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ODOUR EMISSION FROM LIVESTOCK BUILDINGS AND GUIDELINES FOR MINIMUM DISTANCES IN GERMANY

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SUMMARY

The purpose of the investigations described in this paper was to develop guidelines to determine the minimum distance between animal farming houses and residential areas for regulatory procedures in Germany. The necessary ventilation of animal houses leads to emissions and air-borne pollution in the surrounding area. Dust, germs and gases are emitted together with the used air. Odours caused by certain gases can lead to annoyance in the neighbourhood of livestock buildings. A 'minimum distance rule' between residential areas and livestock buildings is defined in Germany by the VDI-Guidelines 3471 and 3472 (Emission control - livestock management - pigs and hens). New developments in animal production demand an accommodation of the guidelines: updates are necessary. The basic question is how to deal with the requirement of increasing the validity of the guidelines. The answer is to combine measurements of odour relevant elements and dispersion modelling. Therefore basic research to the emission streams and the distribution behaviour of odour plumes in the surroundings of livestock buildings is carried out. The Institute of Agricultural Engineering Bornim (ATB) and the Federal Agricultural Research Centre (FAL) collaborate with other institutes in Germany. The immission (impact/nuisance) is a function of emission and transmission. The emission mass flow from real livestock buildings with natural and forced ventilation systems is the product of the volume stream and the odour concentration. The volume flow is measured by a special tracer gas technique by means of Krypton 85, the odour concentration by olfactometry. In parallel to this, the meteorological data (especially wind velocity, direction and turbulence) are recorded to describe the transmission conditions. On the immision side the frequency of odour recognition is determined. In combination with transmission and immission data a dispersion model is calibrated. By means of this the greatest distance $d_{max\ cattle}$ of no-effect in the surrounding of the special animal house of interest is calculated. The results of several investigations lead to a distance function $f(d_{max\ cattle})$. In comparison with the disctance rule between pig houses and residential areas as reference distance curve a so-called 'odour equivalence factor' is determined. The advantage of this procedure is to integrate new research results without changing of the entire guideline. The guideline is used as screening model to make a first assessment of the minimum distance at low cost.

Keywords: livestock buildings, emission, immission, odour, distance

INTRODUCTION

Odour caused by certain gases can lead to annoyances in the surroundings of livestock buildings. Therefore the establishment of a minimum distance between human living areas and livestock buildings is necessary. Guidelines established in Germany to define these distances are the guidelines VDI 3471 (emission control - livestock management - pigs) and VDI 3472 (emission control – livestock management - hens). In Austria and Switzerland similar regulations are used (Figure 1). Nevertheless there are distance variations caused by different ways of grading the influences of emission, transmission and immission. Of course the physical background is always the same: the expansion of odour by the atmospheric wind.

Simulations of special conditions of emission and transmission lead to a variety of immission results because of the lack of concrete physical data. Under false pretences simulations give the impression of high exactness. Several questions are unanswered concerning the production of odour in mechanically ventilated and wind induced naturally ventilated systems of animal housing: the turbulent diffusion, the human reaction on odour. Though there is a great need of research the administration is forced to determine the minimum distance and whether it is allowed to stay a little bit below the minimum distance without risk to human health or threat to animal production.

Figure 1. Distance function *f* in dependency on odour equivalence livestock mass $M_{T,eq}$ in different European countries

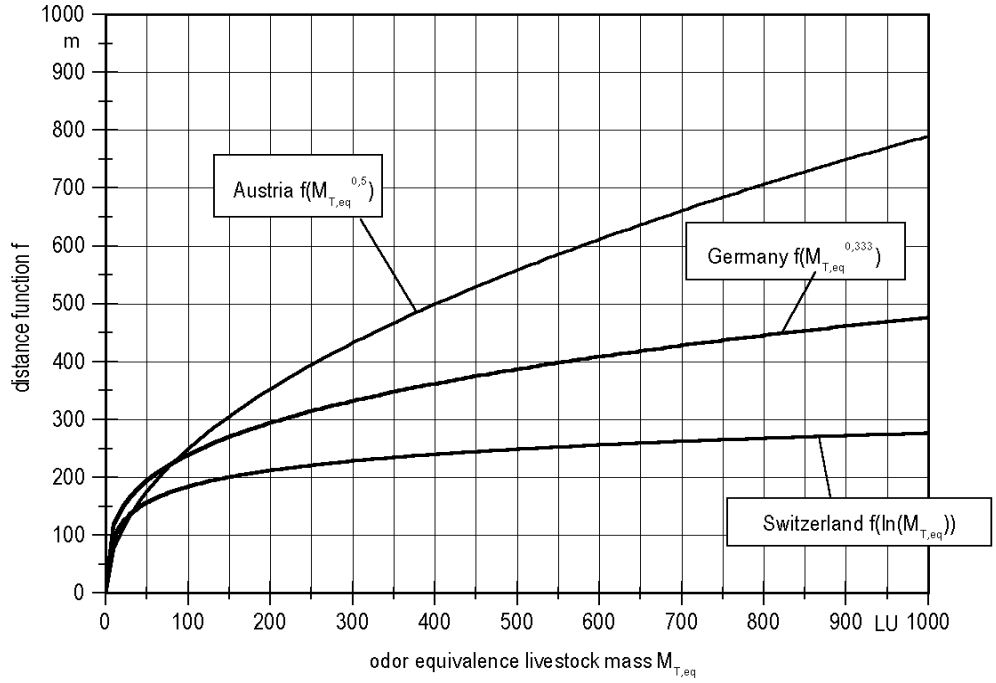

Figure 1. Distance function *f* in dependency on odour equivalence livestock mass $M_{T,eq}$ in different European countries

MATERIALS AND METHODS

In order to determine the emission stream of a livestock building we have to measure the odour concentrations of fresh and exhaust air and the air flow rate. In cattle houses we primarily have do deal with naturally ventilated systems. We use the tracer gas Krypton 85 to measure the air change rate by the theory for well mixed boilers. The exponent of the decay function of the concentration of Krypton 85 is the local air change rate. In connection with the volume of the livestock building the volume flow can be determined (Müller et al., 1998). Parallel to this the meteorological data are recorded to describe the transmission conditions. On the immission side the impressions regarding odours are recorded with a portable computer (palmtop) by registration a yes- or no-decision of the operator. Very rarely the widest distance d_{max} is determined by inspection. For that reason the frequency of recognition w_S is simulated by an expansion calculation with parameter calibration. After this the widest distance d_{max} is determined by simulation making use of different combinations of wind speed, wind direction and atmospheric turbulence class. Here the frequency of recognition is set to $w_S = 0.05$.

DISTANCE DETERMINATION FOR CATTLE PRODUCTION

The main idea behind the creation of the guideline VDI 3471 was the determination of the threshold distance for odour transmission. The investigations were carried out in the seventies with many inspections on about 600 pig-housing units. The odour threshold distance was established in the inspections in each case as the result of a certain meteorological situation with distinct emission conditions; the number of times such situations took place was disregarded.

Within the guideline VDI 3473 (emission control – livestock farming – cattle – odorants) the so-called odour equivalence factor f_{eq} was established for the first time. This factor allows to use the same distance curve for pigs (VDI 3471) for other kinds of animals. The livestock mass M_T is substituted by the odour equivalence livestock mass $M_{T,eq}$ by means of f_{eq}:

$$M_{T,eq} = f_{eq} M_T \quad (1)$$

Together with the points *P* awarded to the quality of the system of the livestock house, whereby a maximum of *P* = 100 is permitted, the central distance relationship is (Krause, 1988):

$$d_{\max} = a(P) M_{T,eq}^{\ b(P)} \tag{2}$$

a(*P*) and *b*(*P*) are polynomials in *P* and lead for *P = 100* to *a(100) = 48.697* and *b(100) = 0.338*. The central distance relationship continues to stay in the new directive VDI 3474 (Emission control – livestock farming – Odorants) when instead of the point-awarding an awarding of notes is introduced through a so-called technology factor. Whatever system is applied one cannot get past the definition of an odour equivalence factor f_{eq} in the further development of the livestock production directive. Formally, such a factor can be developed through the determination of a distance according to the specific type of animal $d_{max\ cattle}$ (example for cattle). This uses the meter as length unit when M_T is given in large animal units (1 LU = 500 kg). The distance relationship $d_{max\ cattle}$ is known to be of the form

$$d_{\max cattle} = A M_T^{\ B} \tag{3}$$

(1) and (2) directly lead to

$$f_{eq} = 1 / M_T \left[d_{\max cattle} / a(P) \right]^{1/b(P)} \tag{4}$$

Currently the guidelines are being revised and extended after 5 years. For the farming of cattle sufficient research results do not exist. Therefore 31 cattle barns have been investigated during 2 years (Müller, H.-J. et al. 2001). The same investigation took place in 16 livestock buildings for turkeys and ducks.

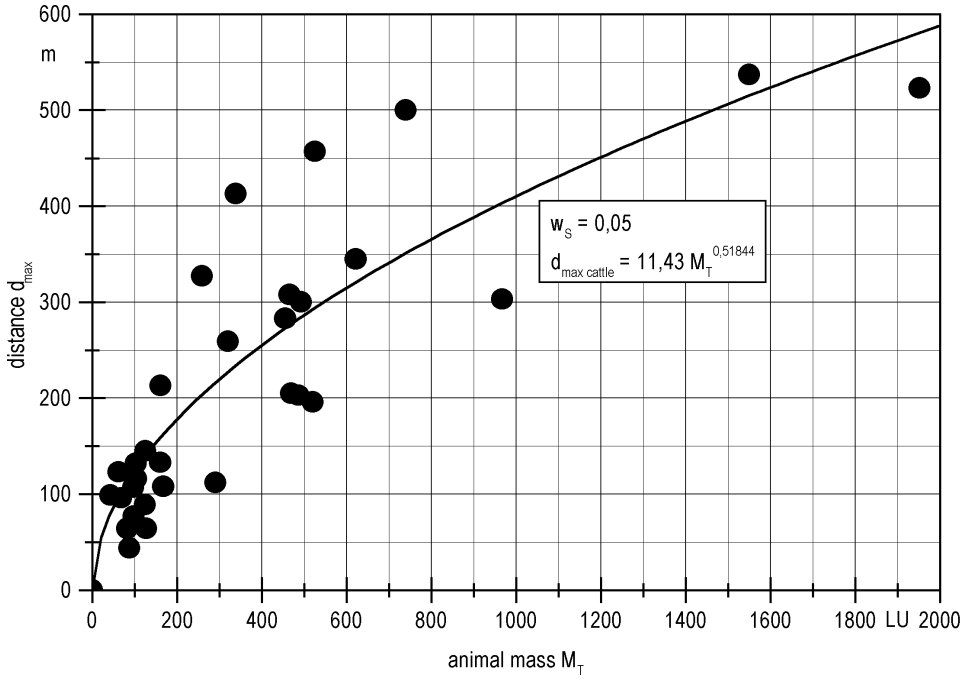

Figure 2. The maximal distance d_{max} in dependency on the animal mass M_T for cattle houses.

RESULTS

$d_{max\ cattle}$ must be determined by experiments and simulations. Finally in Figure 2 the equation for $d_{max\ cattle}$ is stated as calculated by least squares method. In connection with equation (4) the odour equivalence factor is

$$f_{eq} = 0.01377 M_T^{\ 0.5338} \tag{5}$$

For $M_T = 50\ LU$ equation (5) gives $f_{eq} = 0.11$, for $M_T = 500\ LU$ the odour equivalence factor is $f_{eq} = 0.38$ and for $M_T = 2{,}000\ LU$ we get $f_{eq} = 0.8$. The stables of investigations were characterised by an animal mass between $M_T = 43.2\ LU$ and $M_T = 1.952\ LU$. So an average value $f_{eq} = 0.523$ based on equation (5) must be obtained within these boundaries.

It is worth mentioning that the odour equivalence factor f_{eq} according to equation (5) depends on the animal mass M_T. The exponent is of magnitude ½. With equation (2) we come to an estimation for the distance function $f(d_{max\ cattle})$ that leads to an exponent of $(f_{eq}\, M_T)^{1/3}$ $(M_T^{1/2}\, M_T)^{1/3} = (M_T^{3/2})^{1/3} = M_T^{1/2}$. This means that the general distance function to cattle houses shows an exponent of ½ rather then of . For production houses of ducks and turkeys the exponent is smaller than ½. Looking at Figure 1 the exponent in equation (2) describes the fundamental form of the distance curve and can assume values between b = in Germany and b ½ in Austria. When the odour equivalence factor f_{eq} shows a dependency on M_T this effect can be incorporated into the exponent b of the general curve. This gives a hint that the starting the reference curve with b = may be a coarse approximation to the immission situation of cattle production. But in the case of other animal production enterprises, there are other exponents for b. It is a question of pragmatism to determine the best reference curve with a minimum of deviations caused by f_{eq} and the dependency on M_T.

DISCUSSION

In general the immissions (impact/ nuisance) emanating from ambient air pollution with odorants by animal production will normally be assessed on the basis of distance rules in Germany: the VDI-Guidelines 3471, 3472 and the new draft VDI 3474. The new draft puts together all the other guidelines. The task is to extend the guideline to modern animal production systems and such kinds of animals that are not taken into account as yet. But there is no financial support for hundreds of inspections to determine the odour threshold distances in the surrounding of animal farming houses and evaluate the results by statistical methods. Therefore a methodology was developed to determine the no-effect levels d_{max} for odour emissions by simulation based on the measurement of emission, transmission and immission values: volume stream rate, odour concentration, wind velocity, wind direction, atmospheric turbulence class, frequency of odour recognition in the surrounding of the animal farming house.

The distance function $f(d_{max})$ is determined and compared with the reference curve for pig houses; in the seventies pig houses with forced ventilation systems were in the middle of interest. This procedure leads to the equivalence factor f_{eq}. By the odour equivalence factor f_{eq} it is possible to use the same distance curve between animal and dwelling houses for different kinds of animals. The distance $f(d_{max})$ depends on the odour equivalent animal mass $M_{T,eq}$. In general the exponent b of the odour equivalent animal mass is .

The odour equivalent animal mass $M_{T,eq}$ is the product of the odour equivalence factor f_{eq} and the animal mass M_T. Latest investigations of cattle houses show that the equivalence factor depends on the animal mass M_T, too. That means that the exponent of the reference curve may be altered. But this should be done with respect to the other kinds of animal production and perhaps in harmonisation with other countries.

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