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Sedimentation Velocities of Animal Dust

Conclusions Concerning Particle Properties

The use of simulation models in the prediction of particle exposure has become increasingly important in permit procedures. Most of the simulation models account for the sedimentation velocity of dust by using only the particle size, disregarding the different material qualities. For the purpose of creating a database, an experimental setup for the determination of dust sedimentation velocities has been constructed. The acquired data lead to more precise predictions in particle models and allow conclusions concerning particle density and possible sources.

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Literature

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The determination of the immission concentration of pollutant materials is becoming increasingly important in the current discussion about the fine dust emissions of vehicles. The currently valid version of the Technical Rules for Air Pollution Control [1] from the year 2002 is the first to count livestock buildings as among the sources of air pollutants which are subject to authorization.

Simulations of air flow, which are intended to predict the transmission and immission of air-foreign materials at distant positions, are becoming widely used in permit procedures. Possible disturbances of residents by smell or particles as well as potential interconnected infection risks [2] can already be avoided in the planning phase of a livestock building. Thus, a basic location and planning reliability is guaranteed.

In most atmospheric dispersion models [3, 4] particles are assumed to be spheres with a density of usually 1 g/cm^3 (unit density) in all size classes. Material qualities such as differences in particle density, which are dependent on the size as well as on the form of a particle, are not integrated into the calculations. However, these parameters have a great impact on particle behaviour.

In the following, a standardised procedure for measuring particle sedimentation velocity is introduced; this makes the determination of the above-mentioned physical parameters possible.

Theoretical Approach

Even under the influence of a constant acceleration strength, particles attain maximum speed after a short time - similar to parachutists, who do not become faster than approximately 200 km/h in free fall. This can be traced back Stokes' friction against air molecules, as a result of which appears a balance between acceleration force and friction force. This leads to a maximum velocity, which is called sedimentation velocity in the case of the acceleration of particles by the earth gravitational field.

The sedimentation velocity vS of a particle is given through [5]

$$v_S = \frac{1}{18}\frac{C_C}{\eta}\frac{\rho_P}{\kappa} g\, d^2 .$$

C_C is the Cunningham correction factor, μ the viscosity of the air, ρ_P the particle density, κ the dynamic shape factor of the particle, g the acceleration of gravity, and d the particle diameter. The dynamic shape factor takes the deviation of the particle from the shape of a sphere into account.

The only material-specific parameters are density ρ_P and shape factor κ. Not necessarily identical for different particle size classes, they are consequently dependent on particle size. Knowing the ratio ρ_P/κ depending on the particle size, a theoretical calculation of the particle velocity is possible.

The particle-specific parameters and material qualities can be determined by measuring the particle sedimentation velocity.

Measurement system

For the purpose of determining the sedimentation velocity of particles, a sedimentation chamber was constructed at the Institute for

Tab.1: Ratio ρ_P/κ for dust types, given in g/cm^3

Particle size [µm]	Dolomit-	pig pen- dust	hen pen-B-	hen pen-V-
2,0 bis 3,0	5,00	3,87	2,56	3,73
3,0 bis 4,0	3,25	2,22	1,96	2,76
4,0 bis 5,0	3,13	1,75	1,91	2,22
5,0 bis 7,5	3,18	1,64	1,34	1,77
7,5 bis 10,0	2,77	1,76	1,37	1,64
10,0 bis 15,0	2,56	1,41	0,94	1,25
15,0 bis 20,0	2,72	1,22	0,68	0,89
> 20,0	2,97	1,89	0,54	0,86

Fig.1: Sedimentation cylinder (left), data acquisition (upper right) and aerosol spectrometer (lower right)

Agricultural Engineering of Bonn University in cooperation with the Institute of Physics. *Figure 1* shows the experimental setup.

The main part of the installation is a vertical standing sedimentation cylinder. At the uppermost point of the cylinder, almost any dust type can be dispersed.

An aerosol spectrometer of Grimm Aerosol Technik, Ainring, at the bottom of the cylinder is used to measure the particle concentration in dependence on particle size. The particles are divided into different size classes.

After dispersion in the upper cylinder area, the particles sink in dependence on their size, density and form. Bigger particles reach the bottom before smaller ones. The average sedimentation velocity can be calculated from the sedimentation time and the distance.

Examined Dust

The following results refer to examinations of dolomite dust (as a calibration dust); deposited dust from a fattening pig barn with slatted floor management and liquid feeding, in the following identified as „pig barn dust“; dust from a laying hen house with floor management (litter: straw) and manual feeding, in the following identified as „hen house dust (F)“; and deposited dust from a laying hen house with aviary management (litter: straw) and automatic feeding, identified as „hen house dust (A)“. These dust samples are not necessarily representative of the respective type of animal or type of management.

Results

The curve progressions for spherical dust particles with a density of 1 g/cm^3 as well as for some of the examined dusts are presented in *Figure 2*.

If the measurement points of a dust type form a parabola, this indicates a uniform density of the dust for all size classes. A characteristic parabola profile can be recognized for dolomite dust (Fig. 2); it confirms the homogeneous density of the calibration dust.

No parabola profile can be found for the animal dust. For the smaller particles, the values of animal dust are close to the values of dolomite dust; with increasing particle size the values approach the unit dust profile. This leads to the conclusion that different size classes have different densities.

However, the absence of a parabola profile is no sufficient condition for different densities. The ratio ρ_P/κ is decisive for the sedimentation velocity; it is shown in *Table 1* for all examined dust types.

Assuming a constant dynamic shape factor for all size classes of animal dust, smaller particles have higher densities than bigger particles. A possible explanation is that smaller particles are primarily dominated by mineral dust particles and bigger particles by organic components like litter, skin sheds, feather fragments, etc.

The differences between hen house dust (F) and hen house dust (A) can be explained by the feeding system. Due to the hand feeding system, more particles are released into the air than with an automatic feeding system. Accordingly, lightweight feed particles can dominate in the bigger size classes.

The determination of the dynamic shape factor κ using complementary measuring methods (e.g. microscopy) would guarantee unambiguous results for particle density. However, this would require additional examinations.

Conclusion

With the presented measurement system, sedimentation velocities of arbitrary dust can be determined. Conclusions concerning particle density and form can be drawn from the curve progression of the sedimentation velocity depending on particle size. The results indicate inhomogeneous density distributions for animal dust. Accordingly, conclusions concerning the dust sources are also possible.

In order to render simulation models more precise, the ratio ρ_P/κ for the examined dust is given in dependence on the particle size classes. The results presented in this paper show that the assumption of a density of 1 g/cm^3 is not justified for animal dust; instead, a class-specific approach is necessary.

Another use of the results is the specific selection of particle sizes by precipitation systems such as cyclone separators. Emission control installations can be optimized for different animal dusts.

Fig.2: Sedimentation velocity of different dust types depending on particle diameter