Gregor Schmitt, Oliver Wallenfang, Wolfgang Büscher and Bernd Diekmann, Bonn

Particle Concentrations in the House Exhaust Air

A Comparison with the Concentrations inside the Livestock House

In typical layer houses the particle concentrations were measured in the interior as well as in the exhaust air. An aviary system as well as a cage keeping system were examined. Different particle concentrations were ascertained in the interior of the stable and in the waste air.

Dipl.-Phys. Gregor Schmitt is a postgraduate student, Dr. Oliver Wallenfang a scientific assistant, and Prof. Dr. Wolfgang Büscher the institute head and head of the 'Livestock Technology' section at the Institute for Agricultural Engineering of Bonn University, Nussallee 5, D-53115 Bonn, Germany; e-mail: *gregor.schmitt@uni-bonn.de*.
Dr. Bernd Diekmann is a private lecturer at the Department of Physics of Bonn University, Nussallee 12, D-53115 Bonn, Germany

Summarized contribution to LANDTECHNIK. You will find the long version under LANDTECHNIK-NET.com

Keywords

Dust, particle concentration, exhaust air

Literature

Literature references can be called up under LT 04602 via internet http://www.landwirtschaftsverlag.com/landtech/local/literatur.htm.

The current version of the Technical Instructions on Air Pollution Control [1], published in 2002, is the first to define critical values for dust emission that apply to livestock houses. Currently, statements about or predictions of dust loads from livestock houses are difficult due to a lack of reliable emission factors.

In recent years a growing number of studies in the field of occupational medicine have looked at dust loads in workplaces in livestock houses [2,3]. Thus, typical dust particle concentrations in livestock houses have been determined for most farm animal species. Due to the practical difficulties in measuring dust concentrations in the exhaust air from livestock houses, the flow of emissions from livestock houses has usually been calculated from the dust concentration in the interior of the house [4]. However, it is questionable whether the concentration of dust particles inside livestock houses may be assumed to be the same as that in the exhaust air.

Basic theoretical considerations concerning particle dispersal suggest that, due to sedimentation and inertia effects, there are relatively fewer large particles in the exhaust air than in the interior of livestock houses. These assumptions are confirmed by a simulation with the particle model NaSt3D, which was developed at the Institute for Agricultural Engineering of Bonn University [5].

In the investigations described below, practical tests were carried out to compare the particle concentrations inside livestock houses with those in their exhaust air. The measurements were performed in two typical mechanically ventilated laying hen houses, i.e. in a cage house for up to 46,000 birds and in an aviary house designed for 13,000 birds.

Measurement Method

Particle concentrations in the interior air and in the exhaust air of the livestock houses under study were determined for different ventilation intensities set via the houses' climate computers.

The measurement instruments used were two aerosol spectrometers manufactured by Grimm Aerosol-Technik GmbH, Ainring. The dust sensors detail the particle concentrations for different particle sizes. These particle number concentrations are expressed as the number of particles in a size class per volume of air.

The dust measurements inside the livestock houses were carried out continuously and in accordance with measuring regulations standardised to ensure health and safety in the workplace [6, 7]. Thus, it is possible to compare the measured dust concentrations with published data. Dust samples were taken from the exhaust air isokinetically by the centroid method in the chimney above the exhaust air fan [8, 9].

In the cage house two exhaust air chimneys (chimneys C1 and C2) which can be switched on via relays were studied. In the

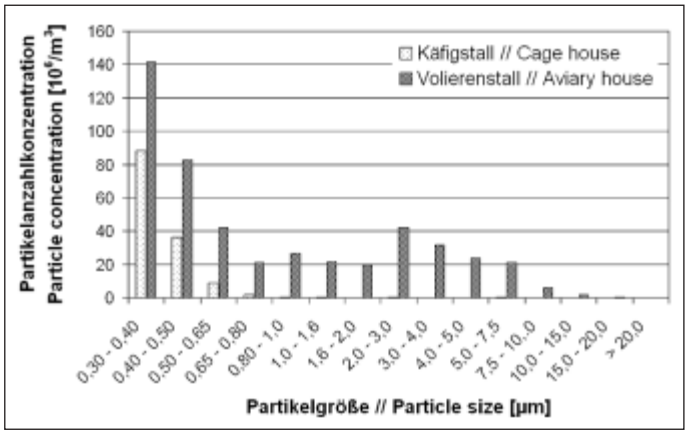

Fig. 1: Typical particle concentration distribution inside the cage hen house and the aviary hen house

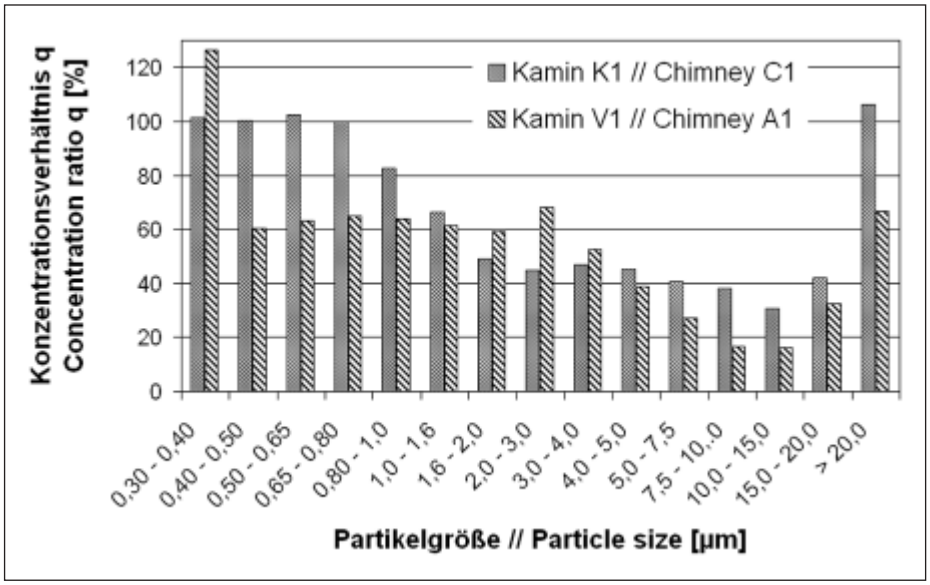

Fig. 2: Average concentration ratio q for the ventilation chimneys C1 (cage house) and A1 (aviary house)

aviary house samples were taken at a static-speed fan (chimney A1) and at a variable-speed fan (chimney A2). In all measurements the measuring period for the determination of particle concentrations in the exhaust chimneys amounted to several minutes. All measurements were carried out on the same day.

Methods of Data Analysis

For a comparison of the resulting data, segments from the particle concentration measurements were used, which had been taken in the interior and in the exhaust air chimney at the same fraction of time. *Figure 1* shows the typical particle concentrations in the interior of the cage house and the aviary house, respectively.

To visualise the results, the quotient q of the particle concentration in the exhaust air and the particle concentration in the interior was calculated for different particle sizes.

$$q\ [\%] = \frac{\text{Partikelkonzentration in der Abluft}}{\text{Partikelkonzentration im Stallinnenraum}} \cdot 100$$

This concentration ratio q 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=100% 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.

Measurement Results

Considering the fans switched on by relays (C1, C2 and A1) the exhaust air velocity is not dependent on ventilation intensity. In these chimneys the quotient q of the particle concentration in the exhaust air and the particle concentration in the interior is almost constant for all particle sizes. There is no indication of the quotient being dependent on the ventilation intensity set via climate computer or on the total volume flow. For easier illustration, the concentration ratios q for the different particle sizes were therefore averaged over the ventilation intensities for the fan chimneys C1, C2 and A1.

Figure 2 shows the averaged quotient q for the livestock houses under study. The concentration ratio decreases from smaller to larger particle sizes. At a particle size of 10 - 15 µm q has a minimum. This means that larger particles are less likely to be transported outside than are smaller particles.

The higher quotients for particles >20 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.

In some of the figures depicting the concentration ratio q there are q values exceeding 100%. One possible explanation, aside from measurement deviation, is that - due to the thermal conditions in the livestock house - the concentrations of these fine particulates are higher in the air closer to the ceiling. These particles in the upper areas of the house are drawn in by the exhaust air chimney, thus becoming measurable in the exhaust air duct. This results in ratios exceeding 100%.

Figure 3 shows the quotient q of the dust concentration in the exhaust air and the dust concentration inside the aviary house at the fan in chimney A2 for different exhaust air velocities v. As in Figure 2, at an average exhaust air velocity of 10 m/s the quotient has a minimum at a particle size of 10 - 15 µm. If the exhaust air velocity falls to 1 m/s, fewer large particles are taken up by the exhaust air chimney. Even at a particle size of 1.0 - 1.6 µm, fewer than 1% of particles from this size class reach the outside. This suggests that the particle concentration in the exhaust air chimney is dependent on the exhaust air velocity, which supports the assumption made in the introduction that particle concentrations in the exhaust air of animal houses cannot be assumed to be the same as those in their interior.

Conclusions and Outlook

The assumption that particle concentrations in the interior of livestock houses differ from those in their exhaust air was confirmed by reproducible measurements. Thus, dust measurements in the interior of livestock houses must not be taken as the calculation basis for dust emissions. These can only be determined by measurements in the livestock houses' exhaust air chimneys.

In what way it is possible to base predictions on flow simulations will be determined in later measurements. In addition to the interrelations described above, evaluations of the dust loads emitted from the laying hen houses under study are still going on. On the basis of the data available it is possible to specify typical emission rates.

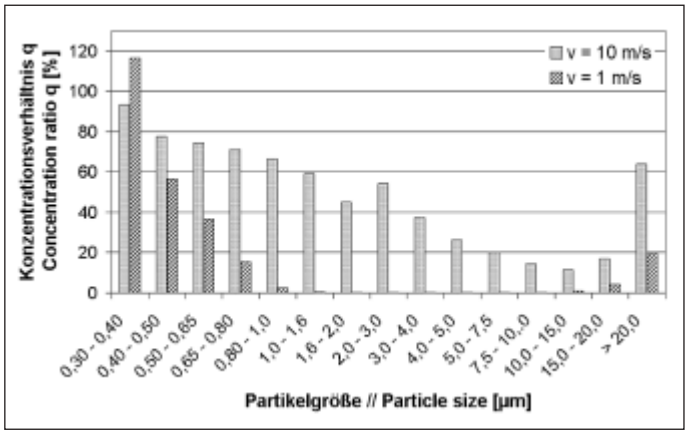

Fig. 3: Concentration ratio q depending on the velocity of the exhaust air at chimney A2