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Regional differences of separation distances between livestock buildings and residential areas in Austria and comparison to the Austrian Odour Dispersion Model

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Separation distances between livestock buildings and residential areas can be determined with the Austrian guide line based on a power function with an exponent of 0.5. We developed a new empirical model which uses a power function $S = \alpha E^{\beta}$ with the separation distance S, the odour emission flow E and the two parameters α and β. These two parameters depend on the relative frequency of wind direction h_w and wind velocity W as well as the protection level h_P. The protection level is expressed by the threshold of the odour concentration of 1 OU/m³ and the exceedance probability (between 3 and 24%) for odour sensation. This paper describes the methodology. The separation distances of the Austrian Odour Dispersion Model (AODM) are compared to those of the new empirical approach. A good fit between modelled and calculated separation distances can be achieved for all sites investigated.

1. Introduction

Complaints by the neighbourhood due to odour emissions of livestock buildings are a major concern in rural areas. Therefore, some countries have already developed guide lines to address odour from livestock. These guide lines are in use to assess the necessary separation distance between livestock buildings and residential areas such that odour is not felt as an annoyance. In all these guide lines, the separation distance is calculated as a function of the odour emission flow, sometimes parameterised by the number of animals. Most of these guide lines are based on a power function with an exponent between 0.3 (Germany), 0.5 (Austria; The Netherlands; Indiana, USA) and 0.6 (USA) (Piringer and Schauberger, 1999).

Since 1996 the Austrian guide line is in use (Schauberger et al., 1997). Therefore a recalculation with the Austrian Odour Dispersion Model (AODM) was done to implement new developments in livestock husbandry. To revise the guide line, a new empirical approach to calculate the separation distance was developed and tested. The calculations are performed for several sites in Austria to evaluate the necessity of a

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regionalisation of the parameters of the regression model. In this paper, the methodologies of the guide line and the empirical approach will be outlined, and the separation distances of the AODM are compared to those of the new empirical approach.

2. Methodology

2.1 The Austrian guide line

The Austrian guide line (Schauberger et al., 1997), to determine the separation distance, uses a constant exponent β of 0.5. Instead of frequencies for h_W, W and h_P, the guide line operates with factors. The wind direction frequencies of the eight cardinal wind directions representing each a 45° sector are converted to the meteorological factor f_M of the guide line varying between 0.6 and 1, and exceedance probabilities are converted to the land use factor f_R of the guide line. The guide line discerns between three land use categories: pure residential areas ($f_R = 1$), common residential areas ($f_R = 0.7$), and areas of mixed residential/commercial activity ($f_R = 0.5$). In the guide line, the separation distance S is calculated according to $S = 25 f_M f_R O^b$, where O is the dimensionless odour number depending on the number of animals and on the conditions how they are kept.

2.2 The Austrian Odour Dispersion Model (AODM)

The separation distances to test the approach are calculated with the Austrian Odour Dispersion Model (AODM). The model is described in detail in Schauberger et al. (2001, 2002). AODM is a Gaussian-based model to predict odour sensation, by estimating the daily and seasonal variations of the odour emission, the average ambient odour concentration and the momentary (peak) concentration for the time interval of a single human breath (approx. 5 seconds). Peak concentrations further downwind are modified by an exponential attenuation function (Piringer et al., 2007).

2.3 Outline of the new empirical approach

The new empirical approach to be tested uses a power function $S = \alpha E^{\beta}$ with the separation distance S (m), the odour emission flow E (OUs^{-1}) and the two parameters α and β. These two parameters depend on the relative frequency of the wind direction h_W and the wind velocity W and the protection level h_P. The protection level is expressed by the threshold of the odour concentration of 1 OU/m^3 and the exceedance probability for odour sensation. The two meteorological parameters, relative frequency of the wind direction h_W and the wind velocity W, relate to a smaller class width of 10° compared to the old version with 45°.

2.4 Model calculations

The AODM model calculations have been carried out for odour emission flow rates E of 400, 800, 1500, 3000, 6000, 12000 and 24000 OU s^{-1}. The source geometry is a single point source with a height of 6 m.

The exceedance probabilities to calculate the separation distances have been chosen according to international thresholds and to those of the Austrian Academy of Sciences. The following values have been chosen: 3%, 4%, 8%, 12%, 15%, 16%, 20%, and 24%.

Meteorological data have been taken from six Austrian stations chosen with respect to the main geographical areas in Austria (Eastern flatlands, North-Alpine foreland, Inner-

Alpine valleys, South-Alpine basins and valleys) and with respect to the livestock density for pigs and cattles. Frequencies of wind direction and wind speed differ considerably between these sites.

3. Results and conclusions

The factor α and the exponent β of the power function S = α E$^{\beta}$ depend on the relative frequency of the wind direction h_W (%), the exceedance probability for odour perception h_P (%), and the mean wind velocity W (m/s).
The two functions which were selected for the factor α and the exponent β are given by

$$\alpha = h_P^a (b\, h_W^c + d\, W + e)$$

$$\beta = \frac{1}{(f\, h_W + i\, h_P + j)}$$

The coefficients of the two equations of the empirical model have been determined with a multivariate non-linear functional fit via the Richardson extrapolation. The aim of this fit is to get modelled separation distances the distribution of which resembles those of the dispersion model as good as possible. So far, the regression function has been chosen and the model error has been investigated. The coefficients of the two equations are depicted in Table 1. The minimum distance of the AODM which was used for the calculation of the regression coefficients was 100 m; therefore the minimum separation distance of the empirical model was set to 100 m, too.

Table 1: Coefficients (± standard deviation) of the factor α (*a* to *e*) and the exponent β *(f* to *j)*

Coefficient		
a	- 0.3862	0.0058
b	165.2	67.9
c	0.0289	0.0116
d	- 3.633	0.0495
e	- 149.7	67.9
f	- 0.0381	0.0003
i	0.0191	0.0004
j	2.309	0.0059

The results of the regression analysis are quite encouraging. 42 % of the modelled separation distances are within ± 10% of those calculated with the AODM. There are no under-estimations larger than 50%, and only 0.4% of all data show an over-estimation of more than 100%. There are 58% over-estimations and 42% under-estimations. The relative frequency of the relative model error peaks around 0.

As far as the modelled separation distances are concerned, the largest relative errors occur with small separation distances. The largest over-estimations occur with low wind speeds and with very low and very high odour emission flows.

Both the modelled and the calculated separation distances comprise a range between 100 and 5000 m, depending on the odour emission flow and the meteorological conditions.

The largest over-estimations occur with separation distances between approx. 200 and 1500 m. The largest under-estimations are found only with low separation distances less than 420 m. As far as the six sites investigated are concerned, all show a similar course of the relative model error described above. A detailed analysis shows that differences among sites are small and not systematic. The new empirical approach to calculate separation distances between livestock units and the neighbourhood can therefore be applied without geographical restrictions.

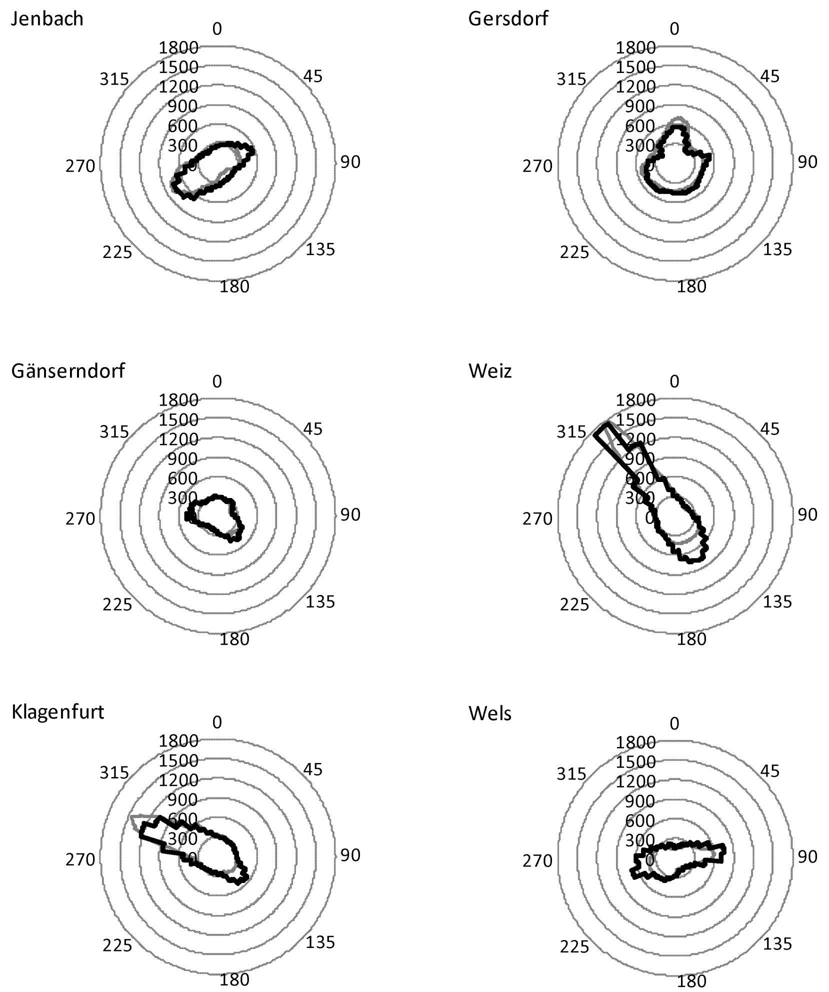

Fig. 1. Separation distances calculated with AODM (grey) and separation distances calculated with the empirical model (black) for an odour emission flow rate E = 6000 OU/s and an exceedance probability h_P = 3%.

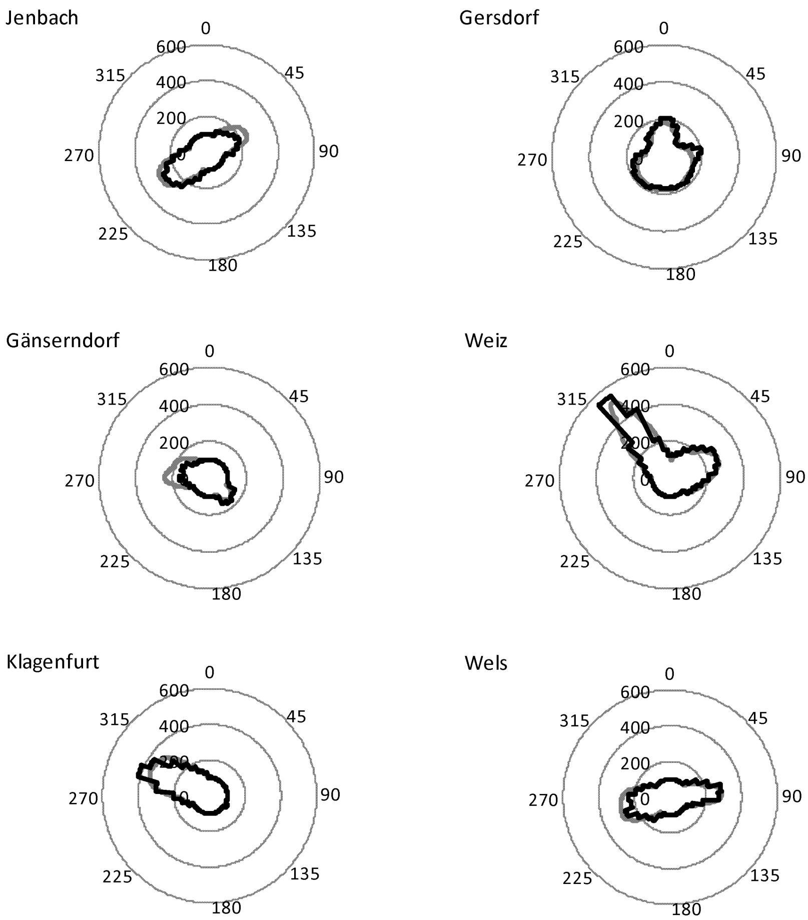

Fig. 2. Separation distances calculated with AODM (grey) and separation distances calculated with the empirical model (black) for an odour emission flow rate $E = 6000$ OU/s and an exceedance probability $h_P = 15\%$.

Two examples are shown in Fig. 1 and 2. The odour emission is selected with E=6000 OU/s which correspond to 925 fattening pigs, 29 400 poultry, and 710 cattle. The protection level is defined for pure residential areas with an exceedance probability of $h_P = 3\%$ (Fig. 1) and for agricultural areas with an exceedance probability of $h_P = 15\%$ (Fig. 2).

The direction depending shape of the separation distances for these two impact criteria ($h_P = 3\%$ and 15%) illustrate the distinct influence of the meteorological circumstances. For some sites the separation distances show a nearly isotropic behaviour (e.g. Gänserndorf, Gersdorf). The ratio between maximum and minimum distance is in the range of 2. For other sites like Weiz, the prevailing wind directions influence the separation distances to quite an extend. The ratio between the two extremes (maximum/minimum) lies in the range of 5.5 – 8.5.

References

Piringer, M., Petz, E., Groehn, I., Schauberger, G., 2007, A sensitivity study of separation distances calculated with the Austrian Odour Dispersion Model (AODM), Atmos. Env. 41, 1725 – 1735.

Piringer, M., Schauberger G., 1999, Comparison of a Gaussian diffusion model with guidelines for calculating the separation distance between livestock farming and residential areas to avoid odour annoyance, Atmos. Env. 33 (14): 2219-2228.

Schauberger G., Piringer M., Petz E., 2002, Calculating direction-dependent separation distance by a dispersion model to avoid livestock odour annoyance, Biosystems Engineering 82, 25-37.

Schauberger G., Piringer M. (2001). Predicting odour impact using the Austrian odour dispersion model (AODM). Water Science and Technology 44, 197-204.

Schauberger G., Piringer M., Eder J., Fiebiger H., Köck M., Lazar R., Pichler-Semmelrock F., Quendler T., Swoboda M., Thiemann G., Teufelhart J. (1997). Österreichische Richtlinie zur Beurteilung von Immissionen aus der Nutztierhaltung in Stallungen. Gefahrstoffe - Reinhaltung der Luft 57, 399-408. (in German)