#6204

AERIAL DUST IN SWINE BUILDINGS

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SUMMARY

Field studies on the nature of the aerial dust in 31 swine buildings on commercial farms were carried out. Concentrations of total dust and respirable dust averaged on 1.6 (range 0.2 to 4.1) and 0.2 (range 0.0 to 0.5) mg m^{-3}, respectively. Supplementary, long term observations on an SjF experimental farm and on a commercial farm were carried out in order to find the effect of environmental factors on aerial dust concentrations.

The most important factors influencing aerial dust concentration were :

a) Ventilation method. (Centre-air-supply ventilation showed higher dust concentration than side-wall-air-intake ventilation.)
b) Weight or age of pig. (Negative correlated)
c) Outside temperature. (Negative correlated)
d) Outside relative humidity. (Negative correlated)
e) Inside relative humidity. (Negative correlated)

Ventilation is regarded as the basic method of dust removal. However, the existing ventilation systems are not able to handle the volume of aerial dust in swine buildings. Better understanding of the dynamic behaviour of aerial dust in the turbulent air stream at animal level is still needed.

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INTRODUCTION

The airborne contamination in swine buildings is characterized by high levels of organic dust [1, 2, 3, 4]. Large numbers of bacteria and mould spores, and high concentrations of endotoxin are found [5, 6, 7]. Toxic gases like ammonia and hydrogen sulphide occur in varying concentrations [8, 9].

About 70 % of disorders which are registered in slaughterhouses in Denmark, are related to the respiratory systems. Swine health appears to be affected by the harmful nature of dust, but the underlying cause is not yet clear.

There is a high incidence of wheezing and symptoms of chronic bronchitis amongst farmers [10, 11]. Pig farmers are more prone to these symptoms than other farmers [2, 12, 13, 14, 15, 16]. Work in swine buildings is associated with an acute decrease in lung function [17, 18], and seems to result in a long term decline in lung function [19]. A high content of organic dust has been put forward as the cause of work-related respiratory symptoms in pig farmers [20]. Vinzents et al. [21] reported that about 40% of the time spent working in swine buildings involved close contact with pigs. During this period the farmers are exposed to high concentration of dust because it becomes airborne during the activity of the animals. Furthermore, work is often strenuous, causing the farmer to inhale large amounts of dusty air.

In this paper, the effects of different variables are discussed on the basis of the collected data to determine the most important factors affecting aerial dust concentration in swine buildings.

Swine Buildings

A swine building contains large spaces with complicated air movement affected by a number of variables, such as the ventilation rate, heat from the animals and heating systems, wind pressure, movement of animals etc.. Air for ventilation is normally taken directly from outside. Depending on stocking density and outside temperature, buildings are ventilated at the rates of 2 - 50 air changes per hour. There is sufficient air turbulence to suspend dust particles in most livestock buildings. The inside temperature is kept at a setpoint temperature by a thermostat control unit. Relative humidity is normally below 75%, and can be much lower.

Factors Affecting Aerial Dust Concentration

The concentrations of aerial dust correlated to some environmental factors, such as ventilation systems [5, 22, 23], feeding practices [5, 24], bedding materials, animal activities [25, 26]. Animal activity is the main cause of sudden increases in dust concentrations.

Methods of Reducing Aerial Dust

Bundy [22] observed that higher air velocities caused more inertial impaction of particles on building surfaces, thus removing them from the air stream. Nilsson [25] observed that fogging seems to be an effective method of reducing the number of particles which are less than 2.5 μm. Chiba et al. [27] demonstrated that adding tallow to the feed reduced the concentrations of aerial dust, ammonia and microbes, and improved pig performance. Heber et al. [28] found that adding soybean oil to the feed is more effective in reducing aerodynamic dust segregation than animal fat. Preliminary results from our laboratory showed that more than 80% of the aerial dust in swine buildings could be removed by spraying a mixture of rape seed oil and soap suds [29]. Because of adhesion of the oil sprayed, dust particles are bound together and less dust would be airborne during the activity of animals.

GENERAL DESIGN

The study examines common trends in the data from three separately conducted studies:

- Study 1 Field studies of 31 commercial farms [30].
- Study 2 Long term observation on the SjF experimental farm [31].
- Study 3 Long term observation on a commercial farm [32].

The study 1 involved different technical categories of ventilation, feeding and bedding. Ventilation techniques were divided into two types with regard to the direction of the fresh air stream. The centre-air-supply type blows fresh air through ducts at the centre of the building, and the velocity of the fresh air is greatest nearest to the duct. The side-wall-air-intake type sucks the fresh air into the building through air intake valves mounted in the side walls. The direction of the fresh air stream is from side walls to the centre of the building, and the velocity of the fresh air is greatest nearest to the side walls. Feeding techniques were divided into two types with regard to the type of feed stuff. Dry feed stuff includes both feed pellets and meal. With wet feeding the feed stuff is mixed with water prior to feeding. Bedding practices were divided into two types with regard to the use of straw. Different combinations of these techniques were used in different buildings. T-tests were used to determine the differences between the two types within the same technical category.

Study 2 was carried out in a building for fattening pigs (abt. 25 - 95 kg) on the SjF experimental farm. Centre-air-supply ventilation and wet feed stuff were used. No bedding material was used. Total dust and respirable dust concentration, inside and outside temperature and relative humidity were measured once a month.

Study 3 involved one building for young pigs (abt. 25 - 50 kg) and three buildings for fattening pigs (abt. 50 - 95 kg). Side-wall-air-intake ventilation and wet feeding were used in all buildings. No bedding material was used. Respirable dust concentration, inside and outside temperature and relative humidity were measured once a week.

MEASURING METHODS

Concentrations of total dust and respirable dust were mearsured using the filter method. A membrane filter (∅37 mm, pore size 0.8 μm) and a sampling rate of 1.9 l/min. ± 10% (for total dust) and ± 5% (for respirable dust) were used. For the total dust measurements, filter cassettes with a 5.6 mm diameter intake hole (calculated inlet air velocity of 1.25 m s^{-1}) were used. For the respirable dust measurements, cyclone pre-separators (50% cut-off at 5 μm) were attached in front of the filter cassettes. The filter cassettes were located 1.8 - 2 m above the floor, away from the feeders and other equipment which could produce dust. The sampling was carried out with the air inlet pointing downwards over a sampling period of 24 hrs.

The collected dust was exposed to a constant set temperature (20 ±0.2 to 25 ±0.2 °C) and a relative humidity (50 ±1%) for one night prior to being weighed. An electronic micro balance with a detection limit of 0.01 mg was used to weigh the dust samples. The overall accuracy of the dust measurement is estimated to be better than ±15%.

Temperature and relative humidity were measured using thermohygrographs. The average temperature and relative humidity over 24 hrs. were determined by reading the graph.

The age of pigs was determined on the basis of production notes. The weight of pigs was estimated by skill technicians.

RESULTS AND DISCUSSION

Effect of Different Techniques

Concentrations of total and respirable dust in 31 fattening buildings on commercial farms averaged 1.6 (range 0.2 to 4.1) and 0.2 (range 0.0 to 0.5) mg m^{-3}, respectively.

Buildings with side-wall-air-intake ventilation gave lower dust concentrations than buildings with centre-air-supply ventilation, p=0.09 for total dust and p=0.00 for respirable dust, Table 1. The location of the maximum air velocity is the main difference between these ventilation types. With side-wall-air-intake ventilation, the velocity of the fresh air is greatest nearest to the side walls. With centre-air-supply ventilation, the velocity is greatest at the centre of the building. The source of dust is generally closer to the centre of building than the side walls. Dust is raised by animal activities, and may be dispersed by the ventilation air.

Feeding and bedding practices had a less significant effect on dust concentration, Table 1. Fattening pigs are normally fed two or three times a day. Feeding is a quick process - less than 30 minutes per feeding. The contribution of feeding practices to the dust concentration measured over 24 hours is probably negligible. Attwood et al. [5] used a sampling period of 6 hours, and found that wet feeding produced less aerial dust than dry feeding.

Table 1. *Effect of different techniques on total dust and on respirable dust.*

	TOTAL DUST mg/m³	RESPIRABLE DUST mg/m³
Ventilation		
Center-air-supply (n=11)	1.99	0.27
Side-wall-air-intake (n=20)	1.42	0.12
P-value (t-test)	0.09	0.00
Feeding		
Dry feeding (n=17)	1.82	0.20
Wet feeding (n=12)	1.34	0.17
P-value (t-test)	0.17	0.59
Bedding		
With straw (n=26)	1.73	0.18
Without straw (n=5)	1.10	0.15
P-value (t-test)	0.15	0.65

Straw can be of different qualities, depending on cultivation, harvesting and storage conditions. Straw of good quality does not contain much dust, and may prevent dust on the floor from being disturbed. In contrast, straw of poor quality is easily broken into small pieces, and often contains a large amount of soil, insects, fungi and bacteria. Dust on a dry floor without bedding material may easily be disturbed by animal activities.

Effect of Environmental Factors

Multiple regressions of total dust and respirable dust on different environmental factors were conducted to determine whether statistically significant trends occurred in the data from the three different studies. The environmental factors analysed were: 1) number of pigs, 2) average weight or age of pigs, 3) inside temperature, 4) inside relative humidity, 5) outside temperature, 6) outside relative humidity and 7) temperature difference between inside and outside.

Multiple regressions of total dust with best R^2 (corrected according to number of data and variables) are shown in Table 2, and for respirable dust in Table 3. As seen in the tables none of the multiple regression coefficients was at such a level that one can use it directly for dust control. However, the tables show some interesting tendencies.

The number of pigs did not significantly affect dust concentrations. Stocking density based on kg pig or number of pigs, should be used for further study.
The weight or age of the pigs appear to be negatively correlated with dust concentration. There could be different reasons for this:

1) Ventilation rate per pig increases with weight or age of pigs.
2) The ratio surface area to weight decreases with weight or age of pig.
3) The surface of the building and the fixtures may bind dust as dirt accumulates on the surfaces.

Only study 2 revealed any significant correlation between inside temperature and respirable dust concentration, but this finding may not be true in all cases.

There was a negative correlation between outside temperature and dust concentration. Within min. and max. airflow rate of the ventilator, ventilation rates increase with higher outside temperature. Beyond this limit the ventilator will remain at either min. or max. level. This may be the reason why only study 1 revealed a significant effect of the ΔT on dust concentration. Heber et al. [23] observed that ΔT had a significant effect, but correlation coefficient of dust concentration was low, which is in agreement with our study.
There was a negative correlation between both inside and outside relative humidity and aerial dust concentration. The effect of humidity is discussed in earlier studies [22, 23]. Two reasons were suggested. 1) The absorption of water vapour by dust particles in humid air produces heavier particles which settle more rapidly, thus lowering aerial dust concentrations. 2) Humid air increases the moisture content of litter and settled dust, so that less dust becomes airborne.

Ventilation is an important method of dust removal. However, relatively low multiple

Table 2. *Result from multiple regression analyses.*
Effect of environmental factors on total dust in swine buildings.

	NUMBER OF PIGS	WEIGHT OF PIG	INSIDE TEMPERATURE	INSIDE HUMIDITY	OUTSIDE TEMPERATURE	OUTSIDE HUMIDITY	TEMPERATURE DIFFERENCE	R^2 (CORRECTED)
Study 1 Range: min. max.	60 500	30 kg 80 kg	11°C 22°C	60% 89%	-11°C 16°C	70% 98%	3°C 24°C	
Coefficient P-value	-	-	-	-0.062 0.001	-	-	0.085 0.002	0.414 0.002
Study 2 Range: min. max.	30 144	35 kg 90 kg	11°C 29°C	64% 84%	- 7°C 18°C	66% 98%	2°C 18°C	
Coefficient P-value	-	-0.019 0.022	-	-	-0.086 0.002	-0.066 0.006	-	0.558 0.023

Table 3. *Result from multiple regression analyses.*
Effect of environmental factors on respirable dust in swine buildings.

	NUMBER OF PIGS	WEIGHT/ AGE OF PIG	INSIDE TEMPERA-TURE	INSIDE HUMI-DITY	OUTSIDE TEMPE-RATURE	OUTSIDE HUMI-DITY	TEMPERA-TURE DIF-FERENCE	R^2 (CORRECTED)
Study 1 Range: min. max.	 60 500	 30 kg 80 kg	 11°C 22°C	 60% 89%	 -11°C 16°C	 70% 98%	 3°C 24°C	
Coefficient P-value	-	-0.0049 0.02	-	-0.065 0.031	-	-	0.0073 0.09	0.414 0.002
Study 2 Range: min. max.	 30 144	 35 kg 90 kg	 11°C 20°C	 64% 84%	 - 7°C 14°C	 66% 98%	 2°C 18°C	
Coefficient P-value	-	-0.0034 0.015	-0.021 0.094	-0.0055 0.289	-	-	-	0.508 0.089
Study 3 (YP): Range: min. max.	 129 pigs 159 pigs	 68 days 117 days	 17°C 21°C	 67% 81%	 -3°C 12°C	 80% 98%	 9°C 22°C	
Coefficient P-value	0.018 0.281	-	-	-	-0.098 0.056	-0.058 0.106	-	0.575 0.065
Study 3 (FP): Range: min. max.	 37 pigs 131 pigs	 120 days 173 days	 16°C 22°C	 66% 79%	 -3°C 24°C	 75% 96%	 -3°C 19°C	
Coefficient P-value	-0.0036 0.333	-0.018 0.011	-	-	-	-	-	0.457 0.011

YP = Young pigs abt. 25-50 kg
FP = Fattening pigs abt. 50-95 kg

regression coefficients indicate that existing ventilation techniques cannot handle the volume of dust produced in swine buildings. To improve the efficiency of the ventilation air for dust removal, better understanding of the dynamic behaviour of aerial dust is needed. As animal activity is a major factor causing high dust emissions, investigations on aerial dust movement in the turbulent air stream at animal level are highly desired.

CONCLUSION

1) The most important factors influencing aerial dust concentrations were :

   a) Ventilation method. (Centre-air-supply ventilation showed higher dust concentration than side-wall-air-intake ventilation.)
   b) Weight or age of pig. (Negatively correlated)
   c) Outside temperature. (Negatively correlated)
   d) Outside relative humidity. (Negatively correlated)
   e) Inside relative humidity. (Negatively correlated)

2) Ventilation is often regarded as the basic method of dust removal. However, existing ventilation systems are not able to handle the volume of aerial dust in swine buildings.

3) For the improvement of the dust removal efficiency of ventilation air, better understanding of the dynamic behaviour of aerial dust in the turbulent air stream at animal level is needed.

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