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A new empirical model to calculate separation distances between livestock buildings and residential areas applied to the Austrian guideline to avoid odour nuisance

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ABSTRACT

In Austria a new guideline is under development to calculate the separation distance between livestock and residential areas to avoid odour annoyance. On the basis of dispersion model calculations for 6 sites by the Austrian odour dispersion model (AODM) a regression model is developed, using a power function $S = a\,E^b$. The power function is defined by four input parameters. The basis of the power function is the odour emission rate E ($ou_E\ s^{-1}$) in the range between 400 $ou_E\ s^{-1} \leq E \leq$ 24 000 $ou_E\ s^{-1}$. The factor a and the exponent b of the power function are defined by two meteorological parameters, the relative frequency of the wind direction F, the mean wind velocity W of the wind direction for 10° sectors as well as the odour exceedance probability P of the odour impact criterion. One of the requirements for this empirical model is the aspiration to substitute the complex calculation with a dispersion model by the new empirical model. The empirical model can be used in a paper and pencil mode, which enables an evaluation of a planned livestock building in a simple way. For a more detailed assessment, a dispersion model can be applied with the entire meteorological information (e.g., stability of the atmosphere, wind field models), the geometry of the emission source, a time depending odour emission rate, and the orography of the site.

1. Introduction

Complaints by the neighbourhood due to odour emissions of livestock buildings are a major concern in rural areas. To handle odour annoyance, a separation distance between the odour source (livestock) and residential areas is used, depending on a certain protection level. Some countries have already developed guidelines to address odour from livestock. In all these guidelines, the separation distance is calculated as a function of the odour emission rate, sometimes parameterised by the number of animals. Recently new guidelines were published for Germany (Schauberger et al., 2012; VDI 3894 Part 2 Draft, 2011), for Belgium (Nicolas et al., 2008), and for the US (Nimmermark et al., 2005). In Austria a new guideline is under development which will substitute the old version published in 1995 (Schauberger and Piringer, 1997). The new empirical model, presented here, should be included in the new guideline.

The empirical approach is a regression model which is based on dispersion calculations by the Austrian Odour Dispersion Model (AODM).

The objectives for the development of the Austrian empirical model generally correspond to the German guide (Schauberger et al., 2012). The main difference is the best fit approach for the Austrian model, in contrast to a worst case calculation for Germany.

2. Materials and methods

2.1. Meteorological data

Meteorological data have been taken from six Austrian stations chosen with respect to the main geographical areas in Austria

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Table 1
Meteorological stations used for the calculations by the dispersion model. Name of the city, sea level (m a.s.l.), geographic latitude (° ′) and geographic longitude (° ′), mean wind velocity (m s^{-1}), and fraction of stable conditions category 6 (stable) and 7 (extreme stable) of the discrete stability scheme of Reuter (1970) (%).

City	See level (m a.s.l.)	Geographic latitude(° ′)		Geographic longitude (° ′)		Mean wind velocity (m s^{-1})	Stable conditions (%)
Weiz	468	47	13	15	38	1.3	35.5
Wels	325	48	10	14	5	2.0	25.7
Gersdorf	396	47	9	15	51	1.3	34.2
Gänserndorf	167	48	20	16	43	3.2	21.5
Klagenfurt	450	46	39	14	19	1.8	34.0
Jenbach	530	47	23	11	45	2.3	27.5

(Eastern flatlands, North-Alpine foreland, Inner-Alpine valleys, South-Alpine basins and valleys) (Table 1). The geographical distribution is depicted in Fig. 1 together with the livestock density (LU ha^{-1}) related to the agriculturally used land. The meteorological data are used as a three dimensional frequency distribution classified by the wind direction, wind velocity, and stability of the atmosphere, according to the system of Reuter (1970), described in Schauberger et al. (2001).

2.2. Odour emission rate

The calculations have been done for all six sites with 8 different odour emission rates 400, 800, 1500, 3000, 6000, 12,000, and 24,000 ou$_E$ s^{-1}, which covers the range of typical Austrian livestock farms. The source geometry is a single point source with a height of 6 m. The emission rate is assumed to be constant in time.

2.3. Dispersion model

The separation distances to test the approach are calculated with the Austrian Odour Dispersion Model (AODM) (Piringer et al., 2007; Schauberger et al., 2000, 2002).

The separation distances S^{disp} were calculated for 36 wind directions, for six meteorological sites, for eight exceedance probabilities P (between 3 and 24%, describing the protection levels used in Austria), and for 7 odour emission rates (between 400 and 24 000 ou$_E$ s^{-1}). The minimum distance of the AODM, which is used for the calculation of the regression coefficients, is 100 m; therefore the minimum separation distance of the empirical model is set to 100 m, too. This results in a dataset of $N = 5991$, which is used to derive the coefficients of the separation distance S^{mod} (Eq. (1)) for the empirical model.

2.4. Empirical model

Many national guidelines (e.g. Germany, Austria, Belgium, US) use a simple power function (Piringer and Schauberger, 1999) to calculate the separation distance S^{mod} (in m) as a function of the emission rate of the odour source E (in ou$_E$ s^{-1}) according to

$$S^{\mathrm{mod}} = a^{\mathrm{mod}} E^{b^{\mathrm{mod}}} \tag{1}$$

with the factor a^{mod} and the exponent b^{mod}. These two parameters are determined by a regression analysis. For the regression analysis the two meteorological parameters, the relative frequency of the wind direction F and the mean wind velocity W of the wind sector, as well as the exceeding probability of the odour perception P are used as predictors.

To determine the factor a^{mod} and the exponent b^{mod}, the calculations by the dispersion model of the separation distance S^{disp} are used.

The performance of the empirical model is investigated by the relative model error Δ

$$\Delta = \frac{S^{\mathrm{mod}} - S^{disp}}{S^{disp}} \tag{2}$$

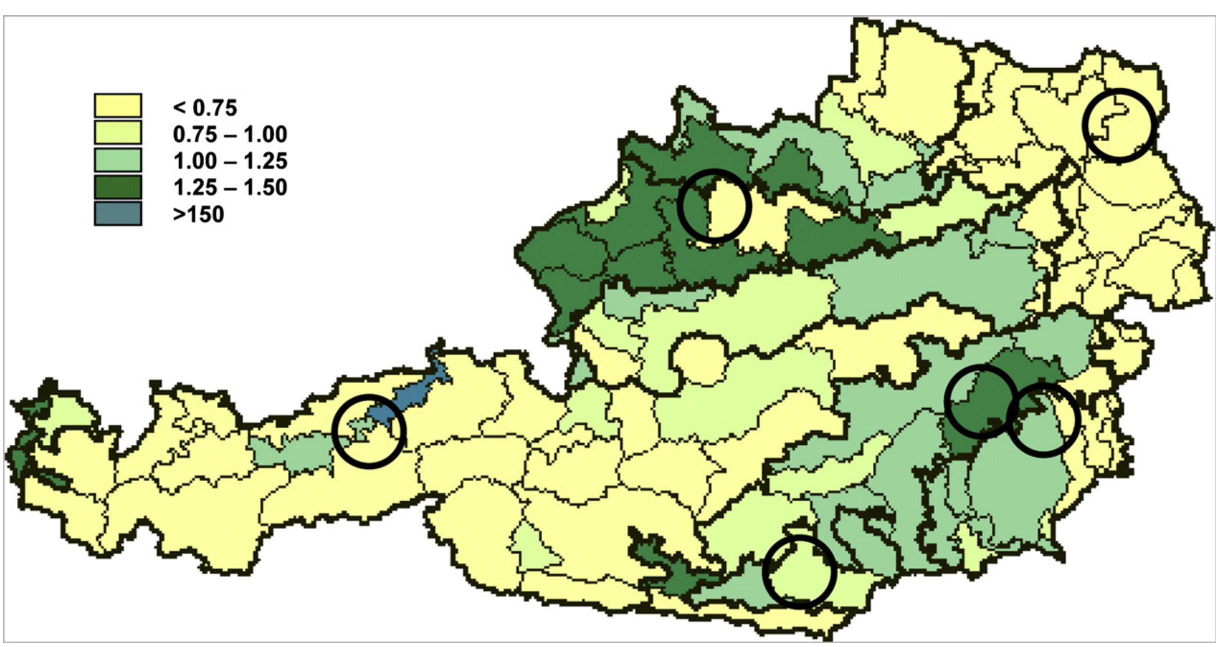

Fig. 1. Geographical distribution of the 6 meteorological stations, which were used for the calculations by the dispersion model and the livestock density related to the agricultural used land (LU ha^{-1}) in Austria in 2009. The sites from West to East are: Jenbach, Wels, Klagenfurt, Weiz, Gersdorf, and Gänserndorf.