ESTIMATION OF ODOUR EMISSIONS FROM FIELD INSPECTIONS (ESOFIN) AND A SCREENING MODEL FOR ODOUR DISPERSION (SMOD)

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ESOFIN: ESTIMATION OF ODOUR EMISSIONS FROM FIELD INSPECTIONS

Introduction

For odour dispersion calculations, emission strengths are often unknown, partly because they are not accessible by measurement. An estimate can be obtained by comparing odour frequencies observed in field inspections with results from dispersion calculations.

In a typical field inspection, odour perception is reported by assessors at given positions across the odour plume in intervals of 10 seconds for a period of 10 minutes. For details see e.g. the German guidelines VDI 3788 Part 1 (2000) and VDI 3940 Part 2 (2006). The result of such a field inspection is the time fraction of odour perception (odour perception frequency) at each assessor position.

On the other hand, odour assessment in Germany and according dispersion calculations are based on the concept of the odour hour (*GIRL*, 2004). An hour (or a suitable smaller time interval) is defined as odour hour if the time fraction of odour perception exceeds 10%. Such a binary decision neglects a major part of the information that is provided by field inspections for an emission estimate.

Therefore, the following concept has been pursued with the model ESOFIN (developed on behalf of the federal state of Nordrhein-Westfalen): The official reference model of the German Regulation on Air Quality Control (*TA Luft*, 2002; *Janicke, L. and U. Janicke*, 2002; *Janicke, U. and L. Janicke*, 2007), AUSTAL2000, is applied for dispersion calculations. As a Lagrangian particle model it gives a realistic description of time-dependent dispersion situations, as well for near-ground sources and in the near field (*VDI 3945 Part 3*, 2000; *Janicke, L.*, 1983, 2002). It is thus well suited for the study of odour sources like stables or sewage plants.

The dispersion calculation is carried out for intervals of one minute with varying wind direction, thereby explicitly accounting for the horizontal meandering of the odour plume. For each monitor position, the concentration fluctuations are analytically estimated from the calculated average concentration (successive averages over one minute) and sampled over the assessment period. The resulting concentration distribution is folded with the perception function of the assessor to obtain the time fraction of odour perception. In the final step, the emission strength of the odour source is varied such that agreement between the sum (over all assessors) of observed and modelled time fractions is achieved. As the calculated concentration is proportional to the emission strength, this variation can be carried out numerically without invoking a new dispersion calculation in each step.

ESOFIN provides a graphical user interface. The model was validated with data sets from field inspections where olfactometrically measured emission strengths are available.

Evaluation of meteorological measurements

The odour perception frequency depends on the horizontal width of the odour plume and on the plume meandering. These in turn depend on the horizontal velocity fluctuations of the ambient air perpendicular to the mean flow direction. A parameterisation in form of meteorological boundary layer profiles, as required for the dispersion calculation, is usually only available for averaging times of one hour.

In contrast, in the context of ESOFIN much shorter time intervals of 1 to 10 minutes are of interest. To get some insight into this regime, an analysis of results from near-ground wind measurements with supersonic anemometers was carried out for various locations and averaging times between 10 seconds and 1 hour. Figure 1 depicts two results: the dependence of the vertical velocity fluctuations on the friction velocity (averaging period 10 minutes), supporting on average the proportionality factor 1.3 usually applied in boundary layer models, and the dependence of the scaled horizontal velocity fluctuations on averaging time.
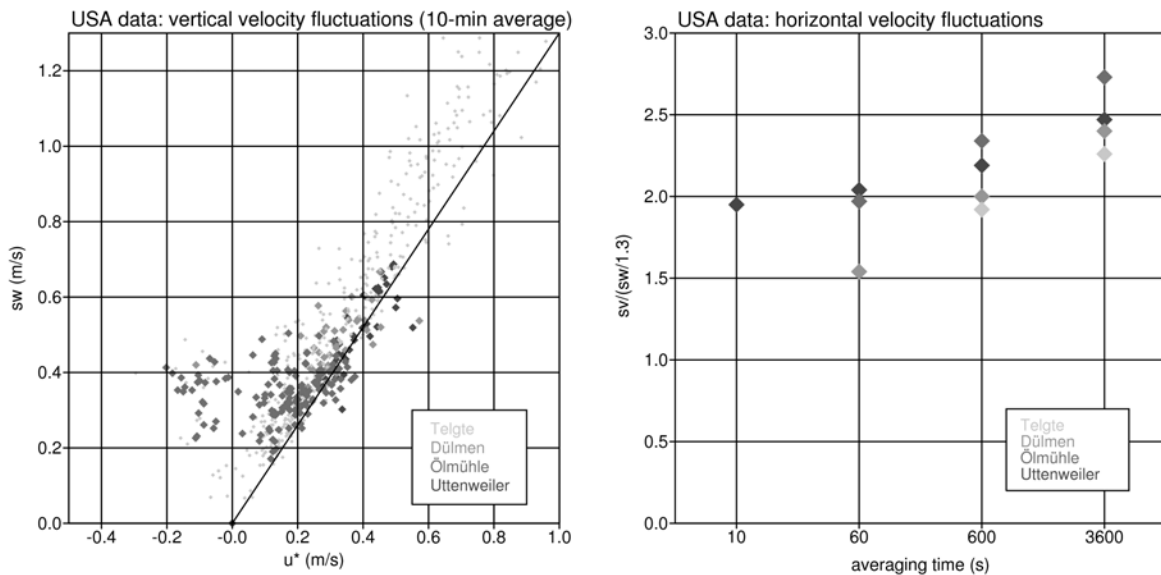

Fig. 1; Analysis of supersonic anemometer measurements.
Left: ambient vertical velocity fluctuations as a function of friction velocity (10-minute averages, solid line: $s_w=1.3u_*$).
Right: ambient horizontal velocity fluctuations perpendicular to the mean flow direction (scaled by $s_w/1.3$) as a function of averaging time.

Tests showed that an emission estimate with ESOFIN is more robust if in the dispersion calculation a larger horizontal dispersion is applied than the one that results from the cited measurement analysis. The boundary layer profiles of AUSTAL2000, specified in guideline VDI 3783 Part 8 (2002), were therefore adjusted (a proportionality factor of 2.5 instead of 1.8 for the horizontal velocity fluctuations).

Validation

The model ESOFIN was validated with a data set that has been set up particularly for odour dispersion models (*Bächlin, W. et al.*, 2002). For a pig barn, a large set of field inspections in combination with parallel SF6 tracer experiments and meteorological measurements was carried out. The barn was prepared so that, at least in principle, odorants were emitted only via a stack on top of the barn, for which the odour emissions at each field inspection were estimated olfactometrically.

Figure 2 shows a comparison of observed and modelled odour perception frequencies for a single field inspection as well as a comparison of all olfactometrically and ESOFIN-estimated emission strengths for different model setups.
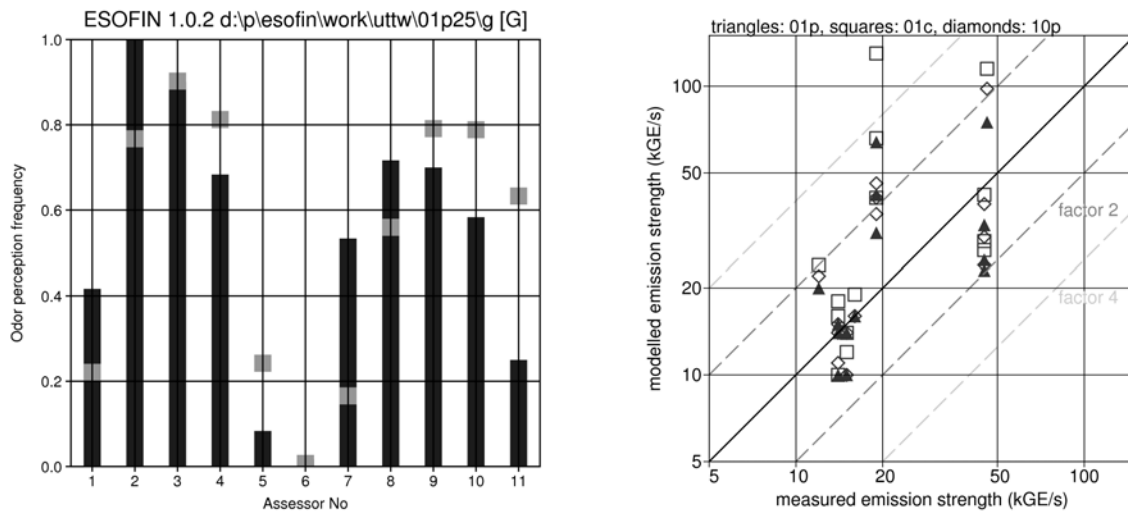

Fig. 2; Validation of ESOFIN with the data set "Uttenweiler" (Bächlin, W. et al, 2002). Left: Observed (bars) and modelled (squares) odour perception frequencies for case G. Right: Olfactometrically versus ESOFIN-estimated emission strengths for all cases and different model setups (01p: plain terrain, meteorological time series, 01c: 3D flow around buildings included, meteorological time series; 10p: plain terrain, 10-minute meteorology converted into a pseudo time series).

SMOD: A SCREENING MODEL FOR ODOUR DISPERSION

Dispersion calculations for odour assessments are carried out in Germany with the Lagrangian particle model AUSTAL2000 (*GIRL*, 2004). Such calculations demand detailed input data and are computationally expensive. For screening purposes, a simpler and faster method is desirable at the cost of accuracy. This is realized with the model concept SMOD which was developed on behalf of the federal state Nordrhein-Westfalen. SMOD utilizes a hybrid Eulerian-Gaussian model that has been already applied as reference model in the development of AUSTAL2000 and its odour part AUSTAL2000G (*Janicke, L. and U. Janicke*, 2007).

The model is restricted to flat terrain without buildings. Building effects can be accounted for by a vertical extent of the source. Sources are modelled without plumes rise, optionally with a horizontal extent. The average surface roughness length required for the dispersion calculation is automatically derived from a land use data base.

Calculation setup and result visualization are performed within an interactive graphical user interface. The user has the option to select a dispersion class statistics from a pre-defined set of statistics with spatial reference information, see Figure 3. Topographic maps of scale 1:25000 covering the whole area of Nordrhein-Westfalen are provided and used for the interactive definition of source locations and as background maps in the result visualization, see Figure 4. The result of the dispersion calculation is the fraction of odour hours, on which odour assessment in Germany is based.

A SMOD calculation for a single source using annual meteorological data (statistic of wind direction, wind velocity, and dispersion class) takes only some seconds on an ordinary PC.
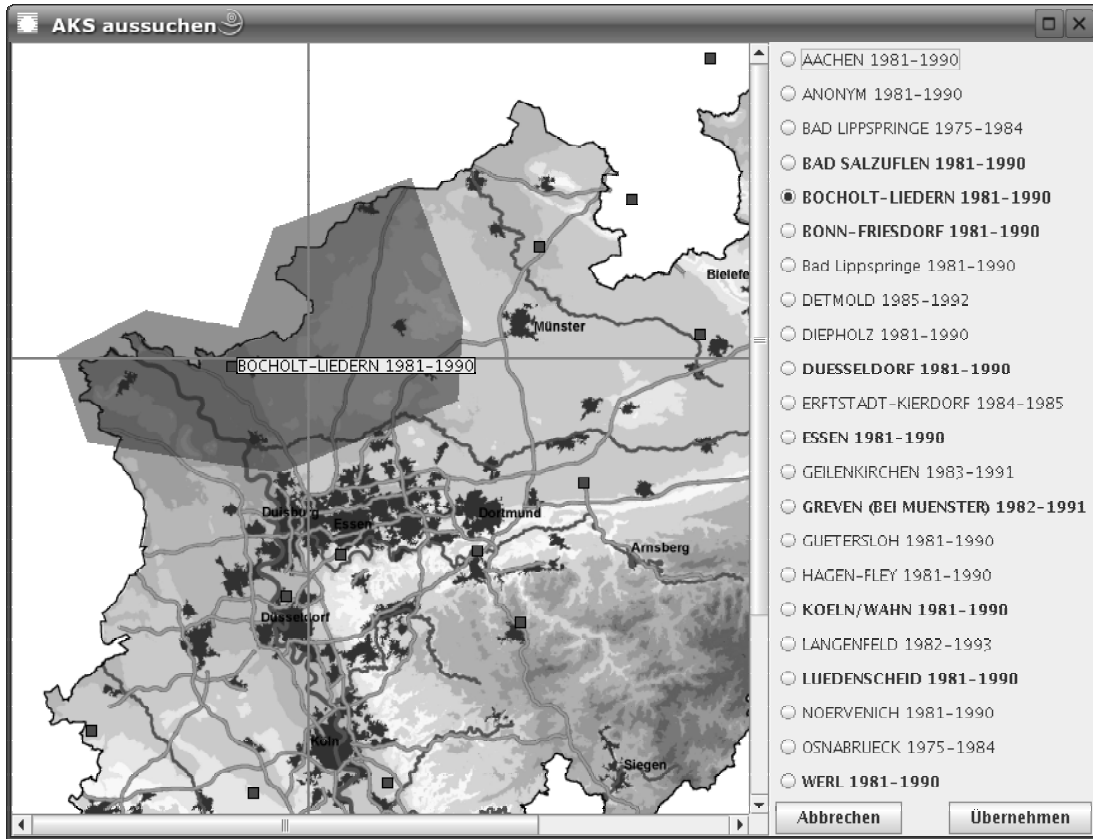
Fig. 3; User interface of SMOD. Selection from pre-defined dispersion class statistics with spatial reference information.
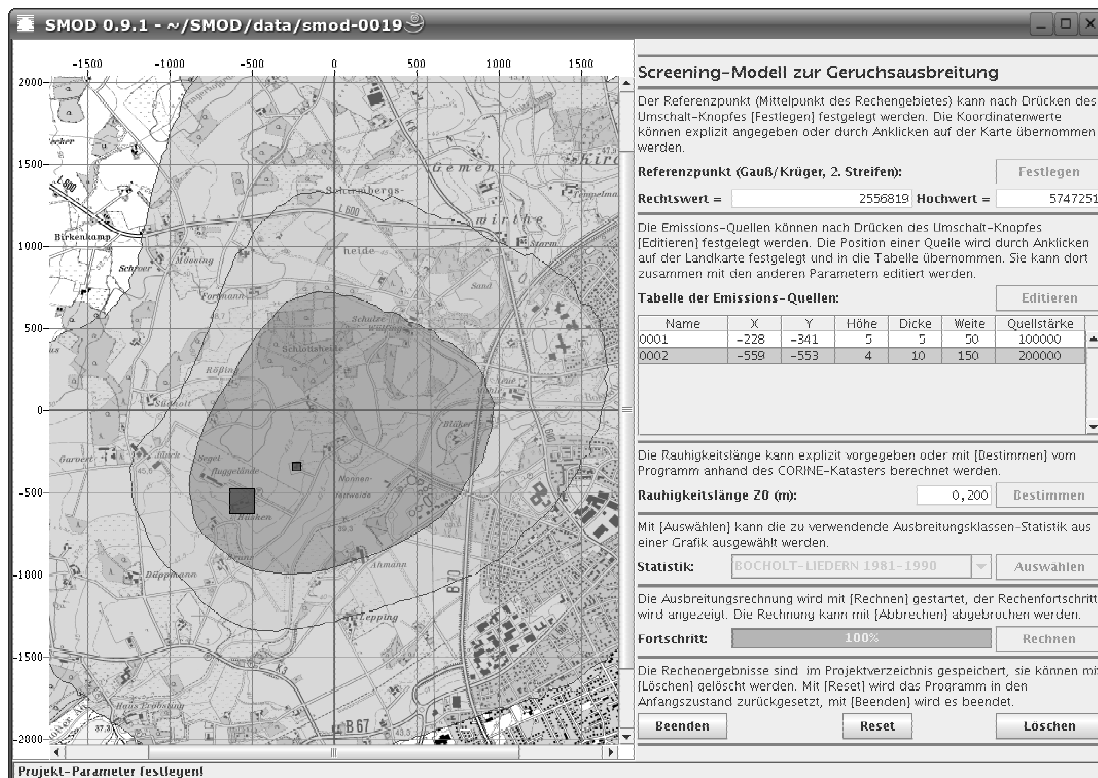

Fig. 4; User interface of SMOD. Input masks (right part) and graphical result visualization with source locations, isolines of odour hour frequencies, and site map (left part).

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