Karl-Heinz Krause and Stefan Linke, Braunschweig, and Hans-Joachim Müller, Potsdam-Bornim

Emission Factors in Turkey Fattening Stables

Methods for Calculating Ammonia and Odour

To issue permits, authorities use emission factors from forced ventilation to specify the immissions for free ventilation. This procedure is not appropriate, but offers the advantage of using something proven. This paper gives recommendations on handling turkey stables and shows that the construction of open stable systems can be authorized. Reality must be given a chance.

Dr.-Ing. Karl-Heinz Krause belongs to the scientific staff and Stefan Linke to the technical staff of The von Thünen Institute (vTI) – Federal Research Institute of Rural Areas, Forest and Fishery – Institute of Agricultural Technology and Biosystem Technology (Director: Prof. Dr.-Ing. A. Munack and Prof. Dr. K.-D. Vorlop) in D-38116 Brunswick, Bundesallee 50;
e-mail: *karlheinz.krause@vti-bund.de*
Dr.-Ing. Hans-Joachim Müller is scientific member of staff of the Leibniz-Institute of Agricultural e.V. (ATB), Max-Eyth-Allee 50, D-14469 Potsdam-Bornim

Keywords

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In the Technical Instructions on Air Pollution Control (TA Luft 2002) an emission factor for ammonia is mentioned for turkey hens and turkey cocks of e_{NH3} = 0.7286 kg/(Tp year). Tp stands for the German abbreviation "animal place". This term is synonym for an animal. The turkey cock has an average mass of a single animal of 0.02222 GV = 11.1 kg (1 GV = 500 kg; GV is used as livestock unit LU in English). With the numbers of animal places or animals the emission mass stream of ammonia from a stable can be calculated. An animal place has an effect like a so-called secondary source. The faeces of animals cause release of ammonia and odour. The releases depend on the age and the mass of animals. *Figure 1* shows the temporal alteration of the animal mass whereby the rhythm of production must be taken into consideration to determine the average animal mass $M_{T,average}$.

If the emission factor e_{NH3} is constant, the average emission stream of mass during a year is determined by

$$\dot{M}_{mittel,\,0,\,NH3} = e_{NH3}\ M_{T,\,mittel} \qquad (1)$$

On the emission behaviour of turkey stables

In several research studies of the institutions the authors belong to, and of the engineering bureau of Dr. Eckhof the real emission behaviour of animal houses have been investigated [1, 2, 3]. The given case refers to the transfer characteristic of the system stable. What happens during the air intake and the air removal with respect to the release of substances into the environment? An appropriate support of the problem solution proves to be the dimension analysis. By means of the source concentration C_0, the concentration in the stable air of removal, is expressed for the emission factor of ammonia [4] by

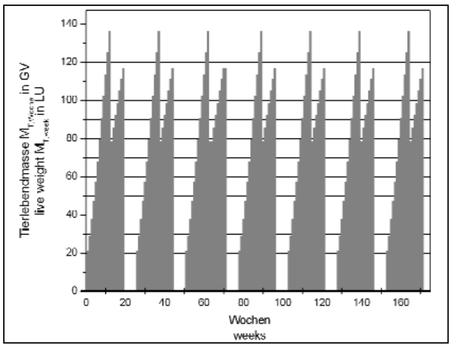

Fig. 1: 3000 turkey hens and 3000 cocks are stabled with a total mass of 20 LU. After 16 weeks the hens leave the stable. The cocks stay there for another five weeks. After six weeks of service time, the cycle starts again. The average animals mass amounts to $M_{T,mean}$ = 74 LU, according to the values of the Technical Instruction on Air Quality Control of 2002.

$$e_{NH3} = N\ u_f\ e^{A + B\frac{N}{K}} \qquad (2)$$

with

$$A = -13{,}65327,\ B = -0{,}11331 \qquad (3)$$

and

$$u_f = u_{NH3} = 5{,}0\ 10^5\ \frac{\text{g}}{\text{GV}} \qquad (4)$$

N describes the rate of air exchange and K the production rate

$$N = \frac{\dot{V}_0}{V}\ und\ K = \frac{C_0}{C_B} N \qquad (5)$$

K is determined by the constellation of inlet and outlet openings of the stable. In principle the emitted mass of ammonia must be produced in the stable of concern, characterized by the concentration at bottom, C_B. Eq.(2) reduces to the form

$$e_{NH3} = N \quad e_{spez} \qquad (6)$$

with

$$e_{spez} = u_f\ e^{A + B\frac{C_B}{C_0}} \qquad (7)$$

The specific emission value e_{spec} contains the flow behaviour of the stable exclusively. The air exchange rate N differs with forced ventilation (index ZL) and free (natural) ventilation (index FL). From the theoretical point of view e_{NH3} may accumulate infinitely. N is bounded by the frequency of appearance during a year, oriented at the DIN 18910.

$$N_{ZL} = 0{,}47\frac{\dot{V}_0}{V} = 0{,}47\frac{\dot{v}_0\ M_T}{V} \qquad (8)$$

For turkey hens and cocks it is expected

$$\dot{v}_0 = 2.000 \frac{m^3}{h\,GV} \quad (9)$$

For free ventilation it follows by the area of flow intake A_W and the degree of flow intake η_w

$$N_{FL} = \eta_w \frac{A_W}{V} \sum_{i=1}^{9} U_i H_i \quad (10)$$

with 0 < Hi < 1. H characterizes the frequency of classified wind velocities U_i, i=1…9 (TA Luft 2002). Up from U_i > 7 m/s the air intake into the stable is throttled.

It makes a difference between the exhausted air with the concentration C_0 and the concentration at the bottom C_B and the concentration C_R in the room. An homogeneous distribution in the sense of stirrer vessel is not observed. The interpretation of measured data is accompanied by three dimensional flow calculation, based on the conservation laws of mass, momentum and energy (*Table 1* and *Figure 2*).

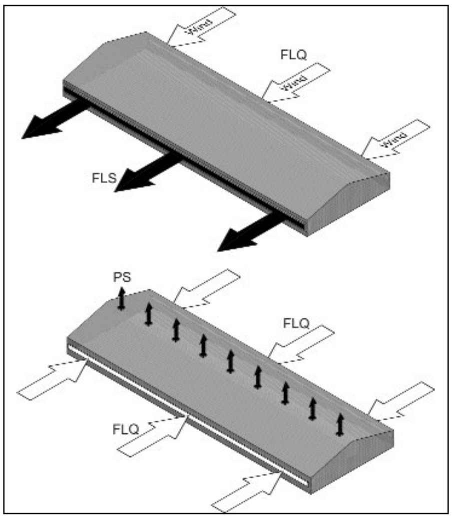

Fig 2: The sides of outgoing air are marked by black colour: Area sinks (FLS) and point sinks (PS). The upper case characterizes a cross flow by free ventilation, the case below a forced ventilation over the ridge. The air goes in by area sources (FLQ).

Exemplification

An average animal mass $M_{T,average}$ = 63.8 LU (3,000 animals) and a stable volume of V = 4,830 m^3 at forced ventilation by fans in the sidewalls with an area effect lead to N_{ZL} = 3.449•10^{-3} s^{-1}, e_{spec} = 3.0308•10^{-1} g/LU and at least e_{NH3} = 1,0453•10^{-3} g/(s LU).

In the German TA Luft 2002 it is set e_{NH3} = 0.7286 kg/(Tp year) = 32.82 kg/(LU year) = 1.0407•10^{-3} g/(LU s).

At free ventilation a ventilation rate N_{FL} is obtained for η_w = 0.6, A_w = 25 m^2 and V = 4,830 m^3 under the meteorological data of Ahlhorn to N_{FL} = 8.64•10^{-3} s^{-1}, for the specific emission e_{spec} = 0.29663 g/LU (*Table 1*) and at least the emission factor e_{NH3} = 2.5629 •10^{-3} g/(s LU) is calculated. For Stuttgart we observe a change to e_{NH3} = 2.0564•10^{-3} g/(s LU) and for Osnabrück to e_{NH3} = 1.7115• 10^{-3} g/(s LU). Equation (10) shows for the determination of ventilation rate that a factor of ventilation technique is added to the meteorological one. By this factor disadvantages by influences of local situation may be corrected.

Conclusion

1. The emission factors of free ventilated stables can be calculated in the same way as those of forced ventilation.
2. The emission factors of free ventilated stables depend on the local meteorological statistics. Free ventilated turkey stables are able to be licensed under the same environmental conditions as stables of forced ventilation, if the air ventilation technique is taken into account (adjusting valves, jalousies or something similar).
3. The presented methodology allows to distinguish between the different ventilation versions, too.
4. The above explanations are valid also for odour.

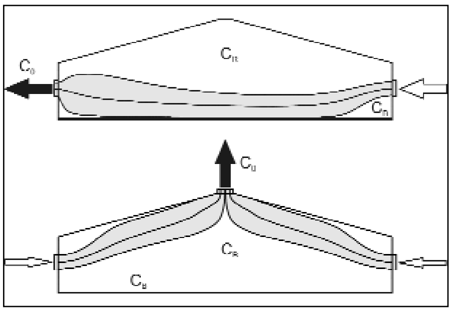

Fig 3: Fresh air is sucked in from outdoor through the stable, whereas the contact to the inner stable emissions areas is very different. It is intensive with cross flow (at the top) and low by extraction over the ridge.

Literature

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Table 1: Overview of the three dimensional flow simulations of turkey stables with different constellation of openings of ingoing and outgoing air. Based to the stable area, each opening of ingoing air acts like a source (Q) and each opening of outgoing air like a sink (S). The openings are of small size (points – PQ, PS) or of large area (FLQ, FLS) and they are located in the length walls (LW) or in the ridge (F). Comparing the stable concentration C_R resp. the concentration C_0 of the outgoing air of the different constellations leads to the assessment of the influence on the stable climate resp. the environment.

impulse	exhaust air		supply air		C_B/C_0	e_{spec}	concentration in mg/m³	
	location	ventilation	location	ventilation		eq.(5)	C_R	C_0
wind	1 LW	FLS	1 LW	FLQ	6.04	0.29663	1.303	2.467
forced	1 LW	FLS	1 LW	FLQ	5.85	0.30308	1.369	2.546
ventilation	1 LW	PS	1 LW	FLQ	5.78	0.30549	1.386	2.578
(under	F	PS	2 LW	FLQ	11.68	0.15655	2.382	1.276
pressure)	F	PS	1 LW	FLQ	10.13	0.18661	2.26	1.471
	F	FLS	2 LW	FLQ	12.31	0.14577	2.097	1.21