Composition of dust and effects on animals

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Abstract

Particulates in the air of animal houses originate from the feed, the litter, the manure and the animals themselves. They consist mainly of dusts and microorganisms. The dust contains high amounts of proteins and carries gases, odours, microorganisms, and endotoxins. About 85 % of its mass consists of organic material. There are clear differences in the composition of dust originating from types of animals and different housing systems. The behaviour of the particulates can be characterized by the processes of formation (condensation, sublimation, and dispersion) and decay (sedimentation, diffusion, and inhalation). The effect of dust and airborne microorganisms on the health of man and animals cannot be strictly separated because both form the particles that are inhaled. The role of compounds like endotoxins and drug residues (e.g. antibiotics) which can be found in animal house dust in relatively large amounts is not yet sufficiently clear. The aerodynamic diameter of the particles determines how deeply they can penetrate into the respiratory tract. Dust in the air of livestock buildings can present a significant burden to the respiratory tract of humans and animals and must be considered in the context of some typical respiratory disease patterns. Their impact can be described as mechanical, chemical, infectious, immunosuppressive, allergic, and toxic. Although there is distinct evidence that high dust levels in pig houses reduce production significantly, dust reduction measures are not yet common. It seems necessary to establish scientifically based maximum levels for dust in livestock houses. This would benefit both animals and farmers. For the development of an infectious disease the presence of the respective infectious agent seems to be necessary. Measures to reduce dust formation and increase hygiene in the animal house should be given more sustained application in practice. This would be in the interests of workers, of animal welfare, and of the wider environment. The role of airborne particulates in livestock production needs close further scientific attention.

Keywords: dust, composition, livestock, poultry, bio-aerosol, micro-organisms, endotoxin, animal health

Introduction

There are numerous reports about dust concentrations in animal house air (Takai H. et al. 1998, Hartung J. 1997, Saleh M. 2006). Less information is available on the composition of this dust. Because of the complex nature of animal house dust the term bio-aerosol was introduced (Hirst J. M. 1995, Seedorf J. and Hartung J. 2002). Bioaerosols are composed of viable and nonviable particles which may carry gases and which remain suspended in the air for longer periods because of their minute dimensions of between 10^{-4} and approximately 10^{2} µm. They are widely considered to be principal risk factors for respiratory diseases (Clark S. et al. 1983; Donham K. et al. 1986; Bruce J. M. and Sommer M. 1987). The particulates in animal houses air originate from the feed, the litter, the manure and the animals themselves. These sources determine also the composition of the dust. Dust particles and micro-organisms usually occur together in an airborne state and may therefore be considered generally as particles. They can combine chemically with gases emitted into the air and also act as a carrier of odours (Hartung J. 1986). However, in spite of this evidence no generally accepted maximum allowable concentrations of aerosols, particles or microorganisms in confined animal houses are defined, because the effects of airborne particles on the health and performance of livestock are still inconclusive (Perkins S. and Morrison W. D. 1991). One reason for this deficiency may be the complexity of husbandry and management factors. These include: unsuitable air temperatures; air humidities and air movements; high stocking densities; low ventilation intensity; and inadequate cleaning of litter and floors (De Boer S. and Morrison W. D. 1988; Perkins S. and Morrison W. D. 1991). These factors can influence the formation, decay, amount, and composition of the airborne particles.

This paper will give an outline of the composition of dust in livestock buildings, cattle, pig, turkey, ducks and laying hens. The potential effects on health and production of farm animals will also be considered.

Aerosols, particles and dust

Several relevant terms are used to describe the particulates suspended in air. `Aerosols' are solid or liquid particles which remain suspended in the air for longer periods because of their minute dimensions of between 10^{-4} and

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approximately 10^2 µm. They can combine chemically with gases emitted into the air and these new compounds are inhaled by living organisms or can settle on them (Straubel H. 1981).

`Airborne particulates' can include both solid and liquid particles. `Viable particles' are living microorganisms or any solid or liquid particles which have living microorganisms associated with them (Carpenter G. A. et al. 1986). `Dusts' are dispersed particles of solid matter in gases, which arise during mechanical processes or have been stirred up. They belong to the aerosols together with smoke and fog (Henschler D. 1990). Dust may cover a wide range of sizes and can be airborne or settled (De Boer S. and Morrison W. D. 1988). It must be seen as a significant atmospheric contaminant and should no longer be perceived as a mere nuisance (Honey L. F. and McQuitty J. B. 1976).

ticles may originate from feed (80 to 90 %), litter (55 to 68 %), animal surfaces (2 to 12 %), faeces (2 to 8 % and, to a lesser extent, from friction against floors, walls, and other structural elements in the house (Hartung J. 1986). A small amount of dust also comes from the air intake into the house (Dawson J. R. 1990). A compound which is regularly found in dust samples from all animal houses is endotoxin. In addition, dust particles can carry residues of drug applications in an animal house.

Endotoxins in sedimentation dust

Dust samples were taken by the help of standardized sedimentation plates in various animal houses with different species. The results are summarized in Table 1.

Table 1:
Mean, min/max values and standard deviation (s) of endotoxin concentrations (EU/g) in sedimentation dust from animal houses of different species. Cattle a = with straw, cattle b = without straw

	Broiler	VOL	AKA	AKB	Turkey	Ducks	Pig	Cattle a	Cattle b
n	8	8	9	9	9	3	10	3	3
Mean (EU/g)	736	1169	1316	1628	1612	855	1143	669	447
s	360	341	535	753	1128	84	809	471	334
Maximum (EU/g)	1178	1740	2240	3295	4131	946	2624	1196	796
Minimum (EU/g)	376	522	518	942	339	782	480	289	131

n*= Number of monthly samples. Vol = aviary. AKA = furnished cage type Aviplus. AKB = furnished cage type Eurovent.

The measurement of dust concentrations should therefore be correlated to response. This requires that particle separation, according to aerodynamic diameter, reflects the deposition pattern of the particles in the respiratory cycle. This can be described in terms of dust fractions passing size-selectors in a model filter system, which can be adopted for practical measuring procedures. Each filter of the series size-selects the particles according to aerodynamic diameter into a transmitted portion and a retained portion. The respective dust fractions can be described as nose-pharynx-larynx dust, tracheobronchial dust and alveolar dust (Henschler D. 1990). Additionally, the nature of the particles and the compounds which they are carrying determine the health effects.

Origin and composition of animal house dust

The main aerial pollutants in animal houses are derived from similar sources. Gases are predominantly produced directly by animals and from their faeces. Microorganisms are released from animals, feed and litter. Dust par-

The highest single concentration was found with 4131 x 10^3 EU/g in the dust from a turkey barn. Taking the arithmetic mean, the highest concentrations were found in AKB (1.6 mio EU/g) followed by turkey, AKA, VOL and pig. The concentrations of endotoxin in the dust of broiler and duck barns were about 50 % lower. The lowest concentrations were found in the cattle house without straw. The relative high endotoxin concentrations in the dust from AKA and AKB may have been influenced by the position of the sedimentation plates which were placed in these systems on the level of the manure belts.

Material composition of the dust

From an earlier investigation of the composition of sedimentation dust from a piggery and a poultry house, it is known that up to 85 % of the dust consists of organic matter. Table 2 shows the results. The crude protein content of the dust is noticeably higher than that of the feed. This indicates that the animal makes a considerable contribution to the formation of dust. Dust from poultry housing appears to be particularly rich in protein. Dust from stables was found to contain over 26 % protein (Zeitler M. 1988).

In a recent study (Saleh M. 2006) the protein content in the dust from pig and poultry buildings was even higher. Table 3 summarizes the results of the analysis of the dust according to protein, fat, fiber, nitrogen free components and ash.

Table 2:
Composition (%) of feed and deposited dust from a piggery and from a poultry house (after Hartung J. 1983; Aengst C. 1984)

Component	Pig house Deposited dust	Pig house Feed	Poultry house Deposited dust
Dry matter	78	88	89
Crude protein	24	19	50
Crude fat	4	4	10
Crude fibre	3	5	-
Crude ash	15	5	-

The dust from poultry houses contains the highest amounts of protein. This is caused firstly by the relatively high protein content in the feed which is usually between 20 and 25 % (Kamphues J. et al. 2004). The other proportion of up to 45 % comes probably from feathers and claw abrasion. Also in the pig house dust a percentage of about 20 % seems to come from the skin and the hairs of the animals. The relatively high amounts of fat in the dust from the duck house can be explained by the behaviour of the duck to use a self produced fatty substance for preening and protecting the feathers. The high fiber content in the turkey house dust may have been influnced by the hay baskets which were offered to the turkeys as a mean to prevent feather pecking and cannibalism.

Amounts of microorganisms in dust

Animal house dust is an important carrier of bacteria and fungi. Table 4 gives an overview of the amounts of total bacteria count, E. coli, staphylococci, streptococci and fungi in the sedimentation dust from animal houses of 6 different species.

Table 3:
Mean (a) and standard deviation (s) of dust analysis from different animal houses in percent (%) of dust mass. T.S = dry matter. R.A = crude ash. R.P. = crude protein. R.Fa. = crude fiber. N.F.E. = nitrogen free substances

		T.S. %	R.A. %	R.P. %	R.F. %	R. Fa. %	N.F.E. %	
Broiler	a	90.8	9	70.6	3.8	4.7	2.6	N = 8
	s	0.8	1.4	3.7	0.5	2.5	2.3	
Aviary	a	88.8	13	62.3	3.6	6.2	3.6	N = 11
	s	1.3	1.5	7.7	1.9	3.7	5	
Furnished cage	a	90.1	11.7	63.9	6.4	3.7	4.3	N = 11
	s	0.6	1.5	4.6	1.5	2	3.2	
Ducks	a	89.4	8.6	58.6	8.4	3.1	10.6	N = 6
	s	2.3	1.2	3.8	0.8	1.7	2.8	
Turkeys	a	89.8	9	53.8	3.4	11.2	12.4	N = 11
	s	1.6	1.9	6	1	4.4	5	
Pigs	a	90.2	14.5	38.4	3.6	1.3	32.5	N = 13
	s	1	1.2	2.9	0.9	0.7	3.6	
Cattle	a	85.8	18.8	29.7	6.6	6.6	24.1	N = 6
	S	5,4	3.8	4.3	1.7	1.7	3.1	

All dust samples contain relatively little water. In poultry and pig dust the dry matter content reaches about 90 %. The dust from the cattle barn showed a humidity of about 15 %. This value is slightly above the threshold of bacterial growth which is around 14 % moisture in dry meal feed (Kamphues J. et al. 2004). The relative high content of ash in the dust from the cattle house is probably due to sandy feedstuff. The very low values in the moskovy duck house are probably caused by the plastic flooring.

The highest concentrations are observed in broiler barns followed by duck, turkey, laying hen, pig and cattle. This reflects the common experience that the highest concentrations of micro-organisms are found in poultry houses. There are clear differences between keeping systems of one species. In the aviary (VOL) distinctly higher amounts of bacteria were found compared to furnished cage systems.

Table 4:

Mean concentrations (a) of typical micro-organisms in sedimentation dust from animal houses of different species. Standard deviation (s)

		Total count cfu/g x 10^6	E. coli cfu/g x 10^3	Staph. cfu/g x 10^6	Strep. cfu/g x 10^6	fungi cfu/g x 10^5
Laying hens Aviary	a	1741	57	1168	5	4
	s	1146	29	676	4	6
Laying hens Aviplus (AKA)	a	200	398	124	8	12
	s	82	352	55	3	12
Laying hens Eurovent (AKB)	a	408	499	342	12	4
	s	268	373	228	2	5
Broiler	a	7772	285	6326	22	289
	s	3990	177	2933	24	129
Turkeys	a	3554	1813	2915	93	71
	s	1938	1304	1866	31	53
Cattle a	a	91.4	1651.6	64.7	1.3	6.3
	s	79.9	1497	59.9	0.6	52
Cattle b	a	85.7	1574	63	0.9	5.7
	s	8.1	109	1.6	0.5	8
Moscovy duck	a	5782	129	1764	224	3
	s	3644	150	1956	193	6
Pig	a	88	90	26	15	2
	s	44	96	17	10	4

The dust from livestock buildings contains a variety of further compounds which are potentially hazardous agents (Donham K. J. 1989). Dust also contains potentially allergic agents, infectious microorganisms, enzymes, and toxic gases. One gram of piggery dust can absorb about 1 mg of gases such as fatty acids and phenols (Hartung J. 1985).

Further compounds which are associated with animal house dust are drugs. In a recent study Hamscher G. et al. (2003) were able to show that pig house dust has an excellent "memory" for all types of antibiotics. Up to 12 mg/kg dust of antibiotic residues were analyzed. It was possible to identify different classes of antibiotics in the dust even 15 years after its application.

Effect of airborne particles

The effects of the particles in livestock buildings on human and animal health cannot simply be attributed to dust levels or the concentration of microorganisms. Effects on health are related to the complex action of particles and gases as well as the physical and psychological environment. Particulates can have effects which may be described as mechanical, infectious, immunosuppressive, allergic or toxic. Table 5 summarizes the possible effects of airborne dust, microorganisms and gases on animal health.

The mechanical effects of high dust levels and the influence of pathogenic microorganisms are relatively easy to understand. Inhalation of large amounts of dust may cause overloading of the clearance mechanisms in the respiratory passages and mechanical irritation which facilitates the beginning of infections. High levels of dust, microorganisms or gases in the respiratory tract may lead to reduced resistance (Parry R. R. et al., 1987), particularly in animals where they may be combined with the effects of fighting within groups or unfavourable climatic conditions in the building.

Particle size is of fundamental importance to the influence of dust, irrespective of whether the inhaled particle is a grain of dust or a bacterium. The smaller the particle diameter, the deeper its point of deposition in the respiratory tract. Particles of less than 7 µm in diameter are known as alveole-accessible (Vincent J. H. and Mark D. 1981; Henschler D. 1990).

A deciding factor in the depth of penetration is the aerodynamic diameter. At diameters of 4 to 5 µm the alveolar deposition rate may be as high as 50 %. It is not only the size of the dust particles which plays a part in animal health and performance. High dust concentrations seem to have a general performance-reducing effect. Carpenter G. A. et al. (1986) demonstrated that removal of a part of the airborne dust, using coarse dust filters in an air recirculation system, led to an increase in fattening pig performance. Although dust removal was only practised in the weaner house for the first 20 days after weaning, and the pigs were subjected to the same conditions as the control group subsequently, the animals reached their market weight up to 8 days earlier than the control group reared entirely without dust removal. Only a low level of clinically recognizable diseases occurred in both groups.

Table 5:
Possible influences of dust and microorganism levels on animal health (after Zeitler M. 1988)

Factor	Effect on the animal
High dust levels	Mechanical irritation: overloading of lung clearance, lesions of the mucous membranes
Specific microorganisms	Infectious effect: infection by pathogens
Dust, microorganisms, and gases	Non-specific effect: defence mechanisms stressed, reduced resistance
Microorganisms and dust	Allergic effect: over-sensitivity reaction
Microorganisms and dust	Toxic effects: intoxication by bacterial/fungal toxins

High levels of aerial pollutants can distinctly influence the health status of pig herds. In a comparison of 44 fattening pig herds with (+AR n = 15) and without (-AR n = 29) clinically recognized atrophic rhinitis (AR) was shown that increased levels of dust, bacteria, endotoxins, and ammonia were associated with a higher incidence of AR (Baekbo P. 1990). When comparing these results with a proposal for an exposure threshold given by Donham K. J. (1989), it is shown that respiratory disease may be absent even under unfavourable concentrations of some of the factors.

A lot of attention has been given to endotoxins which seem to be implicated in the pathogenesis of hypersensitive pneumonias in humans (Thelin A. et al. 1984). Apart from their allergic potential, they also affect the immune system (Rylander R. 1986). In sensitive individuals, even very small amounts of these lipopolysaccharides are sufficient to cause an increase in antibodies (Clark et al., 1983). In cattle and horses, allergic diseases such as rhinitis, alveolitis, and asthma are well known and are primarily associated with the use of mouldy feed, hay or straw (Siepelmeyer F. J. 1982). The role of endotoxins in respiratory diseases of animals has not been sufficiently researched. In humans it is known that only chronic exposure over years will contribute to clinically apparent respiratory alterations like chronic bronchitis. The lifetimes of livestock may therefore be too short for damage to occur. However, even younger workers, who have spent a relatively short period in pig farming, can show temporary symptoms of irritation of the airways (Rylander R. et al. 1989).

Dust in the air of livestock buildings can present a significant burden to the respiratory tract of humans and animals and must be considered in the context of some typical respiratory disease patterns. The effects of dust, microorganisms, gases, and toxins cannot be separated, but dust is of special significance as the carrier of these substances. High dust burden can distinctly influence the health of animals kept in confined buildings. For the development of an infectious disease the presence of the respective infectious agent seems to be necessary. Measures to reduce dust formation and increase hygiene in the animal houses should be given more sustained application in practice. It seems necessary to establish scientifically based maximum levels for dust in livestock houses. This would be in the interests of workers, of animal welfare, and of the wider environment. The role of airborne particulates in livestock production needs close further scientific attention.

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