiological studies, it is known that FMD virus can travel over distances of more than 50 kilometres (e.g. Donaldson and Ferries, 1975; Gloster *et al*., 2005). Experiments around farms revealed elevated levels of dust particles and bacteria between 50 and 300 m downwind of animal houses compared to upwind control meas-

TABLE 4
Reported transmission distances of bio-aerosols emitted from livestock buildings

Component	Distance (m)	Reference
Dust particles	50	Schmidt and Hoy (1996)
	115	Hartung *et al*. (1998)
Bacteria	50	Platz *et al*. (1995)
	100	Sarikas (1976)
	200	Köllner and Heller (2005)
	200–300	Müller and Wieser (1987)

urements (Table 4). These figures are far from being safe distances, because they do not reflect the spread of specific pathogens or allergenic components (e.g. feather fragments), which may be transported much longer distances, and which can cause health risks even in small quantities.

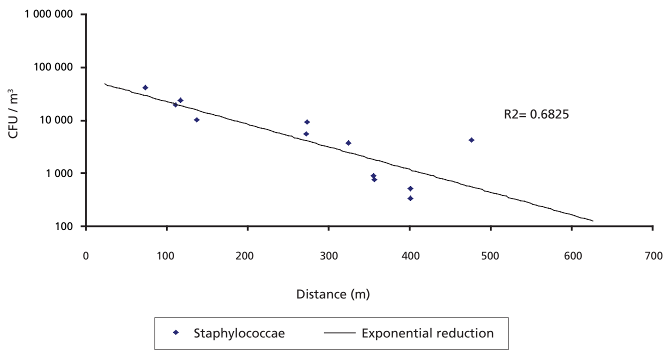
Most important for the possible transmission of a pathogen is its ability to survive in an airborne state over a longer period. Table 5 presents some data showing that micro-organisms are strongly influenced by environmental conditions such as temperature and humidity of the air; other factors include radiation, sunlight and additional chemical compounds in the air.

Recent investigations in and around broiler houses have shown that the travel distance of staphylococcae downwind can be more than 500 m from the source. Under stable wind

TABLE 5
Loss of viability of various pathogens in air at varying temperature and humidity

Pathogen	Relative. humidity (%)	Temperature (°C)	Loss of viability after 250 seconds in air (%)
Escherichia coli (O78)	15–40	22	14
Mycoplasma gallisepticum	40–50	25	up to 3
Salmonella enteritidis	75	24	up to 20
S. newbrunswick	30	10	38
S. newbrunswick	70	21	11
S. typhimurium	75	24	up to 20
Staphylococcus aureus	50	22	up to 1
Influenza A virus	50	21	more than 70
Influenza A virus	70	21	more than 66
Newcastle disease virus	10	23	No loss detectable
Newcastle disease virus	35 and 90	23	20

FIGURE 1
Decreasing concentrations of staphylococcae with increasing distance downwind from a broiler barn with 30 000 birds



Notes: Sampling 1.5 m above ground. Animals in second half of production cycle. Air temperature about 16 °C, wind speed between 1.7 m/s and 6.3 m/s. n = 12. CFU = Colony forming unit.
Source: Seedorf *et al.* (2005).

conditions more than 4 000 CFU/m³ were found 477 m downwind of the barn (Seedorf *et al*., 2005). Staphylococcae are typical bacteria in broiler house air (Figure 1). They can probably serve as indicators for bacterial pollution, because they do usually not appear in relevant concentrations in normal outside air.

These results show that there is a considerable distribution of micro-organisms from poultry houses into the surroundings.

5 STRATEGIES TO MINIMIZE THE RISK FOR EMPLOYEES AND ANIMALS

Several approaches to reducing air pollution in animal houses and protecting employees on the job are available. These include wearing protective gear, reducing exposure levels within the buildings, and eliminating pollutants at source. Employees should be encouraged to wear dust masks (or ventilators) and eye protection when working in sheds, particularly in straw-based shelters when handling or moving animals. As a minimum, a mask that can be shaped for individual nasal structures, with two head straps (above and below the ears) should be used. Reliable protection requires the use of ventilated masks. The disadvantage is the weight of the helmet with the filter system and the battery-powered ventilator. Employees who wear glasses may need to consider contact lenses while wearing a mask and eye protection. A recent survey is given in the book KTBL Schrift 436 (Anonymous, 2005).

Various strategies have been recommended for reducing the concentrations of air-borne pollutants in animal houses. These include management measures as well as strict hygienic rules and direct reduction techniques such as fogging sheds with oil and water (Pedersen, 1998; Banhazi *et al*., 1999). All these methods have to be carefully investigated as to whether they may cause side effects in the animals, the environment or meat quality (Cargill and Hartung, 2001). End-of-pipe techniques such as biofilters and bioscrubbers, which filter the exhaust air and reduce the pollution of the surroundings of the farm, are recommended in some countries. These techniques are, however, still rather expensive, and are presently largely restricted to sensitive situations such as when farms are located very close to residential areas.

Reducing air pollutants in animal houses is an urgent requirement for the development of future poultry production. It will provide a safer and healthier work environment for employees, and a better atmosphere for the animals – improving their health, welfare and performance. Reducing emissions will at the same time reduce the risk of transmission of pathogens indoors as well as between neighbouring farms. Future-oriented sustainable farm animal production should (in addition to improving to animal welfare, consumer protection, economy and occupational health) also enhance standards aimed at preventing or reducing the aerial spread of pathogens via the air.

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