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Measurement of ammonia emission and determination of the emission factor in animal production

Part 2: Planned box stable as an example of a free ventilated system

A planned box stable with multiple interfaces – openings – is observed by simulation technique to analyse its ammonia emission behaviour [1]. There emission data are used as starting point of distribution calculations. The use of the program AUSTAL2000G [2] is demanded from the administration. Its use requires a default emission mass flow. This emission mass flow value is related to the animal mass or the animal place and listed in tables. In the particular case, these emission factors are multiplied with the relevant animal mass or animal place, respectively. Especially for open stables false starting conditions are created with this procedure. What we need is a transfer function of the stable without any relation to the meteorological parameters. Only then we have constant initial conditions, a fact known from forced ventilated systems.

Keywords
Open stable, emission factor, emission simulation

Abstract

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Transfer functions in box stables

The search for emission factors is just the same as the search for relations which describe the system but are in no way linked to the meteorological parameters. This is known in the case of forced air ventilation in stables, and is the way we would like it to be in free ventilation systems.

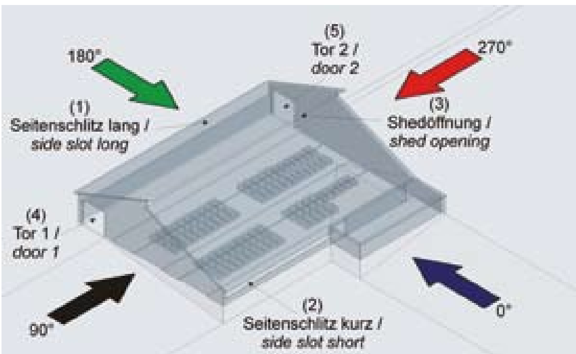
Box Stables as a Subject of Study

The planned lying box stable includes 75 beef cattle places and has five openings (**Figure 1**). A general statement on the emissions can be found in the RL VDI 3894 [3]. Accordingly the ammonia emission factor is f_{e,NH_3} = 14,6 kg per year and animal place TP– converted 0,000463 g/(s • TP). For the planned laying box stable the thus emitted emission mass flows comprise M_{0,NH_3} = 0,0347 g/s. The same holds true for odours, dust and bacteria. Without going into detail about particularities of the stable, one can thus begin a distribution calculation. It is absolutely irrelevant how the animals are kept, one would be obligated to come up with the data based on the emission factor if there were not a opening clause in RL VDI 3894 based on the TA Luft 2002. [4]. It is allowed to use its own well-based data. Such limits are not of interest from the scientific perspective, but from an administrative point of view this means that only recognized regulatory and tabular works should have authority. This creates legal certainty. But here we are dealing with scientific insights, whereby it could be assessed whether they would find socio-political consensus.

Material release from the planned open stable

With the help of simulation techniques the insights into the occurrence of processes can be gained and then be realized in planning. In this regard, stable simulation is a proven method

Fig. 1



Planned box stable with openings at th end of fhe feed alley (4), (5), in the sidewalls (1), (2) and in the roof (3). The arrows show the direction of the incoming wind

Table 1

Emission streams out of the different openings at different wind velocities U and different wind directions α

Windrichtung α *Wind direction α* [°]	**Windgeschwindigkeit U/** *Wind velocity U* [m/s]	**Massenstrom aus Öffnung/***Mass flow out of opening* [mg/h] 1	2	3	4	5
0	1	13 111	0	0	1 543	289
	2	19 898	0	0	1 820	731
	4,5	39 169	0	0	3 496	1 438
90	1	3 582	2	5 784	0	3 232
	2	6 875	3	10 753	0	5 834
	4,5	13 621	15	21 275	0	11 929
180	1	0	11 334	3 602	7 485	4 366
	2	0	20 727	6 341	11 971	7 851
	4,5	0	37 628	13 403	26 835	16 070
270	1	5 764	2 653	5 757	3 171	0
	2	9 339	6 436	8 984	5 992	0
	4,5	13 027	11 835	19 573	11 277	0

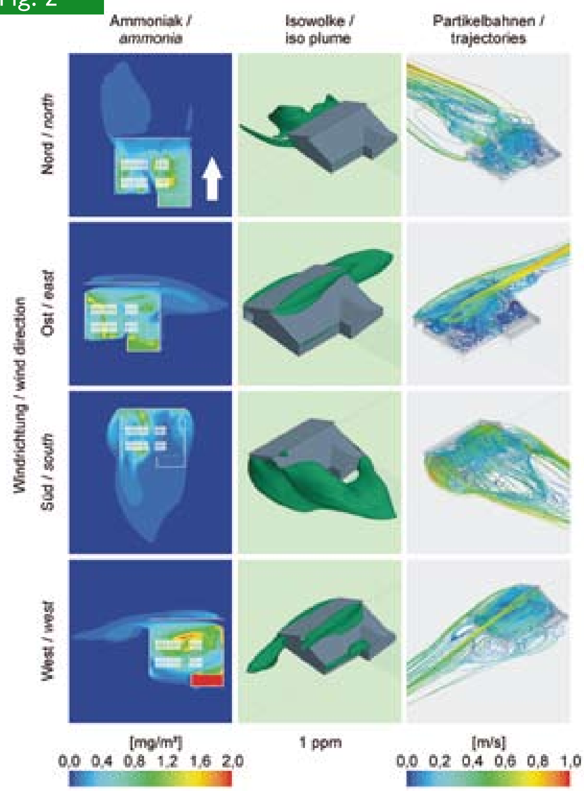
to point to factors which appear to be disadvantageous or possibly even contradictory in the planning phase of development rather than to wait until something happens in practice. The interactive influences of the stable air flow pressures are so complex, that general construction statements values for emissions behaviour are very difficult to make. The DIN 18910 assumes that the stable climate is a "homogenous stirrer kettle." But this does not permit the uses of nuances into the statements in stable construction. The simulations show that very different wind flows (meaning variable wind velocity and wind direction) cause a very differentiated distribution behaviour. With the simulations, the question necessarily follows of how measurement techniques must be included in the realized stable construction in order to check the results of the stable simulation. It is not a matter of snatching a glance at the measurement technical data, but rather of how such measurements fit into the concept of emission factors. Just because all information in the stable system can be called up in a simulation, this does not mean that the same information can also be obtained with measurement technology.

Simulations were conducted for three wind velocities and eight wind directions to document the ammonia output from the planned box stable. The slatted floor in the stable acted as a source of ammonia insofar as the ammonia emissions from the slurry in the upper hall area passed over the surface. The soil concentration in the lying areas is set at 10 mg/m³, in the feeding slots at 20 mg/m³. In **Table 1** simulation results are listed that result for the single simulation runs and in **Figure 2** they are presented as examples. Here one must state: in the simulation techniques, in contrast to measurement technology, every information may be called up.

Box stables with regard to Ammonia Output

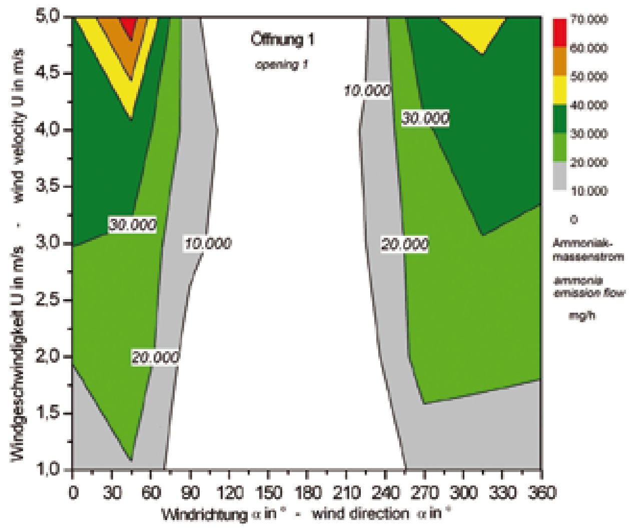
The numerous opening in the external stable walls had a transfer behaviour on the stable facilities that requires interpretation in the presentation of results in **Figures 2**, **3**, and **4**.The 100 percent ammonia output is presented in such a manner that it is distributed for every wind approach according to the openings. This presentation leads to an emission behaviour for every gust of wind in Germany. Should one already have drawn the wind velocity and also the wind direction dependence into

Fig. 2



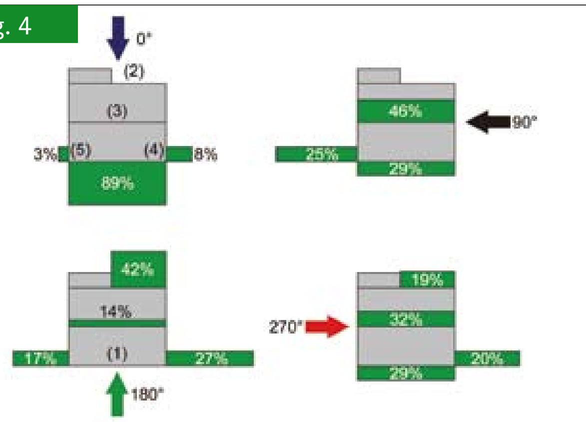
The rows show the ammonia concentration in an horizontal cut 0.5 m above floor, the ammonia cloud of 1 ppm leaving the stable and the path lines of fluid parcels of air at a wind velocity of 1 m/s; the columns show the influence of different directions of incoming wind

Fig. 3



Example for the emission behaviour of the opening 1. White marked are the areas without emission and in colour shades the areas of emissions

Fig. 4



In dependency on the wind direction the incoming wind blows the stable air loaded with ammonia through the openings with different rates, e. g. by the wind incidence from 180° (south) through the opening (5) with 17 %, through the opening (4) with 27 %, through the opening (2) with 42 % and through the opening (3) with 14 %

the factors, then the distribution calculations will cause an incomprehensible over-emphasis of the wind direction and velocity. The creation of such a factor would clearly depart from the opening requirement of finding a constant emission flow under the influence of meteorological parameters. In the simulation form developed here, the concept of the emission factor takes on a quite different importance as presented to date. Time row measurements were used to calculate the transfer function. All emissions leave the stable via the interface of the stable to the environment.

The internal stable distribution via the opening has nothing to do with a wind frequency distribution, but rather is consequence of redirection within the stable. According to the dimension analysis as described in Part 1, there is a correlation between the room size (i. e., in relation to the animal places) in dependence of the concentration relation on the ground and in the opening, or rather to the production relation K on the ground and the ventilation relation N in the opening.

$$\frac{N}{K} = \frac{C_B}{C_0} - 1 \qquad \text{(eq. 1)}$$

$$\text{with} \quad N = \frac{\dot{V}_0}{V_R} \quad \text{und} \quad K = \frac{k}{V_R} \qquad \text{(eq. 2a, b)}$$

$$f_e = \overline{\frac{C_0 \dot{V}_0}{M_T}} = \overline{N \exp(A + B\,X)} \qquad \text{(eq. 3)}$$

Accordingly a correlation is found for the concentration via the dimension analysis

$$\frac{C_0 V_R}{M_T} = \exp(A + B\,X) \quad \text{mit} \quad X = \frac{C_B}{C_0} - 1 = \frac{N}{K} \qquad \text{(eq. 4)}$$

From this we can draw the relationship for the animal mass related emission mass air flow

$$\frac{C_0 \dot{V}_0}{M_T} = N \exp(A + B\,X) \qquad \text{(eq. 5)}$$

$$\text{with} \quad X = \frac{N}{K} \qquad \text{(eq. 6)}$$

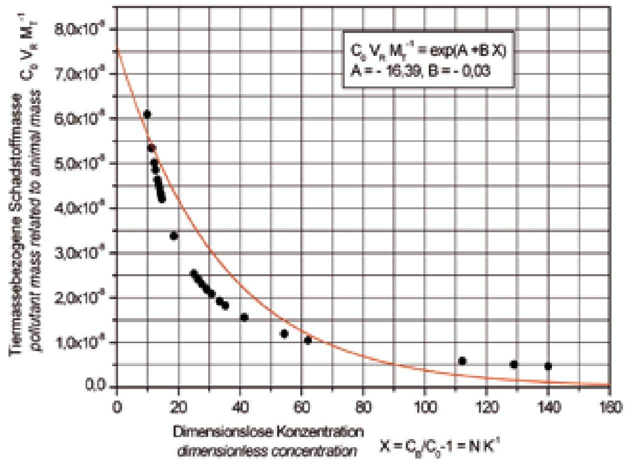
and the values from **Figure 5**

$$A = -16{,}39 \qquad \text{(eq. 7)}$$

$$B = -0{,}03 \qquad \text{(eq. 8)}$$

through integration of Equation (5) and averaging via the breadth $\Delta N = N_{max} - N_{min}$ for the emission volume flow via the ventilation rate N. N_{max} is to 500 s^{-1} , N_{min} is almost zero and K is set at 30. These are standard values that emerged in the simulation. Only the combination of simulation opening areas causes a certain reduction in the combinatorics.

Fig. 5



Graphical representation of the substitution function, which covers all stable openings for the mass outlet and is used as avarage function

The emissions factor from Equation (5) for the studied box stables results in 0,007817 g/(s • GV). The total mean emission volume flow caused by a stable occupation of 90 livestock units causes an ammonia output of 0,70353 g/s for the distribution calculation to start with the AUSTAL2000G program. This value differs in how it results in the general statement of the RL VDI 3498: the mean emission volume flow results as an emission factor to 0,0003858 g/(s • GV). The emissions volume flow for 90 livestock units for ammonia is then to be set at 0,034722 g/s. The emissions data are thus significantly higher than those gained in the simulation.

As mentioned previously the data in RL 3894 Sheet 1 did not come into the causal analytical path, but rather count as values from experience and thus cannot be drawn into the future planning. The proposed methods permitted an advance decision on how the stable can be classified in terms of environmental pollution.

Conclusions

1. The approach of drawing conclusions based on a transfer function independent of local meteorology proved successful with simulation techniques. It principally holds true for forced air stable facilities, but also for free air ventilation. With the approach practiced here, both a "fan wind" and "a natural wind" are blowing.
2. Such a transfer function results from the integration of ventilation rates. In this manner wind direction flows are neutralized as soon as they enter the stable.
3. Here a mean emission factor can be given, and then a clear legal requirement. This legal requirement does not only hold true for existing stable facilities, but also for the facilities in planning. In the planning phase, simulations provide the needed values in a clear form.
4. Measurement results, such as those obtained in time series, should continue to be used for the creation of transfer functions. Thus specifics about the stable can be included among the general considerations.

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