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THE DETERMINATION OF AIR CHANGE RATE IN NATURALLY VENTILATED CATTLE BARNS

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ABSTRACT

The keeping of animals in livestock buildings requires the ventilation of these buildings. On the one hand good climatic conditions for the animals in the livestock building have to be provided, on the other hand the emissions have to be kept at a low level. The airflow through the livestock building plays an important role for both opposing requirements. The targeted control of the climate in the livestock building and for the minimization of emissions calls for knowledge about airflow and emission streams.

Especially for naturally ventilated buildings, the determination of air change rates leads to a few problems. For those cases, the Institute of Agricultural Engineering Bornim has developed a 40-sampling-points system which is using Krypton 85 as a tracer gas. All 40 sampling points are running simultaneously with a maximum sampling rate of one second. Air change rates of up to 1000 h^{-1} have been measured.

During the past 2 years more than 20 naturally ventilated cattle barns have been investigated. Apart from the measurement of volume flow, the concentration of gases and odours has been measured as well. In parallel to these inside investigations inside the barns, the climatic conditions outside have also been recorded. The results are extensive data on emissions. The measured emission flows of odours can be used - among other things - to calculate the minimum distance between livestock buildings and human living areas.

Keywords

Air change, livestock building, tracer gas method, emission flow

INTRODUCTION

The climate in livestock buildings shall be such that it meets the requirements of animals, that the animals can give their maximum performance, that the livestock building is protected against high humidity and that proper working conditions for human beings are provided. Therefore the ventilation of a livestock building is necessary. For some kinds of animals heating may be necessary for the winter period. For cattles, the ventilation of a livestock building is generally sufficient. Since cattle tolerate a pretty wide range of temperature, the requirements of ventilation and its control are low. Therefore most of the cattle barns in Germany are working only with natural ventilation. The control of volume flow is guaranteed by flaps which are situated in inlet and outlet openings. The position of those flaps can be changed either automatically or manually. During the summer season doors and windows are used for ventilation, too.

The necessary ventilation of livestock buildings leads to emissions. The targeted control of climatic conditions in livestock buildings and emissions requires knowledge about the ventilation of buildings. Therefore extensive measurements will be done at animal farms. These measurements determine the volume flow through the building and the concentration of gases and odours. With these data it is possible to evaluate the climatic conditions in a livestock building establish and the emission flows. The complicated air flow patterns of natural ventilation make it very difficult to get accurate measurements. According to wind conditions, temperature differences between inside and outside and the position of openings for ventilation, very different air flow patterns can be observed. Especially the measurement of volume flow through the livestock building is very difficult under such conditions. For the investigations the tracer gas method with Krypton 85 is applied. Experiences with that method have already been reported during the last ROOMVENT-Conference (Müller et al., 1998a). The following report continues to illustrate this research work and provides information about the measurements which have been conducted in various cattle barns.

METHODS

The measurements have been done in a wide variety of livestock buildings all over Germany and under different weather conditions. Altogether 31 cattle barns have been investigated. Types and sizes of buildings as well as ventilation systems vary a lot. Fig. 1 - 3 show examples of different livestock buildings for dairy cattle in which these measurements have been done.

Fig. 1: Livestock building with shaft ventilation (enclosed space: 5445 m³; number of animals: 202)

Fig. 2: Livestock building with eaves/ridge ventilation (enclosed space: 10694 m^3; number of animals: 225)

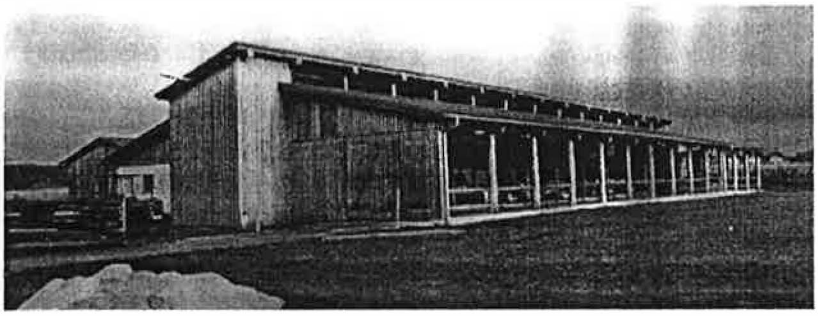

Fig. 3: Front opened livestock building with spaceboard (enclosed space: 3411 m^3; number of animals: 74)

The **airflow rate** through the livestock building is determined by means of the tracer gas method. Sulphur Hexafluoride (SF_6) or Krypton 85 have been used as a tracer gas. For the measurements of SF_6 concentration the multigas monitor is used. A multi-point sampler allows to switch among 12 measuring points (max.). The measuring cycle for one measuring point takes about 2 min and for 12 measuring points about 30 min. As far as time is concerned, this is a small resolution. Therefore SF_6 has to be dosed with a constant mass flow rate. The mass flow rate is adjusted by means of a rotameter and for the precise determination of the SF_6 mass flow, the mass reduction of the dosing bottle is determined dependent on time. The tracer gas is distributed as evenly as possible in the building through a hose system.
Especially in the summer, when air change rates are high and cattle barns ventilated naturally the small number of measuring locations and the small temporal resolution leads to higher measuring uncertainties. Therefore a special measuring system for Krypton 85 as tracer gas has been installed at ATB.

With this system it is possible to measure the concentration of Krypton 85 in the barn at 40 locations in parallel. The shortest measuring interval per location is 1 second. The tracer gas is distributed in the building in thinned solution and as fast as possible. This is done either with a distribution system (pumps and hoses) or manually, that means dosing equipment is moved evenly across the entire surface of the livestock building. Then the tracer gas is mixed with the air of the livestock building by waving big cardboard fans. After that, the decay of the concentration of Krypton 85 is measured. The exponent of the decay function is the local air change rate. In connection with the volume of the livestock building, the volume flow can be determined. This method is described by Müller et al. (1998a). The **concentration of gases** (Ammonia - NH_3; Carbon dioxide - CO_2; Dinitrogen oxide - N_2O; Methane - CH_4; Sulphur Hexafluoride - SF_6; Water Vapour - H_2O) is measured with a Multi-Gas-Monitor inside the livestock building at a maximum of 12 locations (Müller et al., 1994).

For the determination of **odour concentrations** the Olfactometer TO 7 by Mannebeck is used. The air samples are taken in the livestock building by means of a special device. After that they are analysed at the laboratory by 4 test persons.

Results

In this article only a few results shall be demonstrated as examples. The examples are shown in Fig. 1 - 3. As the decay curves are measured at different measuring points in the building, we can show the varying distribution of air change above the entire surface of the barn (see Fig. 4 to 6). Fig. 4 - 6 show that fresh air distribution within livestock buildings is uneven. The distribution of air change depends on the design of the openings, wind direction and velocity.
These examples make clear that many measuring points are needed in order to get a relatively reliable statement about the air change. For every test the average value will be determined from the sum of all evaluated points.
In each livestock building several tests will be performed. From these tests, emission streams can be determined. The value of the emission mass flow which is shown in Fig. 4 - 6 is the product of the average value of the air change rate and the measured odour concentration. Parallel to these emission recordings, immissions outside of the livestock buildings are measured too. This makes it possible to see the emissions in direct connection to immissions.
Fig. 4 shows the distribution of air change in a livestock building with shaft ventilation. The high air change results from the opened doors and resultant longitudinal flow through the building.
In Fig. 5 the door in the east gable was opened. Although the air change is higher in the front opened livestock building (Fig. 5) than in the livestock building with eaves/ridge ventilation (Fig. 5), the emission flow is lower (Fig. 6) because of a significantly lower odour concentration.
The determined odour emission flow is an important input for the dispersion calculation. From this calculation (this is not the topic of this lecture) the necessary minimum distances between livestock building and human living areas is derived.

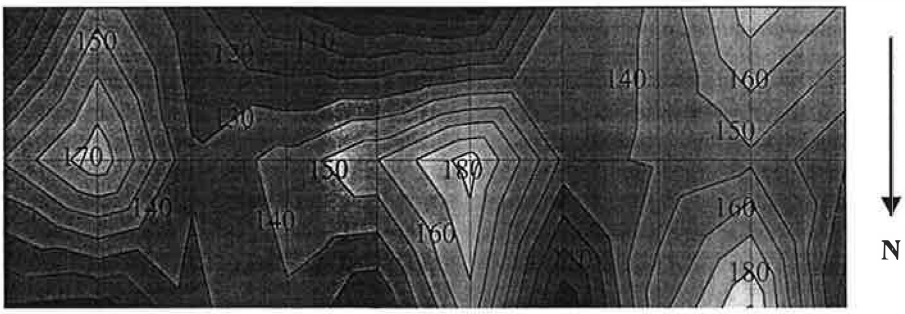

Fig. 4: Distribution of air change (measuring unit of the values: h^{-1}) across the surface area of the barn - example shaft ventilation
Average air change rate: 135 h^{-1}; maximum: 192 h^{-1}; minimum: 81 h^{-1}
Concentration of odours: 120 OU/m³; Emission flow: 119 OU/(sLU)
LU: livestock unit (500 kg); OU: odour unit

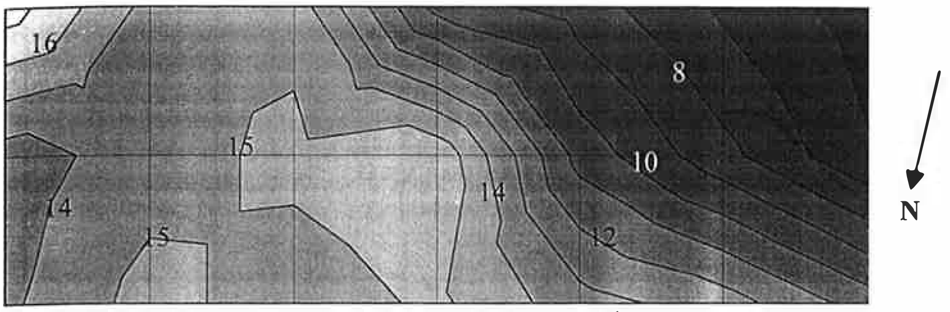

Fig. 5: Distribution of air change (measuring unit of the values: h^{-1}) across the surface area - example eaves/ ridge ventilation
Average air change rate: 12.2 h^{-1}; maximum: 17.5 h^{-1}; minimum: 5.5 h^{-1}
Concentration of odours: 157 OU/m³; Emission flow: 22.8 OU/(sLU)

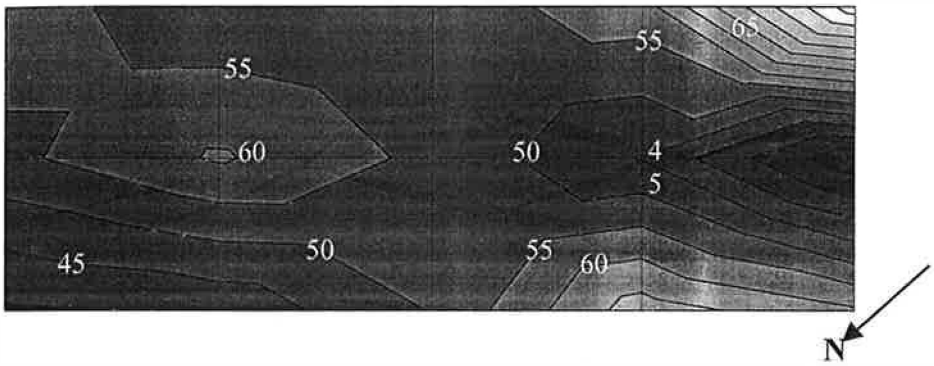

Fig. 6: Distribution of air change (measuring unit of the value: h^{-1}) across the surface area - in a front opened livestock building with spaceboard
Average air change rate: 54 h^{-1}; maximum: 93 h^{-1}; minimum: 26 h^{-1}
Concentration of odours: 18.8 OU/m³; Emission flow: 20.6 OU/(sLU)

From publications (Hartung et al., 1994) it is well known that the emission mass flow in animal farming (livestock buildings) in general rises with rising volume flow. The representation of the relation between emission mass flow and volume (Fig. 7) shows, that this close relationship between the two parameters does not exist in the case of cattle barns.

With regard to the average odour emission and to the statistic mean variation our own measured values go along very well with the values obtained by Oldenburg (1989).

The connection between emission mass flow and volume flow is not as obvious as with turkey and duck farming (Müller et al., 1998b). Evidently, things like animal keeping, manure removal and feeding play a bigger role in cattle farming, when it comes to odour emission.

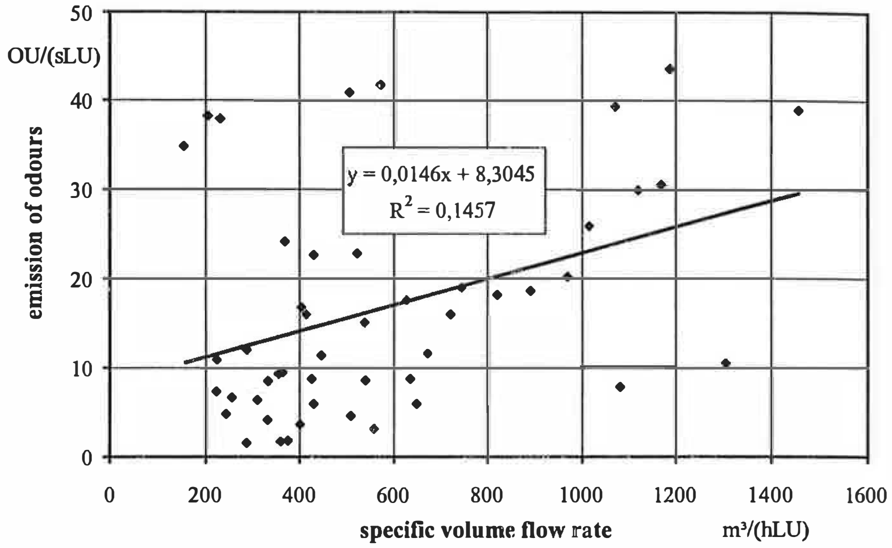

Fig. 7: Mass flow of emission depending on the volume flow rate

CONCLUSION

The emission of odours from livestock buildings can become a major environmental problem. Distances large enough between livestock buildings and human living areas will lead to sufficient rarefaction of odours in the atmosphere. For the determination of these distances, measurements have been carried out in 31 cattle barns. The distances are determined by means of a dispersion calculation. As an important input for the simulation model the emission flow is needed. With mainly naturally ventilated cattle barns, especially the determination of the volume flow is a problem. One suitable method to measure the flow volume is the tracer gas method using Krypton 85 as a tracer gas. The values of odour emission flows from cattle barns are to be found in a wide range. Nevertheless, the measured values are an important basis for simulation calculations in order to determine minimum distances between livestock buildings and human living areas.

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