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Sedimentation of Animal-specific Dust Particles in Livestock Houses

Dust emissions from livestock houses are becoming increasingly important. Predicting aerosol transmissions must take a multitude of parameters and effects into account. Particle sedimentation in livestock houses is an important process that influences not only the transmission process, but also the relationship between dust concentrations in the interior of the livestock house and in the exhaust air.

While the indoor concentration of gases may generally be assumed to be the same as the gas concentration in the exhaust air, this assumption is not valid for aerosols. Due to their significantly higher mass, aerosol particles are subject, among other things, to sedimentation processes, which can lead to differences between the aerosol concentration in the exhaust air and inside of livestock houses. A particle's sedimentation velocity, i.e. the vertical speed at which it sinks to the ground, is determined mainly by two factors: the weight and the shape of the particle. In many cases, exhaust air flows and sedimentation are two competing processes. If exhaust chimneys are installed in the ridge, this can lead to sedimentation and ventilation airflows being oriented in opposite directions. Accordingly, in analysing sedimentation processes it is important to take the ventilation airflow into consideration as well [1]. Generally speaking, lower air velocities mean that fewer particles with a large diameter are to be found in the exhaust airflow, because they will have sedimented already. If the air velocity increases, the velocity at which particles sink to the ground decreases in comparison with the sedimentation velocity in still air. Consequently, there is a greater number of larger particles in the air. If air velocities relative to the ground are even higher, particles that have sedimented and settled on the ground may be taken up again by the airflow. Called resuspension, this process additionally increases the proportion of particles in the air. In this case, too, the influence of the design of the ventilation system, especially of the type of supply air system, can be a significant one.

The degree of the sedimentation's process is decrease depends mainly on the shape and density of the particles, because it is these parameters that determine the aerodynamic behaviour and the inertia of the individual particles. Accordingly, predictions of the behaviour of particles merely require information about their shape, density and size. As it is possible to derive typical patterns for all kinds of animals, the above-mentioned parameters must be determined experimentally [2]. As a particle's sedimentation velocity depends on its shape and density, it is conversely possible to determine these parameters on the basis of a measured sedimentation velocity. Utilising this fact, the measuring system used to determine sedimentation velocities consists of a cylinder in which particles are shielded from external influences so that sedimentation can take place under defined climatic parameters. Based on the time interval between the release of the animal dust and the optical detection of a particle, it is possible to calculate the sedimentation velocity of individual particles if the distance travelled by the particles is known. Based on measurements of the parameters temperature, air humidity and air pressure made during the experiment, the ratio bet-

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Keywords

Sedimentation, dust, particle shape, particle density, indoor concentration, transmission

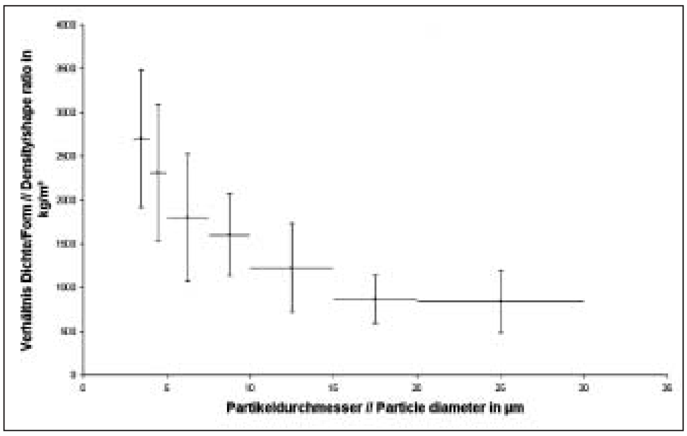

Fig. 1: Ratio of particle density to particle shape for different particle size classes in a dust sample from an aviary house for laying hens

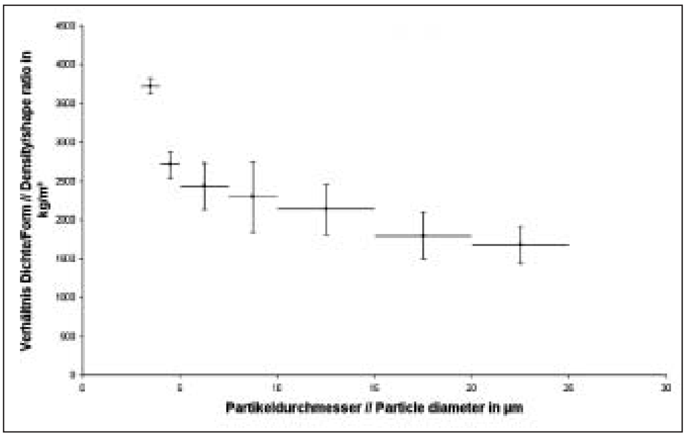

Fig. 2: Ratio of particle density to particle form for different particle size classes in a dust sample from pig fattening

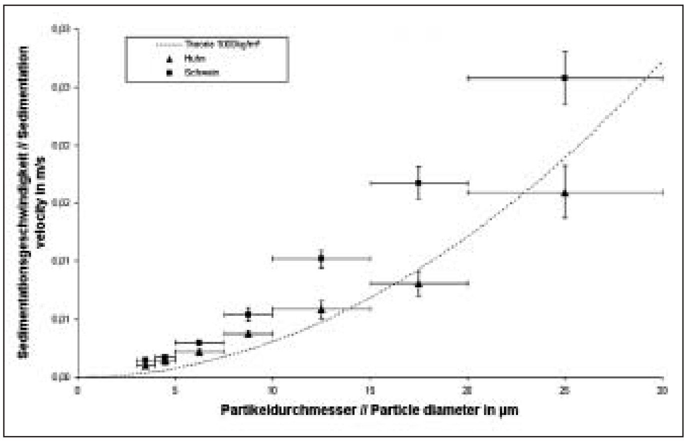

Fig.3: Comparing measured sedimentation velocities depending on particle size classes from dust samples from pig fattening and from an aviary house for laying hens. The broken line is the sedimentation velocity of spherical particles with a density of 1000 kg/m³

ween particle density and particle shape can be determined by mathematics. The density of aerosol particles can only be determined on the basis of information regarding their shape. Therefore, animal dusts from different housing systems have been systematically analysed under the microscope. By this means it has been possible to analyse the shape and density of particles separately [3].

The results

of the experiments made so far show that there are mainly differences between aerosols from animals of different species. The dust samples analysed so far were from pig, poultry and cattle facilities; so far, results are available for the pig and poultry facilities. The influence of different management systems on the sedimentation velocities and, consequently, on the ratio of particle density to particle shape for different particle sizes is only minimal. The most important factor is whether or not litter is used in the respective management system.

The dust samples from poultry facilities analysed in the present tests were from an aviary house. As an example of these measurements, the measured values for the ratio of particle density to particle shape for a dust sample from an aviary house with laying hens are presented in *Figure 1*.

The different ratios of particle density to particle shape in different size classes are a striking characteristic. For small particles with an average diameter of 3.5 µm the ratio of particle size to particle density is three times higher than for large particles from the same sample.

A possible reason for the large differences between the individual particle sizes is not so much the different shapes of the particles as is the variance of the particle densities. The density of smaller particles with a diameter of 3 to 5 µm is in the same range as concrete, which has a density between 2000 and 3000 kg/m³ depending on the admixtures used, whereas the density of larger particles is in the range of organic material such as fine feed components , epidermal scales or feather fragments [4]. Moreover, the shape of mineral particles is usually more spherical than the shape of organic particles so that both the denominator and the numerator can lower or raise the ratio at the same time.

At the same time, for the purpose of isolating differences between the different farm animal species, several dust samples were taken from a pig house with approximately 480 pigs. The pigs were fed liquid feed four times a day. In order to rule out differences due to a particular feeding system, control samples were collected in an otherwise identical house with dry feeding.

There are no significant differences between the curve shapes of the two analysed dust samples. There are differences, however, if dust samples from different animal species are compared. In *Figure 2* the ratio between particle density and shape is presented as an example of the analysed dusts from pig houses.

In comparison with the dust samples that were taken in hen houses, the measurement results for the sample from the pig house (*Fig. 2*) were more homogeneous over different particle diameters. Once again, particles with smaller diameters have higher ratios of density to shape than particles with larger diameters. However, the differences are smaller in pig aerosols than in poultry aerosols. Particles with a mean diameter of 3.5 µm are an exception, since the ratio of particle density to particle shape is higher than in poultry particles. This suggests that the particles in this size class may be of mineral origin, whereas particles with a larger diameter are more likely to be of organic origin. Moreover, it has to be determined whether a particle's origin (plant or animal) has an influence on its sedimentation velocity and, consequently, on its density.

The measurements carried out in this context show that there are differences between different kinds of animal. This affects not only the sedimentation behaviour of aerosols inside animal houses but also, of course, the transmission of emitted aerosols. In *Figure 3* the sedimentation velocities of typical dusts from pig and poultry farming are compared.

Conclusion

The measurement results and the reasons mentioned above suggest that the behaviour of aerosols should be analysed specifically for different animal species. There are significant differences, particularly with regard to sedimentation, which affect not only the transmission process but also the ratio of the indoor concentration to the exhaust concentration of a dust. In order to widen the base of relevant data, the Institute for Agricultural Engineering keeps analysing dusts from various animal species. The experimentally obtained data can be used in dispersion simulations, thus enabling specific aerosol transmission predictions for different animal species.

Literature

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