Occupational and environmental risks caused by bio-aerosols in and from farm animal houses

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Abstract

The air in modern animal production systems contains a large variety of aerial pollutants which are widely recognised as detrimental for the respiratory health of animals kept in these facilities and the work force working regularly in this atmosphere. Primary and opportunistic microbial pathogens may cause directly 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 animal houses, and to the spread of pathogens from farm buildings. Studies reveal that up to 20 % of farmers and farm workers complain about symptoms of respiratory affections such as coughing, sputum, wheezing and others. Some develop asthma, others develop diseases which are described as e.g. ODTS (organic dust toxic syndrome). There are indications that various pathogens can survive in an air-borne state for several minutes and can be distributed over long distances in the ambient air of farms, e.g. foot and mouth virus can travel aerially more than 50 km. In a recent study it was shown that *Staphylococcae* can be found in significant concentrations (4000 cfu/m³) in about 500 m down wind of broiler barns. A future-oriented sustainable farm animal production should enhance - beside the topics of animal welfare, consumer protection and economy - also standards to improve occupational health and to prevent or reduce the spread of pathogens via the air.

Keywords: air pollutants, animal farming, disease transmission, occupational health.

Introduction

The air in modern animal 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 addressed as bio-aerosols, are increasingly regarded as a source of air pollutants which can be both aggravating and environmentally harmful. The pollutants give cause for concern for several reasons. (1) Animal respiratory health may be compromised by pollutants such as gases, dust, microorganisms and endotoxins (eg Baekbo, 1990). (2) The second reason concerns the environment. There is vast knowledge that the 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 (eg Jarvis and Pain, 1990; Hartung et al. 1990). (3) The third concern is farmer's health. There is epidemiological evidence that the health of farmers working in animal houses may be harmed by regular exposure to air pollutants like ammonia, dust, micro-organisms and endotoxins (Donham, 1987; Whyte et al., 1994, Donham, 1995, Radon et al., 2002, Hartung, 2005). Providing a safe and healthy work environment for employees is an important aspect of any industry – including animal farming (Cargill and Hartung 2001). (4) A major reason for concern are the bio-aerosol emissions such as dust and micro-organisms from buildings which are supposed 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 by way of the air between farms (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 of air pollutants in poultry houses, shows examples of health effects of this pollution on man and animals, discusses survival times of bacteria and viruses in air and their possible travel distances in the surrounding of farms and reflects on "safe distances" between flocks.

Common pollutants found in farm animal houses and definition of bio-aerosol

The key pollutants recognised in the airspace of livestock buildings are particles including dust, microorganisms and their toxins, and gases such as ammonia, carbon dioxide and more than 100 trace gases e.g. like 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. Because of their complex nature these airborne particles are also addressed as bio-aerosols (Seedorf and Hartung 2002). The typical character of bioaerosols 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 animal houses

Gases	Ammonia, hydrogen sulphide, carbon monoxide, carbon dioxide, 136 trace gases, osmogens
Bacteria/Fungi	100 bis 1000 cfu/l air 80 % staphylococcaceae/streptocococcaceae
Dust	e.g. 10 mg/m³ inhalable dust organic matter approx. 90 %, antibiotic residues
Endotoxin	e.g. 2 µg/m³ in piggeries

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

Table 2 summarises the results of a broad EU-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 (Seedorf et al., 1998). However there are existing considerable differences between production systems within one species. The highest dust concentrations regularly occur in aviaries for laying hens. These concentrations often exceed the occupational health limit at the work place of 4 mg/m³ (for Germany) 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.

Table 2. Bioaerosol Concentrations in Livestock Buildings

		Cattle	Pig	Chicken
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 equals approx. 10 EU (endotoxin units)
CFU: Colony forming units
(Seedorf et al. 1998, Takai et al. 1998; modified)

Health effects of bioaerosols at the work place in farm animal houses

The number of farmers and employees complaining about respiratory symptoms during and after work in animal houses has risen in recent years. The number of obstructive airway diseases caused by allergic compounds rose from about 90 in the year 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 occupational health board in agriculture, 1996). In a study comprising 1861 farmers in the north of Germany about 22 % of the pig farmers, 17 % of the cattle farmers and 13 % of the poultry farmers displayed airway problems (Nowak, 1998). The data are detailed in Table 3.

Numerous studies have demonstrated links between dust and human health in a number of livestock related industries (Donham, 1995). A survey of 69 full-time poultry stockmen found that although levels of exposure to respirable dust were within occupational health and safety guidelines, 20% were exposed to levels of dust 2.5 times the figure of 10 mg/m^3 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).

First reports indicating significant health hazards for humans working in intensive livestock production systems were published 30 years ago (Donham et al., 1977). A number of syndromes have been recognised in workers in the intensive animal industries. They range from an acute syndrome that 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 their 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% of workers, depending on the type of intensive animal production and the facilities used (Donham, 1995).

Table 3. Frequency of workplace-related respiratory symptoms in livestock farmers/employees in Lower Saxony, Germany (Nowak, 1998)

Animal Species		Number of Persons	Percentage (%) of complaints
Pig	Sow	619	22,7
	Fattening	799	21,9
	Weaner	551	23,0
Cattle	Cow	1245	17,4
	Beef	895	17,2
	Calf	1190	17,8
Laying hen		279	14,7
Broiler		47	12,8

A range of acute respiratory symptoms, described by employees following contact with their work environment, but not necessarily associated with a generalised 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 generalised clinical signs that may or may not be present include headaches, tightness of the chest, shortness of breath, wheezing, and muscle aches.

Exposure to dust produces a variety of clinical responses in individuals. These include occupational asthma due to sensitisation to allergens in the airspace, chronic bronchitis, chronic airways obstructive syndrome, allergic alveolitis and organic dust toxic syndrome (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 (FEV_1) was not changed in most people studied, decreases in the FEV_1/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%) occurred in forced expiratory flow rates (Hagland and Rylander, 1987). In both Swedish and American workers, significant changes were also recorded in FEV_1 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% of Canadian workers (Dosman et al., 1988) and 20% of Dutch workers (Brouwer et al., 1986).

Exposure to bio-aerosols has also been shown to cause a 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 endotoxins increases the inflammatory reaction of the nasal muceous membranes of humans distinctly (Nowak et al., 1994). The broncho-constrictive effects of bioaerosols have also been demonstrated in guinea pigs (Zuskin et al., 1991) as well as stockpersons in Sweden and North America (Donham, 1995).

Further studies are required to understand 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 bioaerosols may vary significantly from shed to shed depending on a range of factors (Banhazi et al., 2000). These include hygiene, dietary composition, as well as the type of bedding and effluent disposal system used. The composition of bioaerosols might be more important for severity of specific occupational health problems than just the concentration of airborne particles within an animal house atmosphere.

Transmission distances of bio-aerosols

There are only few experimental data available on transmission distances of bioaerosols from animal confinement houses. From epidemiological studies it is known that FMD-virus can travel over distances of more than 50 kilometres (Gloster et al., 2005). Experiments around farms revealed elevated levels of dust particles and bacteria in comparison to reference point measurements between 50 and 115 m and 50 and 300 m, respectively. 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 develop health risk even in small quantities.

Most important for a possible transmission of a pathogen is its ability to survive in an airborne state over a longer period. Micro-organisms in an air-borne state are strongly influenced by environmental conditions such as temperature and humidity of the air. Other factors are radiation, sun light and additional chemical compounds in the air.

Recent investigations in and around broiler houses showed that the travel distance of *Staphylococcae* downwind can be at least 500 m from the source. Under stable wind conditions more than 4000 cfu/m³ were found 477 m downwind the barn (Figure 1). *Staphylococcae* are typical bacteria in broiler house air. They can probably serve as indicator bacteria for the 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 production in the vicinity of livestock houses.

Strategies to minimise the risk for employees and animals

Several approaches aimed at 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 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. A reliable protection is realized by ventilated masks only. 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 (Anonymus, 2005).

Various strategies have been recommended for reducing the concentrations of airborne 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 carefully to be investigated whether they may display side effects on the animals, the environment or on meat quality (Cargill and Hartung, 2001). Also end-of-pipe techniques such as bio-filters and bio-scrubbers are recommended in some countries which filter the exhaust air and reduce the pollution of the surrounding of the farm. These techniques are however still rather expensive and presently more restricted to sensitive situations when e.g. farms are in very close neighbourhood to residential areas.

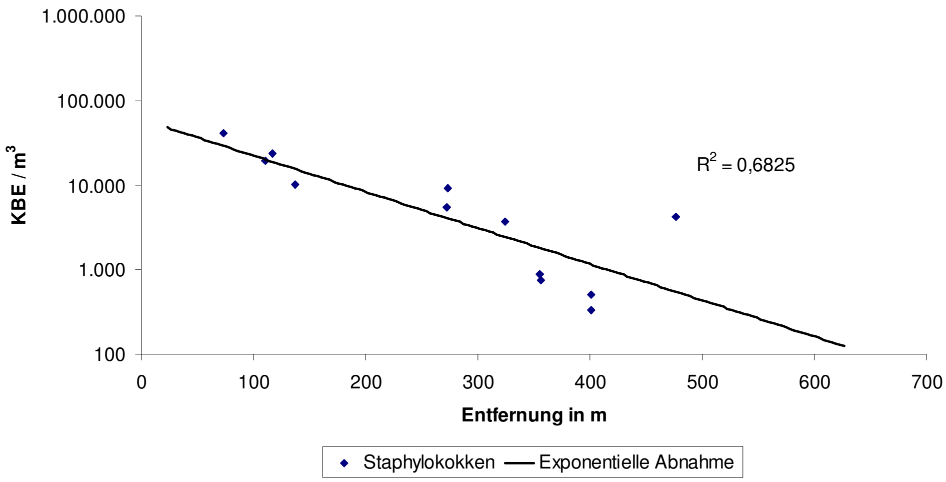

Figure 1: Decreasing concentrations of Staphylococcae with increasing distance downwind a broiler barn with 30,000 birds. Sampling 1.5 m above ground. Animals in second half of production cycle. Air temperature about 16 °C, wind speed between 1.7 m/s and 6.3 m/s. n = 12.

Reducing air pollutants in animal houses is an urgent demand for the development of future 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. A future-oriented sustainable farm animal production should enhance - beside the topics of animal welfare, consumer protection and economy - also standards to improve occupational health and to prevent or reduce the spread of pathogens via the air.

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