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SENSITIVITY ANALYSES OF DISPERSION MODELS TO ASSESS ODOUR NUISANCE: A QUALITATIVE COMPARISON WITH COMPLAINT STATISTICS

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1 INTRODUCTION

Odour is one of the major nuisances from livestock husbandry especially in the swine industry causing an increasing need for odour related research (Thu, 2002). The final report of the Iowa State University and The University of Iowa Study Group (2002) defines odour, besides hydrogen sulphide and ammonia, as emission which has been of major concern by residents in the vicinity of livestock. Environmental agencies are confronted by complaints of people living in the vicinity of animal producing farms. Reports about these complaints show similar time patterns (Strauss et al. (1986); Schiffman, 1994; Lohr (1996), concentrated during the warm season and in the afternoon and evening hours.

In this paper the time pattern of the complaints is compared to the time pattern of odour episodes calculated by the Austrian Odour Dispersion Model AODM described recently (Schauberger et al. 2001 and 2002). The AODM consists of three modules: the first calculates the odour emission of the livestock building, the second estimates mean ambient concentrations using the Austrian Gaussian regulatory dispersion model, and the last transforms the mean odour concentration of the dispersion model to instantaneous values that depend on wind velocity and atmospheric stability. The direction-dependent separation distance is defined as the distance from the source where a sensation level dependent on a pre-selected odour impact criterion occurs. The odour impact criteria used in this study are a combination of odour threshold and probability of threshold exceedance (Schauberger et al., 2001).

2 METHODS

The odour release is calculated for a 1000 pig unit according to Schauberger et al. (1999 & 2000b).

The mean ambient odour concentrations are calculated using the Austrian Gaussian regulatory dispersion model (ÖNorm M 9440, 1992/96), a Gaussian plume model for single stack emissions. The model has been validated internationally. The mean odour concentrations of the dispersion model are transformed to instantaneous values depending on wind velocity and atmospheric stability. The meteorological background to calculate the instantaneous values using a peak-to-mean parameterisation is described in detail by Schauberger et al. (2000a).

The separation distance is calculated for eight wind direction classes (sectors of 45°) in two steps: First, sensation distances, defined as distances from the source where the momentary odour concentration is 1 OU/m³, are calculated for each half–hourly period of the meteorological 2-year time series. The second step is the calculation of the separation distance. Therefore, selected limits of the combination of odour concentration threshold and probability of the threshold exceedance are taken. For the calculation presented here, we selected a threshold of 1 OU/m³ and a probability of the threshold exceedance of 3% indicating that, during a typical year, there are 525 out of 17520 half-hour values (3%) during which the ambient odour concentrations will be momentarily equal to or higher than 1 OU/m³. On the basis of the cumulative probability of the sensation distances for each of the eight wind direction sectors, the separation distances are calculated for the selected odour impact criterion. For a selected wind direction sector, the distance at which this definition is fulfilled, is called separation distance. E.g. for North wind, the corresponding separation distance points to the South of the odour source (Schauberger et al., 2002).

The meteorological data for January 30, 1992 to January 31, 1994 were collected at Wels, a site representative of the Austrian flatlands north of the Alps. The sample interval was 30 minutes. The surrounding area is rather flat and consists mainly of farmland. The mean wind velocity 10 m above the mean roof top level of 15 m is 2.2 m/s with a maximum velocity of about 13 m/s.

3 RESULTS

First of all the separation distances for the 8 wind direction sectors were calculated. The separation distances can be compared with the distribution of the wind direction, centred at Wels. For northerly winds (for a southward separation distance), the separation distance is lowest, caused by low average wind speeds and predominantly unstable conditions associated with this wind direction sector. The highest of the direction-dependent separation distances are found for the prevailing wind directions West and East with 362 m and 348 m, respectively.

An important parameter describing the nuisance potential of odour is the duration of consecutive odour episodes (Fig. 1). The duration of odour episodes was investigated in relation to the hour of the day and the day of the year. It is expressed by the size of the circles in the graph. The lines, marking the time of sunset and sunrise, separate daytime from night-time, which changes the character of the dispersion process in the atmosphere, expressed by the stability class. For all four wind directions, a distinct pattern can be seen. The two wind directions (N and S) influenced by the valley wind system show a distinct diurnal pattern: For North wind, episodes occur at daytime (Fig. 1a), for South wind, at night-time (Fig. 1c). The occurrence of long lasting odour episodes is much smaller than for the prevailing wind directions (West and East). For the prevailing wind directions, the influence of solar radiation on the occurrence of odour episodes is less pronounced but still present (Fig. 1b, 1d). For these directions, the occurrence of odour episodes shows a minimum at midday in summer.

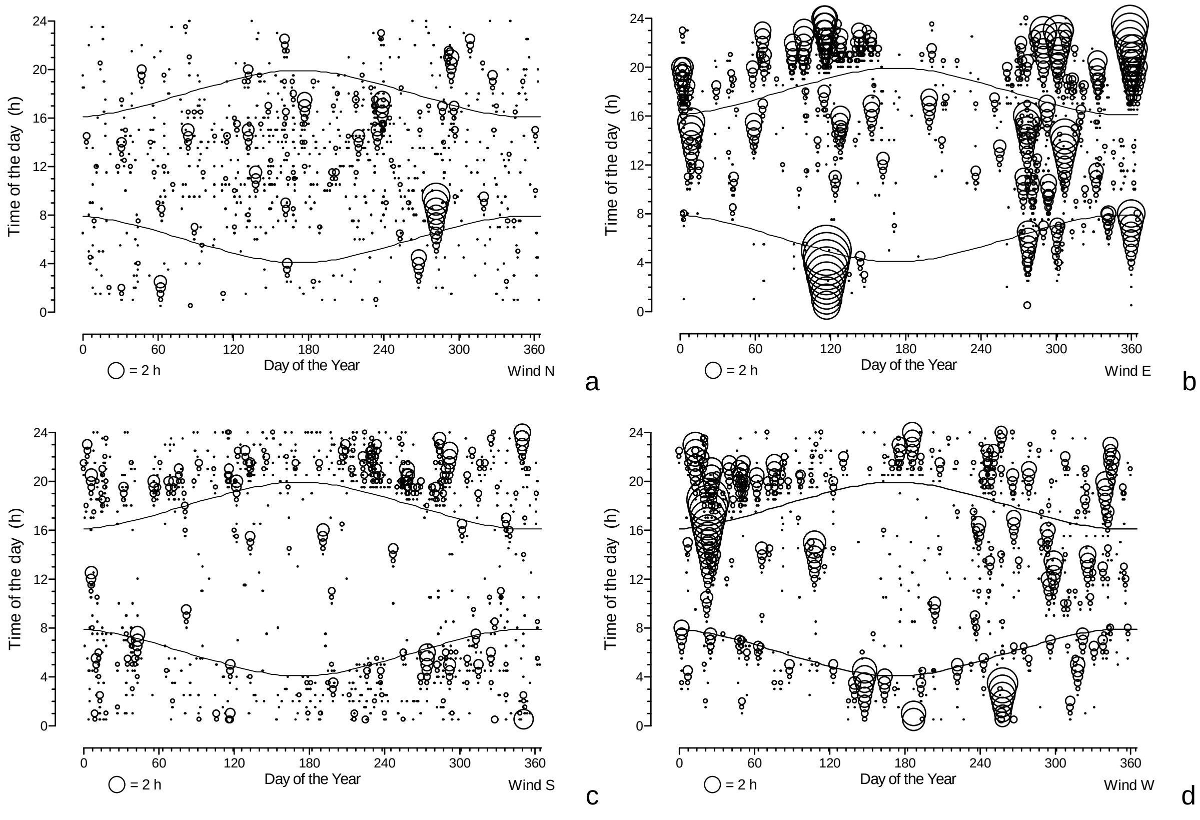

Fig. 1. Duration of odour episodes as a function of the day of the year and the time of the day. The diameter of the circles is proportional to the duration of odour episodes. (a) North wind, (b) East wind, (c) South wind, and (d) West wind (all 45° sectors). The lines mark sunrise and sunset for Wels (geographic latitude: 47.17°N)

4 DISCUSSION

In this paper, the Austrian odour dispersion model (AODM), a Gaussian model suitable for the prediction of ambient odour concentrations, is used to calculate direction-dependent separation distances, defined by odour impact criteria chosen as a combination of odour threshold and probability of threshold exceedance. At these direction depending separation distances the occurrence of odour episodes is analysed and compared with complaint statistics for odour via a literary survey.

Most complaints (‘time of most complaint’) from swine odour are recorded early in the morning or late at night under stable conditions (Schiffman, 1994). In the Canadian community Capilano (http://freenet.edmonton.ab.ca/capilano), the following distribution of odour episodes over time was reported for 2002: 54 % of odour complaints were registered between 20:00 to 23:00 and 78 % of all complaints were registered during evening hours between 16:00 – 24:00. 13% of complaints only were registered during mid-day hours (08:00 –16:00) and 9% during early morning hours (00:00 – 08:00). 67% of all complaints were registered during June and July. The reported duration of odour episodes (in hours per episode) by Lohr (1996) shows a similar pattern: 16.59 for summer, 12.00 for spring, 10.59 for autumn, and 2.47 for winter. Another time of above-average complaints could well be the transition from day- to night-time, when a stable stratification evolves in the near-surface boundary layer.

For the annual variation the complaints statistics and the calculated odour episodes show a weaker relationship. Strauss et al. (1986), in a survey about the complaints due to livestock units in Austria, found a higher probability during summer (50%) compared to spring (34%), autumn (25%), and winter (1%). Only 26% of the persons interviewed feel constantly annoyed all year. Lohr (1996) investigated the odour perception for the four seasons by the frequency of odour episodes (number of episode noticed per month) and found 3.24 for summer, 1.18 for spring, 0.71 for autumn, and 0.12 for winter. The AODM calculation of the direction-dependent separation distances for Wels does not show such a clear dependence of odour episode on the season. The results, however, indicate high odour levels during summer for North wind and South wind in August only, whereas for East and West winds, summer months show a minimum in odour episodes. Instead, AODM predicts more frequent odour episodes for the winter months.

A residents-based field observation of odour in the vicinity (4.8 x 4.8 km^2) of livestock buildings was done by Jacobson et al. (2001). Odour was detected in 71% during neutral to slightly stable conditions and during light winds (<2.5 m/s). Odour episodes occurred predominantly during the warm season and either in the early morning or during evening hours. Jacobson et al. (2001) found the following reasons: increased odour emission due to higher temperatures and more outdoor activities of residents during summertime.

One reason why odour complaints are registered more often in the warm season compared to the model calculations presented could be caused by the annual variation of the outdoor temperature. The first influence might be the sensitivity of odour perception (Strauss et al., 1986): Fang et al. (1998) found a weak linear correlation between the acceptability of air quality and the enthalpy of the air with the restriction that the investigation was done for indoor air and a limited range of both air temperature (18-28°C) and relative humidity (30-70%). Speculating that this weak influence could be extrapolated to outdoor temperatures during wintertime, this could cause a reduction of frequency of perceived odour episodes. The second influence could be the temperature dependent production of odorous substances inside the livestock building (Oldenburg, 1989; Schauberger et al., 2003). Van Langenhove and de Bruyn (2001) found a correlation coefficient between odour emission and indoor temperature of 0.35 and 0.85 for the outdoor temperature, respectively. Huegle and Andree (2001) found that temperatures strongly influenced odour emission from head space of swine and cattle slurry.

The most important reason for the discrepancy between complaint statistics and model calculations seems to be the time pattern of the behaviour of the neighbours. This influence is not included in the odour impact criteria which are applied to calculate the separation distances. It is obviously not the same with respect to odour nuisance if odour episodes occur e.g. around sunset in summertime or during night-time in winter. It has to be discussed if the odour impact criteria, defined solely by a probability of exceedance of the selected odour threshold, are sufficient to guarantee protection with respect to the time of the day or the season of the year.

The presented comparison of odour complaint statistics with calculated odour episodes is a helpful tool to find out when odour is perceived as most annoying. This could help to weight the modelled odour episodes to get a better fit of the model calculations to the observed complaints.

5 CONCLUSION

The Austrian odour dispersion model AODM is used to predict the occurrence of odour perception. The evaluation of the direction-dependent separation distances leads to a calculated occurrence of odour episodes which differs from various odour complaint statistics which show odour to occur predominantly during the evening hours of warm summer days. As a result, the evaluation of these values by the odour impact criteria should not only be based on statistical limits as it is done today but also by considering the annoying potential of odour due to the behaviour of the neighbours. Therefore odour episodes should be weighted by the time of the day and time of the year, as is done with the limit values for noise.

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