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

Part 3: Comparable use of regulation based emission factors with causal analytical approach of free ventlated stables

The administration demands in line with immission projection the use of the program AUSTAL2000G. Therewith the user is bound to look for adaptability of the data input at the data transfer interface. This duty is taken from him by federal demands and similar guidelines, respectively. The portability of data onto the individual case, which has to be analysed, is not questioned. So the users are able to integrate problems of agriculture into immission protection. However, the theme of emission acquisition with regard to the measuring technique turns out to be complex. The situation gets worse in a planning case. How the results of expansion calculation can diverge is shown by the example of box stables with free ventilation. It starts with emission data conform to guidelines, and then the emission model DEMAP is used.

Keywords
Open stable, emission factor, emission data, dispersion calculation

Abstract
Landtechnik 67 (2012), no. 1, pp. 73–76, 7 figures, 5 references

In Part 1 [1] time series measurements on volume streams and ammonia concentrations were used to derive a general transferability function of the emitted ammonia mass flows for the stable to be studied. The demonstrated approach also held for odours and other air components from a stable. The time series measurements first took place in a forced air stable in order to limit the results. The evaluation of data led to a general emissions model, DEMAP, from which the emission factor can be determined as an average animal weight or animal slot emission mass flow for whichever air component is of interest.

In a freely ventilated stable, a great deal of uncertainty surrounds the technical measurement documentation of the factors mentioned above in terms of positioning and simultaneousness. In order to not allow the entire view of the basic similarities to be clouded, the simulation technology is used, see Part [2]. This means on no account that experimental testing will be left out, but rather reaches to known physical correlations in combination with each other. One of the most important correlations can only be documented by the simulation: that is the flow field as a whole. Punctual measurements can be supportive, but do not in any way convey a total impression. One must go further and particularly look at the dynamic given with the flow fields and the continuation and development of the spatial conditions. If one is obligated not to exceed certain ammonia concentration levels, then a spatial perspective is certainly required.

Accordingly open box stables were considered with a simple open structure. Thereby it must be stated that the long drawn openings serve both as emission sources and fresh air sinks; depending on the pressure conditions and how the exchange movements between the contaminated stable air and the fresh outside air take place via the open areas. If describes the meteorological wind access angle (α = 0°: North, α = 90°: East etc.) and β clockwise the angle of the ridge axis in a north-south direction (here β = 355°) then with

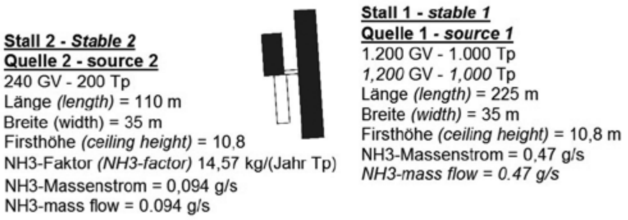
$$\gamma = \alpha - \beta \qquad \text{(eq. 1)}$$

One can approximate the volume flow that penetrates the stable system and exits it again with the following formula:

$$\dot{V}_0 = \frac{1}{2} A_F U_H \left(1 + |\sin \gamma|\right) \qquad \text{(eq. 2)}$$

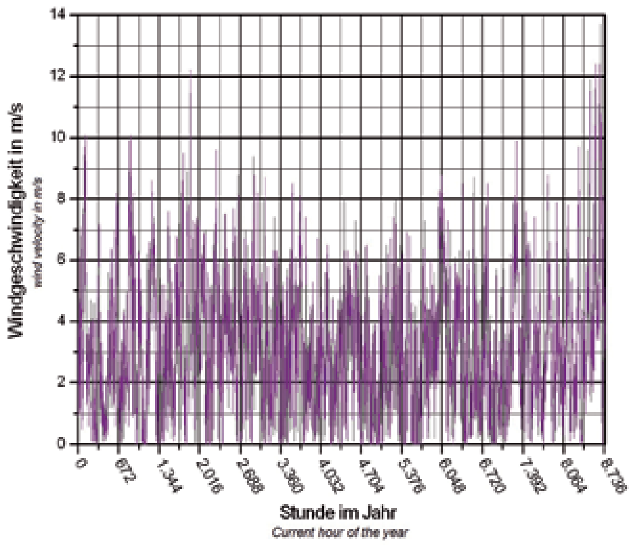
A_F describes the effective central opening areas. This information can also be used as a variable, depending on the meteorological conditions, which however is not done here. U_H stands for the horizontal wind at a height of 10m from the floor. Eq. (2)

Fig. 1



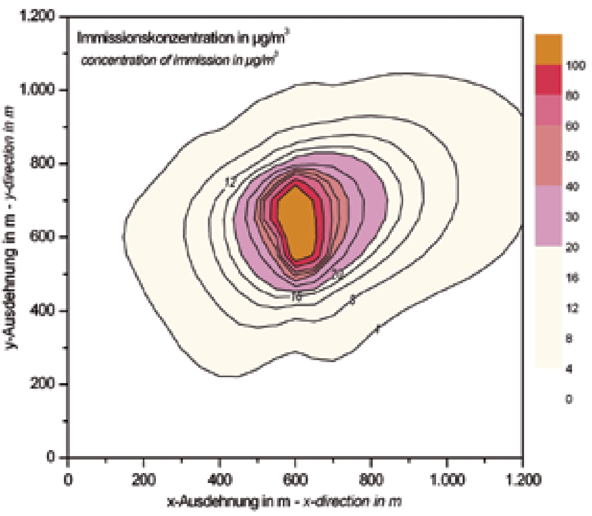
The quadratic area shows an edge length of 1,200 m. Two box stables are planned. They differ by 5° to west from the north-south direction, that means β = 355°. The emission of these stables are simulated as volume sources by the program AUSTAL2000G. Mass flow according to VDI 3894,1

Fig. 2



Wind velocity as a function of the current hour of that year that is representative for the selected site. Such data files are produced by Deutscher Wetterdienst (German Weather Service)

Fig. 3



Isolines presentation of ammonia concentration. According to the wind frequency the expansion expand further to north-east than to south-west

ensures that there is no zero value. As effective stable internal emission area A_E the product is derived from the stable length and stable width.

Local pollution through the cattle barn

Two box open stables are to be built. Their emissions data can be seen in **Figure 1**. Of interest is the ammonia pollution in their area. According to the Guideline VDI 3894 [3] the ammonia emissions factor is $f_{e,NH3}$ = 14,6 kg per year and T_P, where T_p stands for an animal slot. The guidelines (RL) do not differentiate between forced air and free ventilation. Here the result is an emissions mass flow of 0.47 g s^{-1} und 0,094 g/s.

Further constraints

In the emission causality chain through to the transmission of emissions, the meteorological and topographical constraints belong to those which, after the material release, have the greatest influence on the dispersion. In **Figure 2**, the wind speed and direction is presented graphically with hourly occurrences for a representative year at a selected location for a new stable building. The presentation of time series of wind direction and dispersion class was not included. The topography is not relevant for the calculations which exclusively reflect various emissions.

Results with the Emissions factor according to the guidelines

It is assumed in application of the guideline VDI 3894, that the emissions factor in the box open stables is not dependent on meteorological influences, see **Figure 3**.

Application of the Emissions Model DEMAP

The DEMAP model takes a different approach. The emission mass flow results from the equation

$$\dot{M}_0 = M_T \, N \exp(A + B\,X) \qquad \text{(eq. 3)}$$

with MT as animal weight and

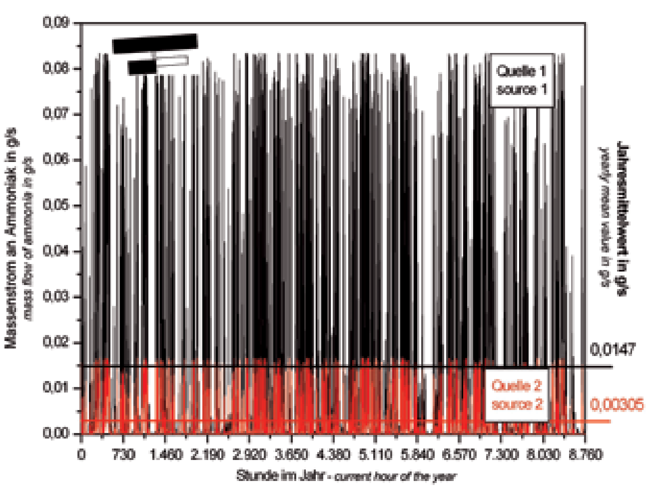
$$X = \frac{N}{K} \qquad \text{(eq. 4)}$$

As for the relationship between the air exchange and the production rate for the cattle barn, it generally holds true [2] for Ammonia A= - 14.30961 and B = - 0.13444. The meteorological data delivers the appropriate frequency of occurrence for each combination of the classified wind speeds and wind directions. **Figures 4** and **5** show the emissions mass flows for ammonia as a time series in the course of a year with various positions of the roof ridge axis.

Results with Emission Factors according to DEMAP

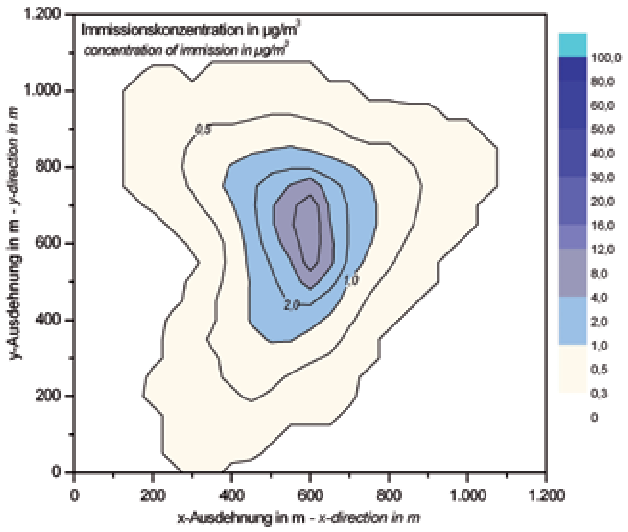
With this data different course are found for the Isolinien in **Figures 6** und **7**. The dependence on the orientation of the roof ridge becomes evident. A constant emissions factor is not appropriate for such an orientation configuration.

Fig. 4



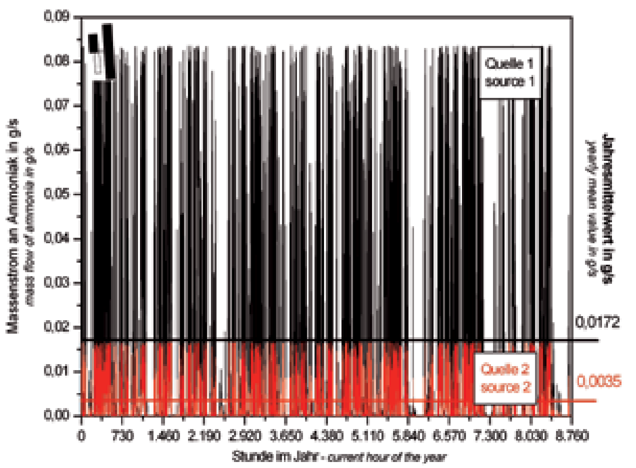
Emission mass flow as function of time. Specified are the hourly values during one year of the two box stables of figure 1 at β = 355°

Fig. 6



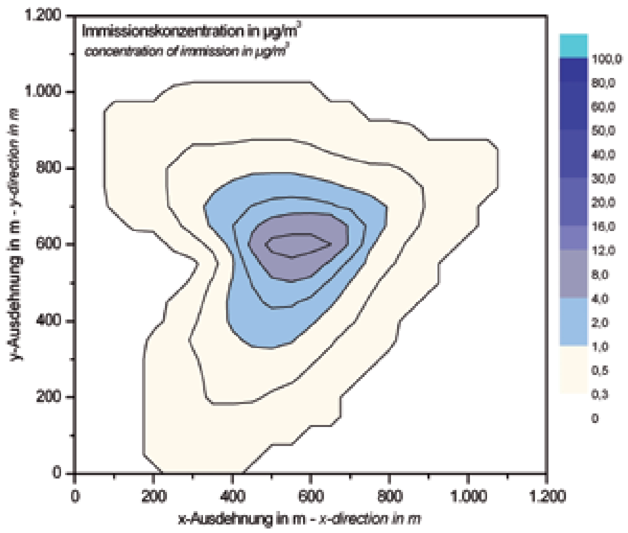
Display of contour lines of ammonia concentration at β = 355°

Fig. 5



Emission massflow as function of time. Specified are the hourly values during ohe year of the two box stables of figure 1 at β = 265°

Fig. 7



Display of contour lines of ammonia concentration at β = 265°

Conclusions

With the DEMAP model, in addition to the dependence on the wind speed, there is also dependence on the wind direction, so that the position of the stable ultimately caused different emissions and thus also immissions by constant meteorological data. Just then when competing uses of different areas meet upon each other, such impacts are decisive for further measurements of in emission creation. With the DEMAP model the emissions from a stable are given as a sum. Emissions information that characterizes every single opening can only be achieved with three dimensions of simulation technology.

According to Guideline VDI 3894, 1 signifies the emission mass flow for the long Stable 1 in ammonia 0.47 g/s, according to DEMAP with a north-south direction 0.0172 g/s and in an east-west position 0.0147 g/s. The differences are very great. Should one assume that Stable 1 shows a soil concentration of 10 mg/m³ with a length of 225 m and a width of 35 and that ammonia moves upward with a speed of 0.001 m/s from the floor, then one has an emission mass flow of 78.75 mg/s or rather 0.0079 g/s, according to DEMAP. With a floor concentration of 500 mg/m³ one achieves 0.4 g/s. If one maintains a floor concentration of 10 mg/m³, then the exit speed (turbulent diffusion speed) has a value of about 0.05 m/s. That would however bring ammonia to a measureable speed level. Both reasons for the approach of the guideline so not seem from a physical perspective to be plausible.

In summary it can be established that detailed knowledge, for example about the material transfer behavior, are essential prerequisites for successful simulation. Otherwise it is illusory to think that measurement technology alone can be used to document complex flow patterns in stable buildings with large emission areas, much less to document the transport of materials that are carried out of the stable into the environment.

Since the AUSTAL2000G program is linked in terms of calculations to the emissions side of the transmission, but cannot calculate emission mass flows, it instead requires input from outside. Suitable replacement models for the emissions with conforming rules and as such emission approaches won via model must be created. This must certainly not remain so, but as long as the rules of causality are lacking in the presentation of data and are based only on the experience of those who establish the data, the room for individual is given too much emphasis. And therefore a further development of modern stable systems is principally placed in question.

Literature

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