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COMPARING DISPERSION MODELLING AND FIELD INSPECTION FOR ODOUR IMPACT ASSESSMENT IN THE VICINITY OF TWO ANIMAL HUSBANDRY FARMS

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Abstract: For two cases odour frequencies obtained by dispersion modelling and field inspections were compared. The GRAL model has been used for modelling. In fact, GRAL is a hybrid model were the dispersion is computed via the Lagrangian approach, while the necessary flow fields in built-up areas are computed with an inherent Eulerian microscale, prognostic flow field model. The German guideline VDI 3940-1 prescribes a method to assess ambient odour frequencies by a group of trained persons. It should be noted that the minimum number of panellists is 10, whereas in the two case studies presented in this work only two persons carried out the field inspections on a fixed grid. While in the first case good agreement was found between modelled and observed odour frequencies, these were overestimated by about a factor of 2-3 in the second case by the simulations. Several tracer dispersion studies gave evidence that modelled mean concentrations with the GRAL model typically do not deviate from average observed concentrations by more than ±30 %. Thus, model uncertainties can be clearly excluded as possible cause for the huge discrepancies. Based on only two case studies conclusive reasons for the differences cannot be drawn. However, possible causes, which are discussed in more detail, might be: (i) different average (over the two testers) olfactory sensibilities of the persons in each case study, (ii) and/or problems linked with odour adaptation especially in areas affected by high odour concentrations. Not further analysed in this work but also conceivable would be (iii) uncertainties of the emission factors for fattening pigs, (iv) statistical uncertainties in the field study due to the limited number of visits (approx. 100 visits in each case), and (v) errors arising from the assumption of a constant ratio between the 90 percentile and hourly average odour concentration in the simulations.

Key words: *Odour dispersion modelling, Odour hours, GRAL, Odour field inspections*

INTRODUCTION

In practice either field inspections (e.g. VDI, 2006) and/or dispersion modelling (e.g. GIRL, 2009) is used to assess odour impact. Both methods shall provide congruent results within the uncertainty range inherent in each method. From a legal point of view the differences between results should not lead to different conclusions e.g. with regard to the necessity of taking abatement measures or not. In this study results of both methods are investigated on the basis of two case studies, which are described in detail in the following chapter.

DATA SETS

Data set A

Panel field inspections to assess the odour burden were carried out in the vicinity of a farm for 1,600 fattening pigs and 17,000 broilers. Further odour sources at the farm were an open liquid manure storage and a partly open corn silage. As multi-phase feeding for the fattening pigs is applied, odour emissions given by VDI (2009) were cut by 20 %, while for all other sources the emission factors as suggested by VDI (2009) were utilized. In total, 55 MOU h^{-1} resulted for the site. The pig stable was ventilated via several stacks mounted at the roof, while the broiler stables were ventilated through horizontal openings in the building. With one exception all points for the field inspection were located at distances several hundreds of metres away from the livestock buildings (**Figure 1**). The area is characterized by softly rolling terrain, small forests, which are treated as obstacles in the dispersion modelling.

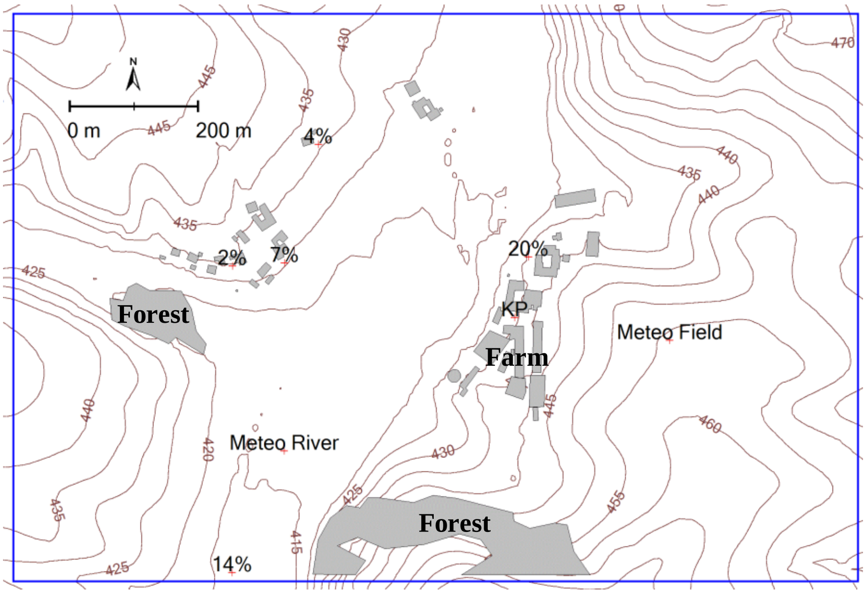

Figure 1. Model domain for dispersion modelling, orography, buildings, forests, and position of the meteorological stations as well as the inspection points for the panel field study. Numbers indicate the observed frequency of odour hours.

Data set B
In this case several farms for fattening pigs were situated within a small village. All receptor points of the panel field study were placed within the village (**Figure 2**).

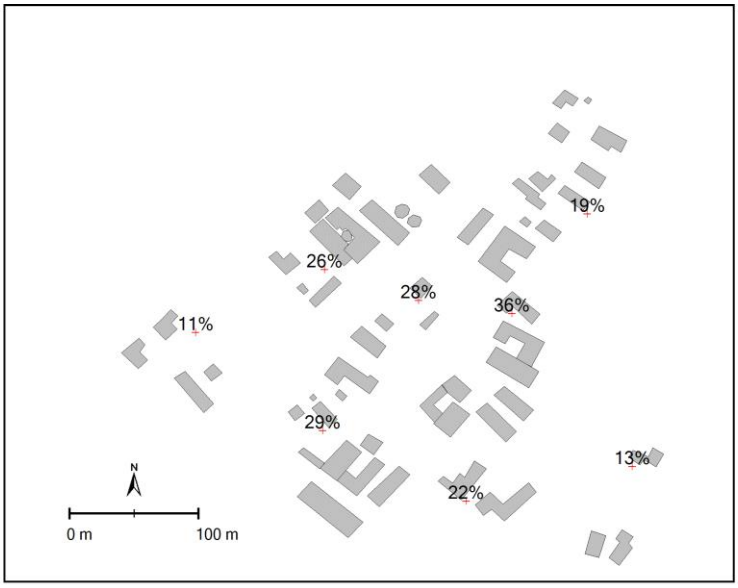

Figure 2. Model domain for dispersion modelling, buildings, and position of the inspection points for the panel field study. Numbers indicate the observed frequency of odour hours. The meteorological site was slightly outside the domain.

Terrain is quite flat and was therefore not taken into account in the dispersion simulations. All in all 2,000 fattening pigs, some 600 piglets, and about 150 breeding sows were present in the livestock buildings. Some of the stables were ventilated via stacks at roof top level, while others had no ventilation, i.e. air exchange was managed by keeping windows open.
Basically, emission factors provided by VDI (2009) were applied. However, in case of the non-artificially ventilated stables emissions were reduced by 50 %. Jeppsson (2003) found a strong positive correlation of

ammonia emission rates in [kg h^{-1}] on ventilation rates in fattening pig stables. It is assumed that the non-forced ventilated stables owe rather low ventilation rates of about 10 % of those being artificially ventilated. KTBL (2012) provides the following relationship between normalized volume flux V_n and emission factor e:

$$e = e_0 V_n^{c_V} \tag{1}$$

In equation (1) e_0 is the basic emission factor taken from VDI (2009), which is only valid for stables with forced ventilation and not representative for non-ventilated stables. Schauberger et al. (2012) found for the empirical constant c_V a value of 0.32 in case of odour. Inserting these values results in e/e_0 = 0.5.
As for data set A, in total 55 MOU h^{-1} were released from the livestock buildings.

METHODS

Panel field studies

The field inspections were carried out on the bases of VDI (2006) with the exception of some minor and one major issue: instead of having a panel of at least ten persons, only two people took part in each of the assessments (note: the two persons were not the same in both studies). Both panellists were tested for their olfactory sensibility with regard to n-Butanol, which, according to VDI (2006), shall fall within 64 and 256 µg m^{-3}. In case of data set A, the average sensibility for the two persons was 84 µg m^{-3}, and in case of data set B it was 189 µg m^{-3}.

Dispersion modelling

The Lagrangian particle model GRAL (Oettl, 2014) has been used for the dispersion modelling. In case of data set A, where orographical effects had to be taken into account, the non-hydrostatic prognostic mesoscale model GRAMM (Oettl, 2016) was used to simulate 3D wind-fields. Grid resolution was 100 m x 100 m x 10 m with increasing vertical grid cells by a factor of 1.4. Buildings were accounted for by utilizing the non-hydrostatic prognostic microscale model implemented in GRAL (Oettl, 2015). Grid size was 3 m x 3 m x 1.5 m in this case. GRAL allows for the definition of various kinds of sources (line, area, volume, point) including plume rise modelling due to momentum and/or excess temperature. The GRAL model provides hourly mean odour concentrations, but the field inspections give (annual) frequencies of odour hours, which is defined by an odour perception of at least 6 minutes (= 90 percentile) within one hour. Therefore, a relationship is needed between the 90 percentile of odour concentrations within one hour and the corresponding average. Mostly, in Austria and Germany a ratio of 4/1 (Janicke and Janicke, 2004) is applied and also used in this study. The GRAMM and GRAL models were driven by locally observed meteorological data 10 m above ground level. It should be noted that both the field inspections and the modelling covered the same time period, which was March – September (data set A) and March – October (data set B).

RESULTS

Based on a threshold value of 1 OU m^{-3} in the GRAL model, modelled and observed odour frequencies are listed in Table 1 and

Table **2** for the two data sets (see also **Figure 3**). While for data set A reasonable agreement was found, larger deviations between the two methods are visible in case of the data set B. In the latter case, GRAL overestimates odour hours significantly.

Table 1. Observed and modelled frequencies of odour hours for a threshold in the modelling of 1 OU m^{-3}. Data set A

Location	**1**	**2**	**3**	**4**	**5**
Field inspection	14%	2%	7%	4%	20%
GRAL	13%	2%	5%	4%	25%

Table 2. Same as Table 1, but for data set B

Location	1	2	3	4	5	6	7	8
Field inspection	13%	22%	29%	11%	26%	28%	36%	19%

GRAL	23%	30%	38%	30%	32%	58%	60%	37%

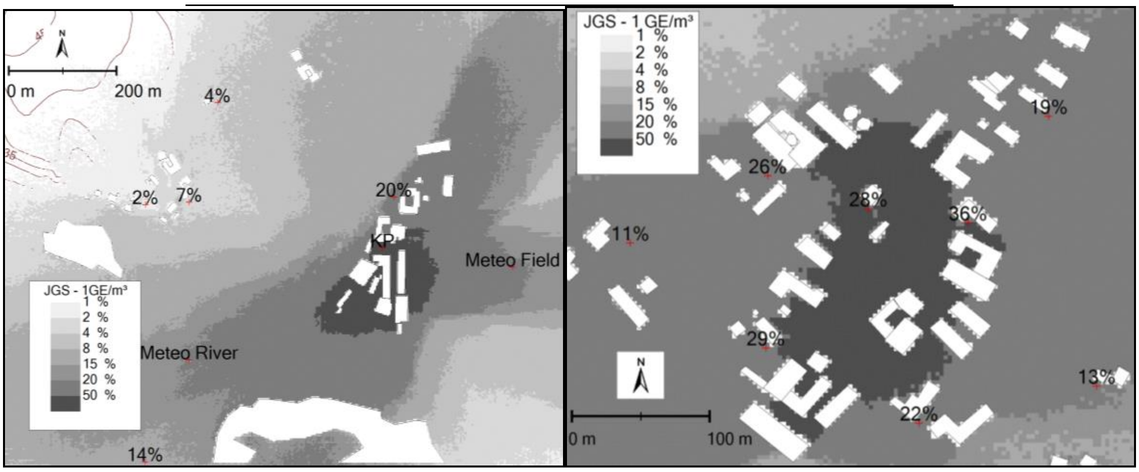

Figure 3. Simulated odour hour frequencies for data set A (left) and data set B (right). Odour threshold: 1 OU m^{-3}

In the following it is investigated how the different olfactory sensibilities of the panellists might have influenced the results of the field inspections. As already outlined, the average detected concentration of n-Butanol for data set B was by a factor of 2.3 higher than that for data set A. That means that the persons involved in data set B were much more sensible and thus, would detect a higher frequency of odour hours than did the participants in data set A. Increasing the odour threshold in the modelling for data set B to 2.3 OU m^{-3} results in far better agreement between modelled and observed odour frequencies (Table 3). Nevertheless, it should be stressed that the average sensibility of the participants in data set B is much closer to the average concentration of n-Butanol of 160 µg m^{-3}, which is to be the expected average sensibility if only enough (at least 10) persons had taken part in the field studies.

Table 3. Observed and modelled frequencies of odour hours for a threshold in the modelling of 2.3 OU m^{-3}.

Data set B

Location	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Field inspection	13%	22%	29%	11%	26%	28%	36%	19%
GRAL	11%	19%	27%	17%	22%	23%	23%	23%

BMWFJ (2009) states that odour is not perceivable outdoors below thresholds of about 2 – 5 OU m^{-3}. Field inspections as described in VDI (2006) foresee a 10 minutes sniffing interval for each location. Especially in areas with constant odour concentrations adaptation cannot be avoided, resulting in lower sensibility and lower observed odour frequencies. However, the German guideline GIRL (2009) fixes the odour threshold for modelling with 1 OU m^{-3}. Hence, in general one would expect a model to overestimate observed odour frequencies. Indeed there exist several studies revealing such overestimations (e.g. Müller and Riesewick, 2013; Grotz and Zimmermann, 2015; Hartmann and Borcherding). In the following, new simulations have been carried out setting the threshold to 2 OU m^{-3}. In addition, the different average sensibilities of the panellists have been taken into account (assuming that the correct average odour sensibility over all panellists would be 160 µg m^{-3} for n-Butanol if only enough participants would take part in an investigation) by applying the following correction factors c to the modelled odour concentrations:

data set A: $c = 84/160 = 0.53$
data set B: $c = 189/160 = 1.18$

In the modelling, the effect of increasing the odour threshold from 1 to 2 OU m^{-3} is the same as if concentrations were corrected by a factor of 0.5. Hence, considering the sensibility of the participants in data set A in combination with an increased threshold in the modelling of 2 OU m^{-3} results in an effective odour threshold of 2 OU m^{-3} * 0.53 = 1.05 OU m^{-3}. For data set B an effective threshold for odour of

2 OU m^{-3} * 1.18 = 2.4 OU m^{-3} can be established in this way. The new results for data sets A and B do not differ from those presented in Table 1 (data set A and 1 OU m^{-3}) and Table 3 (data set B and 2 OU m^{-3}), which show in general a good agreement between field inspection and modelling.

CONCLUSIONS

Panel field investigations based on the German guideline VDI (2006) might give quite different odour hour frequencies than obtained by dispersion modelling, if an odour threshold of 1 OU m^{-3} is applied in the simulations. Several studies as well as the comparisons presented in this work indicate that dispersion modelling provides in general significant higher odour hour frequencies than field inspections. The reason is probably that odour cannot be detected by panellists at the theoretical threshold of 1 OU m^{-3} in an outdoor environment. Indeed, for the two cases herein a threshold of 2 OU m^{-3} leads to a significant better agreement of modelled and observed odour hour frequencies.

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