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Emissions Factors for Ammonia in Naturally Ventilated Dairy Cow Barns

Agricultural production contributes to the factors, which effect climate change, too. For this reason it is important to take low emissions from housing systems seriously, in addition to a species-adapted microclimate house climate. The purpose of regulations like the TA-Luft (Technical Instructions on Air Pollution Control) is to contribute to the preferred application of low-emission systems, within permitted procedures. Since agriculture is the largest ammonia emitter, special attention is directed to this gas. In this paper proposals for determining emission rates are made under the difficult conditions of naturally ventilated dairy cow barns. These rates must be known in order to assess the environmental impact of the stables.

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Keywords

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Literature

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Fig. 1: Exterior view of the cow barn from the south

Together with the waste air from livestock buildings gases, odours, dusts, germs and bio aerosols are transported into the vicinity. These emissions disperse and affect the surrounding, which can have negative influences under certain conditions. For avoiding or at least for reducing the negative consequences the emission mass flows must be known. Not only for implementation of dispersion calculation but the data about emission mass flows are necessary also for mitigation strategies.

Current stage for ammonia emissions from naturally ventilated cow barns

In the guideline "Technical Instructions on Air Quality Control – TA Luft" (TA Luft 2002) constant emission factors e_{NH3} for the year are specified for dairy cows for given animal husbandry systems: 4.86 kg/year for tying stalls with solid manure and liquid manure systems up to 15.79 kg/year for free stalls with sloped floor manure system. Such average annual values can be taken from different scientific works, in which the comparison of the particular literature sources shows dramatic differences in the single values [1, 2]. Especially in naturally ventilated animal houses the wind induced emissions are connected with wide variations, due to the stochastic character of the wind; furthermore the accomplishment of such emission factors is not always comprehensible.

While husbandry, manure removal and feeding influence the ammonia emission likewise at forced ventilation and at natural-ly ventilation, the building envelope including ventilation openings (design and control) and the outside climatic conditions are the dominant influencing factors for naturally ventilated barns. In the literature again and again attention is payed to the problem of determining the emissions of naturally ventilated animal houses [1, 2, 3, 4]. In particular the determination of volume flows is a problem. With high grade measurement meticulousness concentrations are determined, but the determination of the volume flow shows enormous errors. But the methods to determine the volume flow have continuously been further developed. In [5] the so called "Compartmentalisation Method" is described, which was used at numerous measurements in cow barns. This tracer gas method (decay method) combine with the dispersion mechanism the concentration measurement with the air exchange measurement within which the volume flows are fluctuating permanently. The aim of such investigations is to derive from tests in the reality and in models general relationships of dependence of ammonia emission mass flow. In the literature approaches are to be

Table 1: Average ammonia emission mass flow during four measuring campaigns in g per day and animal place. The intervals of measuring are not sufficient to determine an average value for the year.

Measuring campaign	time interval	Ammonia emission g/day and animal
I	16.03.2004 – 24.03.2004	82.2
II	24.04.2006 – 05.05.2006	42.2
III	14.02.2007 – 27.07.2007	30.1
IV	27.06.2007 – 20.08.2007	104.7

found to calculate the emission behaviour of animal houses – for example by Monteny [3] and Wang et al. [6]. The ATB has investigated together with the vTI (former FAL) and with the engineering office Dr. Eckhof the real emission behaviour in many real livestock buildings. A system of equations is derived in [7] and [8], based on dimensional analysis, which demonstrate an approach for a forecast model. Subsequently is:

$$e_{NH3} = N\, e_{spez} \quad (1)$$

$$e_{spez} = u_f\, e^{A + B\frac{C_B}{C_0}} \quad (2)$$

$$u_f = u_{NH3} = 5{,}0\; 10^5\; \frac{g}{GV} \quad (3)$$

e_{NH3} characterised the emission factor (i.e. the product of exhaust air concentration and exhaust air volume flow relating to animal mass), N is the air exchange rate of the livestock building. e_{spez} is the animal house specific emission factor, which describes the emission behaviour by the values A and B, as well as the ratio of the concentration at the surface of the emission source C_B and the concentration in the exhaust air C_0. The ratio of the concentration can be interpreted also as ratio between the production rate of air pollutants and the air exchange rate in the animal house. e_{spez} can be determined by experiments and by numerical flow simulation.

The constant u_f is a conversation factor for the animal mass. 1 LU stands for 500 kg of animal mass. Equation (1) is in connection with Equation (2) transcendental relation to determine C_0.

Description of the investigated com barn, investigation methods and results

The investigated cow barn is a non-insulated animal house (*Fig. 1*). The metal roof has no insulation. The cow barn has the following size: length 96.15 m, width 34.2 m, height of the side wall 4.2 m, height of the gable 10.73 m, room volume 25,499 m^3. The lying box loose housing is designed for 364 dairy cows and isequipped with winch-drawn dung channel cleaner. The ventilation takes place by adjustable openings in the side walls, by open doors in the gable walls respectively by space boards and by permanently open ridge slot.

Beside the concentration and volume flow measurements the climatic parameters inside and outside the building are recorded. The wind direction and wind velocity are registered as additional important influencing factors. The air velocity outside is measured in 10 m height by ultrasonic anemometer [4, 5]. Four measuring periods were carried out since 2004. These periods contain weather conditions in winter, in transitional period and in summer. One example of determination of the volume flow by using different methods for a selected short time interval is shown in *Figure 2*. This figure shows clearly the well-known measuring problems. By using the CO_2-balance method it is problematic, since on one hand the CO_2 production of the animals is not known sufficiently exact and on the other hand the measurement of the exhaust air concentration is faulty because of the complicated air flow conditions and a no ideal air mixing inside the building.

The volume flow can be determined by means of outside wind velocity [7] according to equation (4):

$$\dot{V}_0 = \eta_{Durch}\, U_{10}\, A\, C_q \quad (4)$$

In this equation stands for volume flow through the animal house, considers the permeability of the openings (e.g. influence of wind nets), is the wind velocity measured in 10 m height near the animal house, is the half of the cross-sectional area of all openings in the side walls and gable walls and the assumed angle of incidence. The value reaches generally values between 0.2 and 0.6 and has in *Figure 2* the value 0.2, a good accordance with the CO_2 balance. The product from volume flow and the ammonia concentration results in the ammonia mass flow. The time dependent run of the ammonia mass flow is calculated for four measuring periods and shows large fluctuations. *Table 1* contains the average values of the different periods. The influence of the wind velocity is the dominant factor. High values mean high emissions (in case that the volume flow is not influenced by variation of size of the ventilation opening).

With the equations (1) and (2) the emission mass flow for the investigated summer period 2007 wase also calculated. From the measurements the values A = -14.30961 and B = -0.13444 were ascertained. With the realistic ratio C_B / C_0 = 6 an average ammonia emission mass flow of e_{NH3} = 3.74 g/(h LU) results (e_{spez} = 136.165 mg/LU and N = 700,000/25,499 = 27.45 h^{-1}). The emission mass flow determined directly from the measured values amounts to e_{NH3} = 3.07 g/(h LU). This result confirms – as well as in many other cases – the described mathematical models. So it is possible to predict the emission behaviour for naturally ventilated cow barns. But the high demands to determine the values for A and B remain and to attain new knowledge about the emission behaviour inside the building (analysis C_B/C_0).

Conclusion

The emission factors of naturally ventilated cow barns are calculable. The site-specific meteorological conditions – especially of wind data – must be taken into account. Emission forecasting for naturally ventilated cow barns can be generated. So assessments can be made, also in view of the effect of the climate change on this field. Needs for further research exist for natural ventilation and the analysis of emission behaviour at the emission sources inside the livestock building.

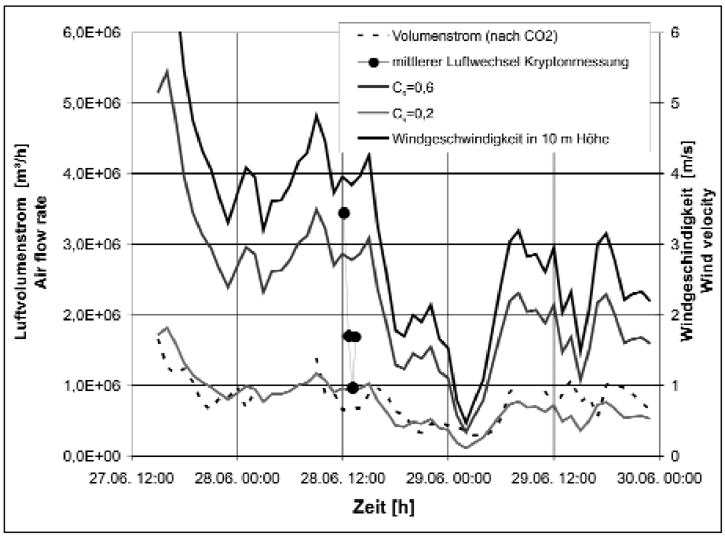

Fig. 2: Time series of air flow rate and wind velocity, determined by different methods

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