Particle emissions from German livestock buildings - influences and fluctuation factors

Ch. Nannen[1] and W. Büscher[1]

Abstract

Dust measurements are done in several animal buildings with different air ventilation and feeding systems. Even if all dust regulations are observed some aspects should be added, which apply to influences on the dust emission factors. These aspects are related to mean emission factors over one day, season or year. For that the parameters air volume flow, animal activity and particle concentration in the interior and exhaust air depending on different seasons are done in a fattening pig barn. Animal activity and air volume flow affected the developing of particle emission factors. A deviation of single half an hour data to the average value of the whole day was determined. So it is necessary to set the minimum analysing interval on 24 hours. The measuring point for the dust measurements should be the exhaust air. A comparison of the interior and exhaust dust concentrations showed that fact.

Furthermore the distribution of particles is changing by different levels of animal activity. The higher the animal activity the higher is the number of particles with big optical diameters. The management of the farmer has a big influence on the interior factors of the barn. Different practises with equal housing and feeding systems, weights of animals and ventilation systems yield different results.

Keywords: dust measurement, animal activity, particle emission, ventilation rate

Introduction

In most animal houses, heating, feeding and ventilation systems are very complex and have many influences on the generation of particles, odor and ammonia. Based on several measurements on dust we are able to describe some important conditions for the measurement setups. The influences of animal activity and ventilation rates should be exposed to get more knowledge about the considering fluctuation factors.

Methods

Diurnal variations in the parameters animal activity, particle concentration and air volume flow rate were recorded with different weather conditions in order to facilitate the analysis of the connection between animal activity and particle emissions. The investigations were made in a fattening house for 112 pigs with dry feeding (ad libitum) and door ventilation.

The continuous particle measurements were carried out in accordance with standardised measuring instructions for occupational safety and health (VDI 2080, VDI 2066). Particle concentrations were measured with an aerosol spectrometer, model 1.108 (GRIMM-Aerosoltechnik, Ainring, Germany). Isokinetic sampling in the exhaust air flow was carried out on the intake side. The measuring interval was one minute. A calibrated measuring fan with a data logger for monitoring the frequency of the fan was used to monitor the volume flow rate. The measuring interval in this case was one minute as well. The measuring fan was positioned on the pressure side of the exhaust shaft. The activity sensors used in this study are commercial passive infrared sensors modified for this particular application. The integrated relay control for the prevention of interferences has been deactivated. Instead, a voltage is tapped directly from the sensor so that it maps a signal that is analogous to the recorded movement. The signal is a differential signal, i.e. rapid temperature increases or decreases in front of the sensor lead to higher positive or negative values than slow changes in temperature. Thus, the amplitude of the impulse is proportional to the intensity of the temperature change. Slow temperature changes induce no signal. Signals are first rectified for further processing so that temperature increases and decreases are no longer differentiated. The

[1] Section Livestock Technology at the Institute for Agricultural Engineering of Bonn University, Germany

incoming signal is then routed through a holding circuit so that short impulses are artificially prolonged; the duration can be adjusted on the sensor. Thus, a data logger records the voltage every six seconds to capture short movements as well.

To get more knowledge about the difference of the particle concentration between the interior air and the exhaust air, two aerosol spectrometers were positioned inside the barn 1.2 m above the animals and in the exhaust air as described before.

Results and discussion

The first and most important fact is that it is necessary to measure emissions over one day to calculate a mean value for those emissions. The deviation of a three or four hour's measurement is factor 2 to 4 in relation to the daily mean. Figure 1 shows that fact.

The reasons for this deviation are changing animal activity and changing air volume rates. So it is possible to underestimate or overestimate the emissions by measuring only short terms.

Animal activity and particle emission levels are closely correlated. Emissions increase drastically especially during periods of activity as you can see in figure 2. The results of the measurements by Pedersen S. (1993) and Bönsch S. et al. (1996) were confirmed by the measurements made for the present study. The example of the development of animal activity and particle emission for several days as depicted in figure 3 shows that especially surveillance walks are connected with high animal activity and consequently with high particle emission. The question arises to what degree animal activity and particle emission are correlated. Figure 3 also contains the scatter plot of the correlation. As expected, the calculated coefficient of determination across all size classes (R_2 = 0.8) shows the correlation between animal activity and particle emission to be high.

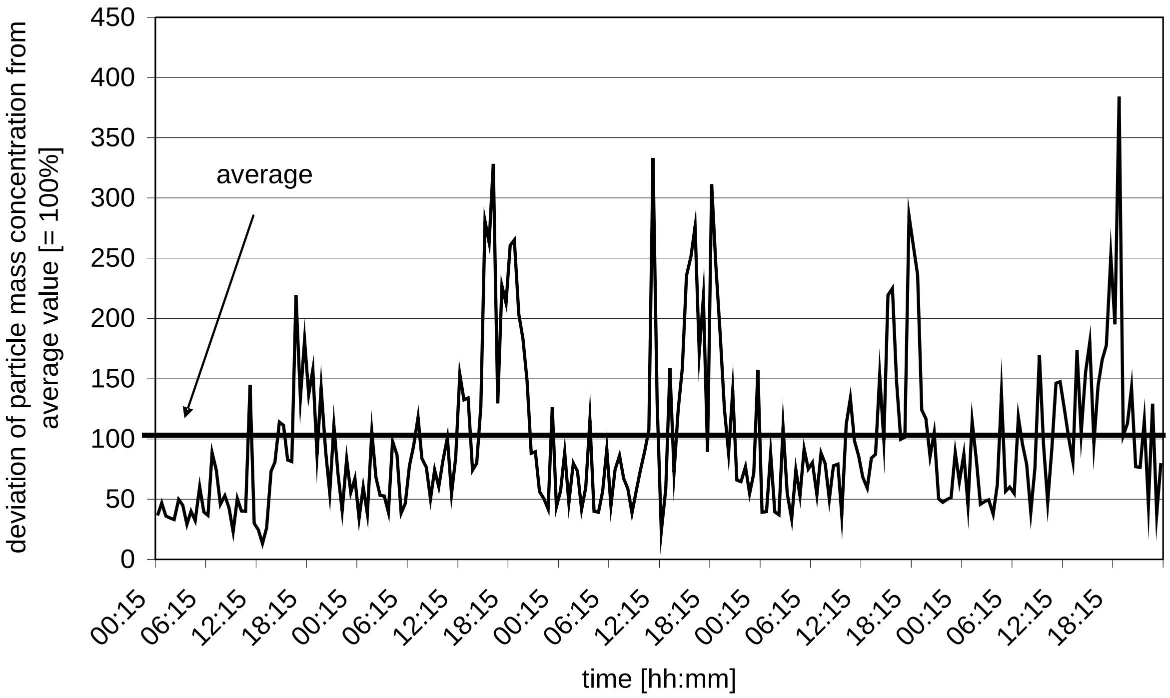

Figure 1:
Deviation of half an hour values of particle mass concentration from average value

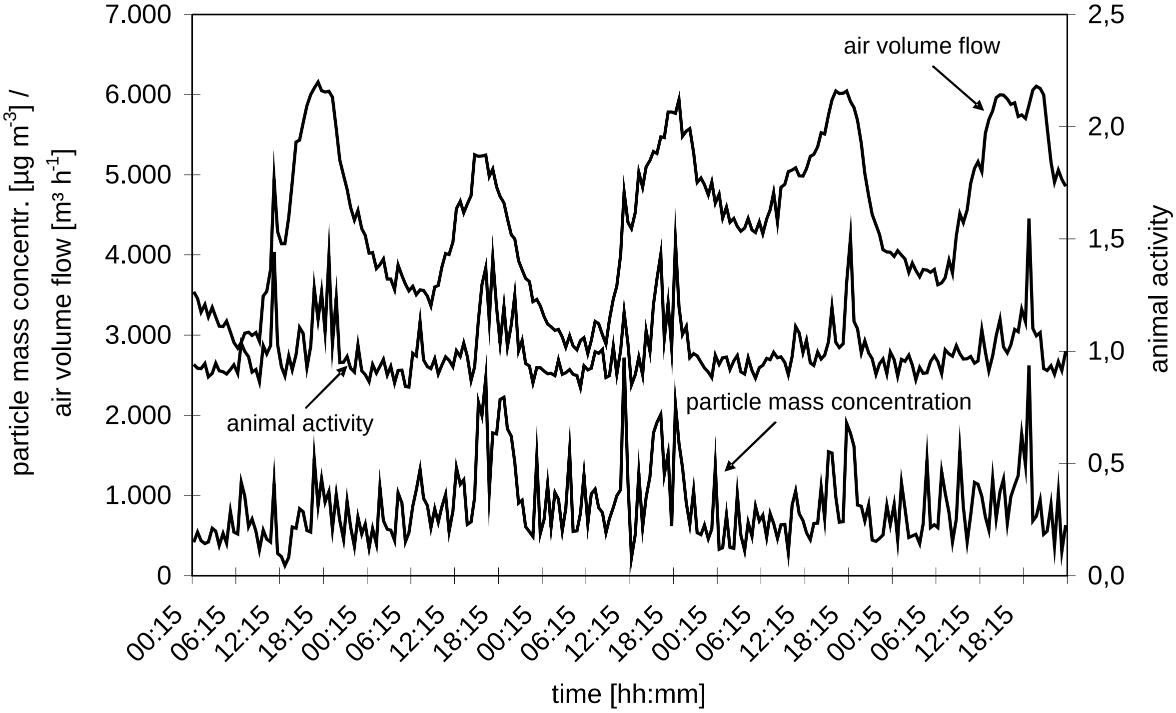

Figure 2:
Particle mass concentration, air volume flow and animal activity

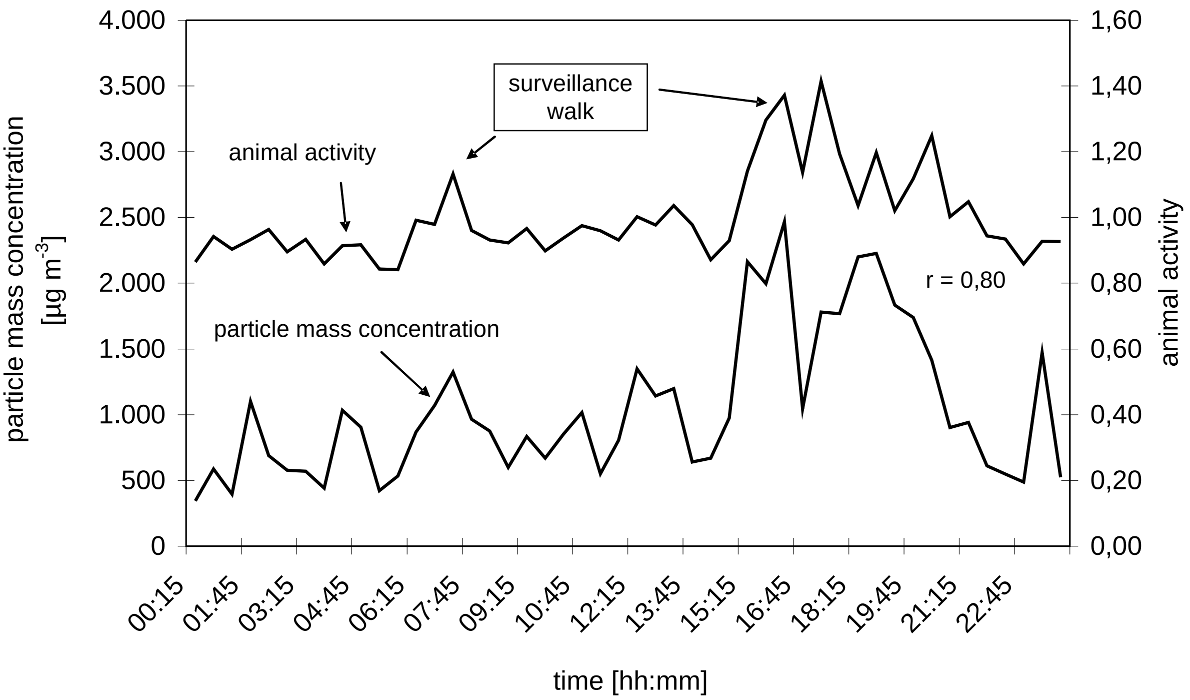

Figure 3:
Particle mass concentration and animal activity - relationships

In this analysis a new aspect was found regarding particle size distribution. Representative for all daily developments, figure 4 shows the development of the total mass concentration, the PM10 concentration and the levels of animal activity.

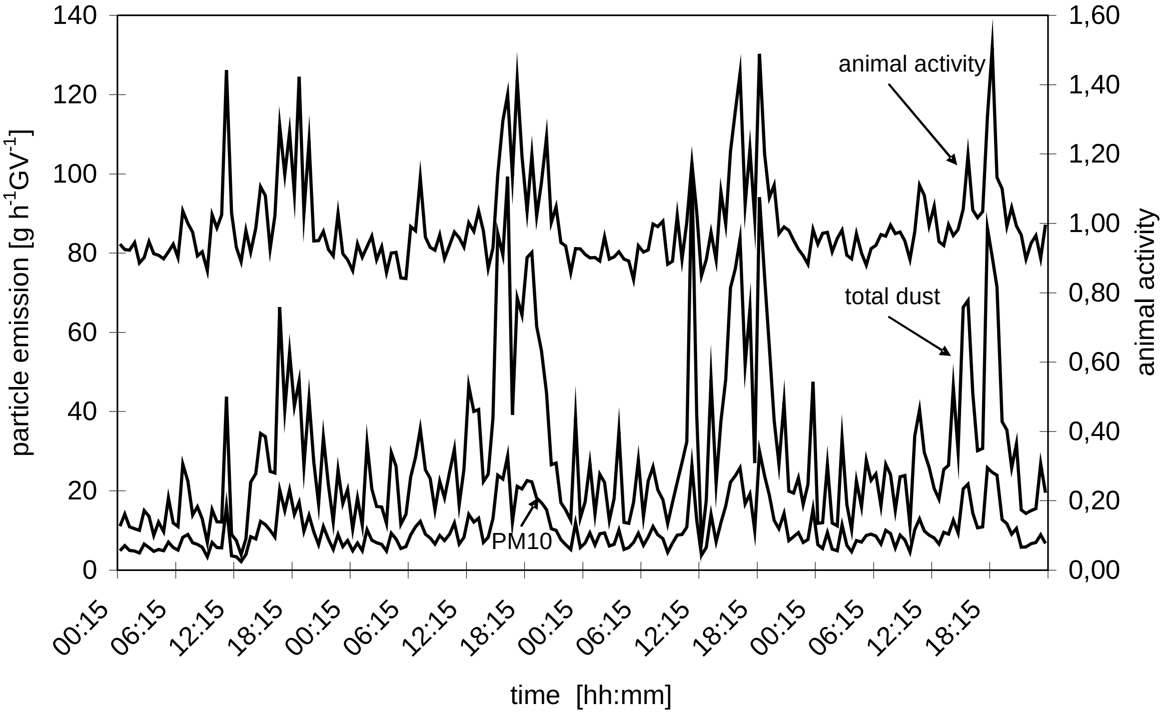

Figure 4:
Total particle mass concentration and PM10 concentration in relation to animal activity

One of the reasons for this is the increasing proportion of larger particles in the total number of particles. In this case high animal activity describes a deviation of one standard deviation from the average value of the day set 100 %. Higher levels of animal activity affect especially the particles with increasing diameter.

The higher the ventilation rate, the lower the dust concentration and the higher the correspondence between the dust concentration in the interior air and in the exhaust air due to better mixing. Because of that, it is necessary to measure the emission in the exhaust air and not in the barn. We calculate factors between the interior and exhaust air depending on different levels of the air volume flow. It was concluded that the barn is not a constant system that emits equal values of emissions over the whole day. The higher quotients for particles >5 µm can be attributed to the deposition of dust in the fan shafts. Particles are deposited on the walls of the exhaust air chimneys, resuspending at sufficiently high air velocities as larger particles formed by agglomeration with other particles. To visualise the results, the quotient of the particle concentration in the exhaust air and the particle concentration in the interior was calculated for different particle sizes. This concentration ratio describes the probability of encountering a particle of a certain size both on the inside of the livestock house and in its exhaust air. At a quotient of q = 1 for all particle size classes, all particles from the interior of the livestock house would make their way into the exhaust air. The particle concentration inside the livestock house would be the same as that in its exhaust air. The assumption that particle concentrations in the interior of livestock houses differ from those in their exhaust air was confirmed by reproducible measurements. The number of bigger particles in the interior air is much higher than in the exhaust air as you can see in figure 5.

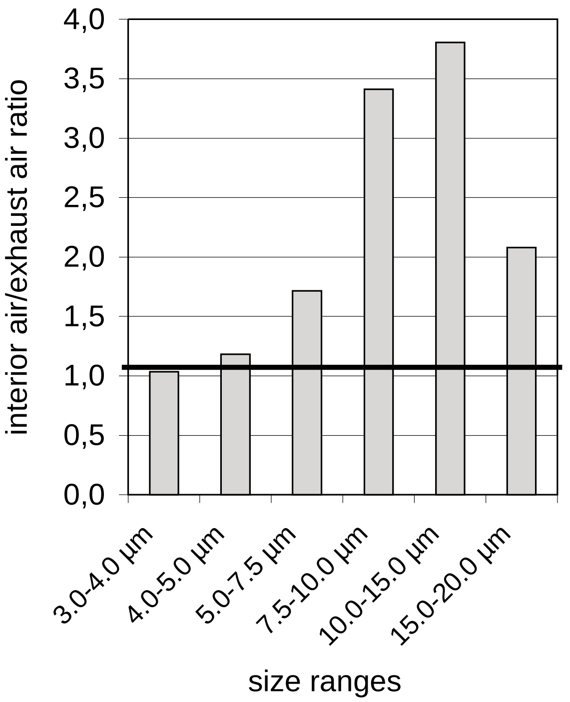

Figure 5:
Ratio of the particle number concentration in the interior air to the exhaust air

The last influencing factor is the management. Two barns, constructed in the same way with equal feeding, ventilation and heating systems were compared. Surveillance walk, adjustment of the air volume flow or number of feeding time per day affect different emission factor, expressed in emission per animal unit. Figure 6 shows the particle mass concentration and the air volume flow in two different fattening pig farms. The management of the farmer is determined by the air volume flow. The airflow is a function of the temperature set of the controller. This includes influences on the particle mass concentration and the particle emission factors.

Other important factors on emissions are the seasonal effects. Because of higher volume flow rates per animal in summer, the emissions are higher than in autumn or winter. On the other hand, the concentration of emissions in the exhaust air in the winter time is higher than in the summer time as you can see in figure 6.

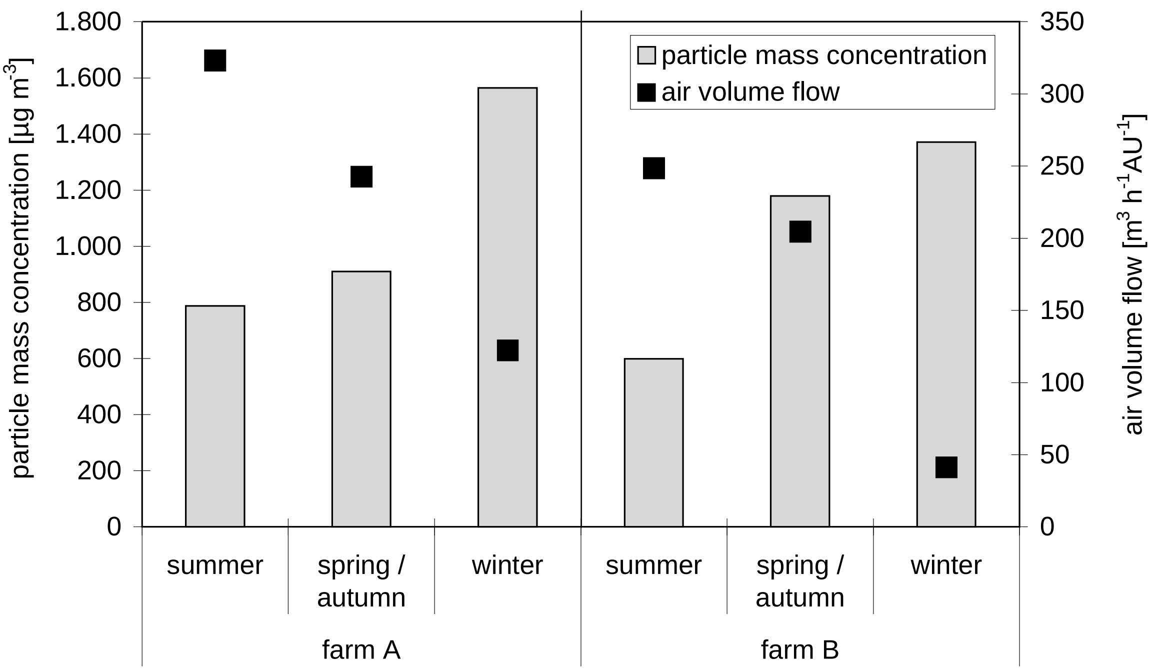

Figure 6:
Particle mass concentrations and air volume flows in different seasons and two different farms

Consequences

The results showed different considering fluctuation factors on dust generation and PM-emissions. To quantify a dust emission factor, it is necessary to measure 24 hours. In that case animal activity is the most important factor. Climatically effects and the house management of the farmer lead to differ between seasons. The position of dust sampling should be in the exhaust air, because the dust concentration in the interior air is not equal to the concentration in the exhaust air.

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