COMPARISON OF TWO PEAK-TO-MEAN APPROACHES FOR USE IN ODOUR DISPERSION MODELS

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ABSTRACT In this paper, two approaches to estimate odour concentrations in dispersion models are compared. The approaches differ in the estimation of the momentary (peak) odour concentration for the time interval of a single human breath (approx. 5 s). The Austrian Odour Dispersion Model (AODM) is a Gaussian model with peak-to-mean factors depending on wind speed and atmospheric stability. The German Lagrange code AUSTAL2000 uses a constant factor 4 in all meteorological conditions to derive the maximum odour concentration over a short integration time. As the Lagrange model, in contrast to the Gauss model, can be applied also in complex topography and with isolated buildings, the implementation of the Austrian peak-to-mean approach in AUSTAL2000 would enable for more realistic separation distances in these environments. In a current scientific project, this implementation will be carried out, and a comparison of separation distances with AODM and AUSTAL2000 will be undertaken.

Keywords: Odour, peak-to-mean, dispersion model, Gauss model, Lagrange model

1. INTRODUCTION

Complaints by the neighbourhood due to odour emissions of livestock buildings are a major concern in rural areas. Odour dispersion models can calculate ambient odour concentrations and thus the separation distance between livestock buildings and residential areas defined by a pre-selected odour threshold and an exceedance probability. In the course of several years, the authors, for this purpose, developed the Austrian Odour Dispersion Model AODM, which is described in detail in Schauberger et al. (2000). Peak concentrations in this Gaussian model are calculated as a function of wind speed and atmospheric stability. The use of this approach has proven to result in separation distances within an expected range of mostly several hundred meters (Piringer et al., 2010). AODM, with its peak-to-mean approach, has been validated successfully with a data set from the German environmental programme BWPLUS within the project “Odour emission and spread” (Bächlin et al., 2002; Piringer et al., 2009).

In Germany, the Lagrange code AUSTAL2000 (Janicke et al., 2004; www.janicke.de) has been developed which uses a constant factor 4 to calculate peak concentrations. This results in sometimes very large separation distances, esp. in stable atmospheric conditions. On the other hand, this model, in contrast to a Gaussian model like AODM, is applicable to a wider range of environments like built-up areas and complex terrain. The use of the Austrian peak-to-mean approach in AUSTAL2000 is therefore desirable to deliver more realistic separation distances also under these conditions.

As the project to implement the AODM peak-to-mean approach in AUSTAL2000 is ongoing, results are not available yet, but will be presented at the conference. Here, an outline of the peak-to-mean approach in AODM and the work programme of its implementation and test in AUSTAL2000 are given.

2. THE PEAK-TO-MEAN APPROACH IN AODM

The approach is described in detail in Schauberger et al. (2000). Only a summary is given here. AODM calculates half-hour mean concentrations. The sensation of odour, however, depends on the momentary ("peak") odour concentration. The problem is illustrated in Figure 1.

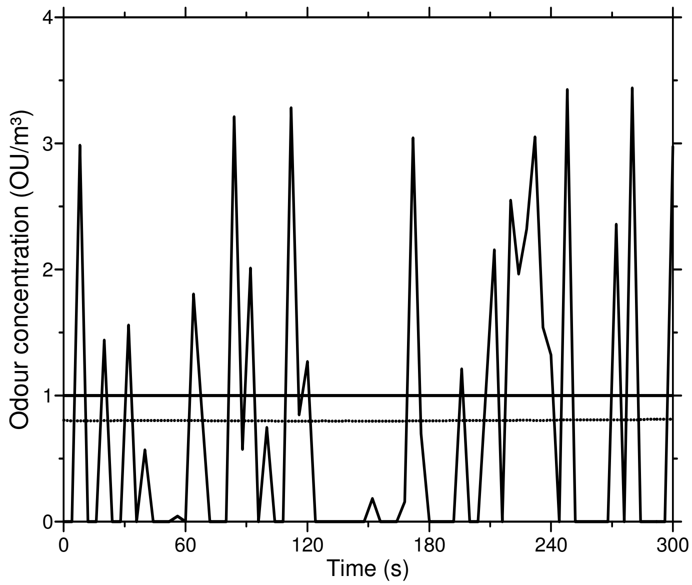


Figure 1: Time course of momentary odour concentrations. Although the mean value is below the odour threshold of 1 OU/m^3 (dotted line), occasional odour sensation is possible due to the single peaks in odour concentrations.

The AODM scheme to calculate peak concentrations is based on the formula (Smith, 1973)

$$\frac{C_p}{C_m} = \left(\frac{t_m}{t_p}\right)^u \qquad (1)$$

with the indices p and m denoting "peak" and "mean", respectively. Application of this formula gives peak-to-mean ratios near the source. These are calculated by setting t_m = 1800 s (calculated half-hour mean value) and t_p = 5 s (average duration of a single human breath). The exponent u depends on atmospheric stability.

An exponential attenuation function (Mylne and Mason, 1991; Mylne, 1992) is used for the postulated reduction of the peak-to-mean ratio with distance due to turbulent mixing. This approach is described in detail in Piringer et al. (2007). The attenuation depends on wind speed and atmospheric stability. Figure 2 gives an example of the decrease of the peak-to-mean ratio with distance up to 1 km for different dispersion categories DC and a wind speed of 1 m/s. For larger wind speeds, lower peak-to-mean ratios are obtained. Also indicated in Figure 2 is the constant peak-to-mean factor 4 of AUSTAL2000. It can easily be seen that this factor dominates for larger distances, thus causing in general larger separation distances with AUSTAL2000 compared to AODM.

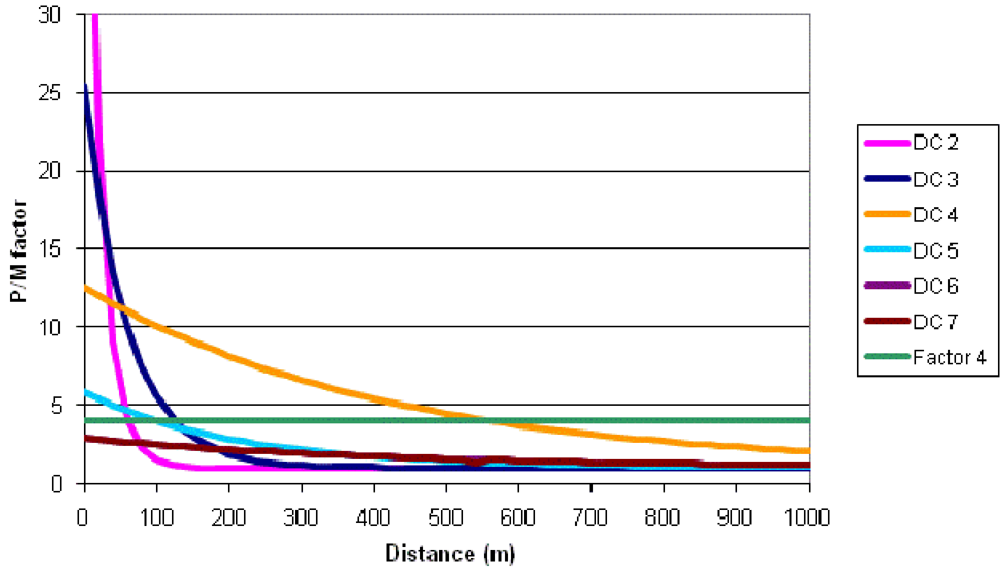


Figure 2: Peak-to-mean ratios depending on dispersion category (DC; from 2 and 3 – unstable over 4 – neutral to 5 to 7 – stable) and distance for a wind speed of 1 m/s. The constant factor 4 of AUSTAL2000 is indicated by the green line.

3. WORK PROGRAMME TO IMPLEMENT THE APPROACH IN AUSTAL2000

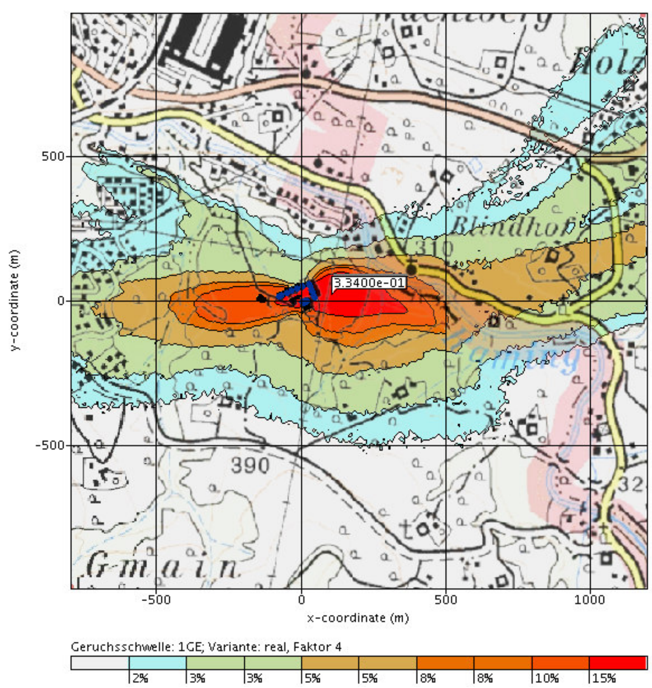
The project to implement the peak-to-mean approach described in Section 2 in AUSTAL2000 is funded and has started in April 2011; its duration is scheduled for one year. It is structured in five work packages. First, the AODM peak-to-mean approach has to be implemented in AUSTAL2000. It is intended to do this in the post-processing mode, so not to interfere with the source code. Second, the input for the calculations has to be set up. This involves not only the definition of the emission scenarios, but also the choice of the odour impact criteria (a combination of odour concentration, usually the odour threshold of 1 OU/m^3, and a selected exceedance probability depending on the land use, mostly varying between 2 % ("irrelevant odour level") and up to 24 %) to determine the separation distance. Also the sites from which the meteorological time series (one year data of wind direction, wind speed and atmospheric stability) are taken have to be chosen; this will be done according to the main landscapes in Austria (Eastern flatland, North-Alpine foreland, Inner-Alpine valleys and basins, and South-Alpine foreland) and according to livestock density.

Work package 3 will then comprise an enormous amount of calculated direction-dependent separation distances (different sites, different emission scenarios, different odour impact criteria) with the two models, and work package 4 will be devoted to the statistical evaluation and comparison of the results. First results will be available at the time of the conference in autumn 2011. The last work package will see the final report and outlines of scientific publications.

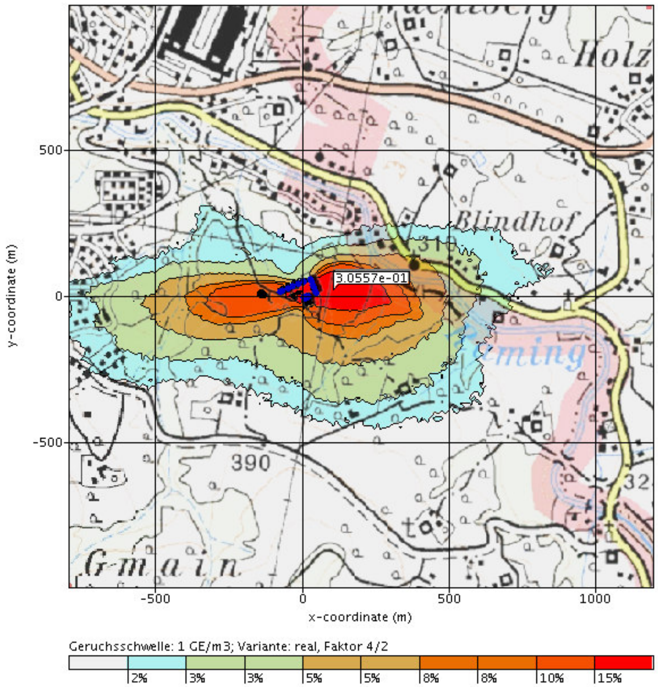
4. CONCLUSIONS

In contrast to AODM with its peak-to-mean ratio dependent on meteorological parameters (Section 2), the Lagrange code AUSTAL2000 for odour dispersion uses a constant factor 4 (independent of wind speed and distance from the odour source) to calculate peak concentrations. This results in sometimes very large separation distances, esp. in stable atmospheric conditions. On the other hand, this model, in contrast to a Gaussian model like AODM, is applicable to a wider range of environments like built-up areas and complex terrain. The use of the Austrian peak-to-mean approach in AUSTAL2000 is therefore desirable to deliver more realistic separation distances also under these conditions. This will be undertaken in a project just funded, the content of which is outlined in Section 3. The work is ongoing, and results will be available in about one year from now.

We have already tried some preliminary work with the German Lagrange model LASAT (of which AUSTAL2000 is the “core”). From Fig. 2 it is seen that, for stable conditions, peak-to-mean ratios beyond 100 m distance from the source approach a maximum value of about 2. We therefore, in recent LASAT calculations, compared the results obtained with the original factor 4 under all meteorological conditions to those derived with a limitation of the peak-to-mean factor to 2 for stable conditions (Fig. 3). The desired strong reduction of the area of exceedances of the odour threshold especially in the main wind directions West and East can already be achieved with this simple measure.



a) Factor 4 in all meteorological condtions



b) Factor 2 in stable conditions, Factor 4 in unstable and neutral conditions

Figure 3: Area of exceedence (in %) of the odour threshold around a livestock unit.

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