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RECENT DEVELOPMENTS IN ODOUR MODELLING AND ASSESSMENT IN STYRIA AND SALZBURG, AUSTRIA

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Abstract:
It can safely be stated that odour assessment is among the least harmonized issues within the EU. Even on a national level, local authorities sometimes use different approaches. In Austria, most regulations concerning odour are determined on a national level. However, neither common modelling techniques nor assessment methods are defined in the corresponding laws. In an effort to harmonize odour assessment in Austria, two provinces – Styria and Salzburg – issued a new guideline setting thresholds for odour-hour frequencies in dependence on the annoyance potential. The limit values were derived from examinations of complaint rates by neighbours of various odorous sources (pig and broiler sheds, compost facilities) and existing dose-response relationships published in literature. Indeed, odour frequency and odour type were sufficient to predict complaint frequencies with high accuracy in a logistic regression model. Recently, the corresponding modelling technique for odour hours has been improved, too. By definition, an odour hour requires 6 minutes of odour recognition by a qualified panel. Dispersion models typically provide hourly-mean concentration values. Therefore, further methods are necessary to obtain the 90th percentile of the odour concentration distribution for odour-hour assessment. For regulatory purposes often a constant value is used (e.g. 4.0 in Germany, or 2.3 in Lombardy, Italy). It can be demonstrated that such a simple approach is not valid in most applications, while the newly developed concentration-variance method, which has been implemented in the Lagrangian dispersion model GRAL, is better suited for odour-hour estimations. A comparison of observed odour-hour frequencies based on EN16841-1 and modelled frequencies using GRAL showed good agreement close and farther away from the odour source. Furthermore, odour emission factors from animal husbandry have been investigated by olfactometric measurements (EN13725) and finally be updated, because the emission factors listed in the comprehensive German guideline VDI3894-1 seem to be much too low, at least for pigs and chicken.

Key words: *Odour assessment, Odour modelling, Odour guideline*

INTRODUCTION

A decade ago, it was still common in Austria to use a rather simple approach relating animal numbers, ventilation types, feeding techniques, and wind direction frequencies with separation distances for assessing potential odour annoyance around livestock buildings (Schauberger et al., 1997). On the other hand, in the frame of licencing procedures within the trade law, dispersion-modelling techniques have already been applied frequently. In the majority of cases, Lagrangian Particle Models are in use in Austria. With the increasing computational power, such models become more and more applicable even for the assessment of – as sometimes considered – small sources/projects such as odour assessment for livestock buildings. In this work, recent improvements regarding the assessment of odour impact in Austria are presented. Besides the issue of new modelling techniques that have been developed, a guideline for assessing odour annoyance has been issued for the first time in the provinces Styria and Salzburg. Finally, new odour-emission factors have been set up for pig and poultry livestock buildings.

NEW MODELLING TECHNIQUES

In Austria, odour assessment is based on so-called odour hours defined by at least 6 minutes of perceivable odour concentrations. Therefore, modelling odour hours requires the determination of the 90th percentile of the cumulative frequency distribution of odour concentrations of an hour. Often the 90th percentile is normalized by the hourly-mean concentration by defining

$$R_{90} = C_{90} / \overline{C}, \qquad (1)$$

where $\overline{C}$ is the hourly-mean concentration, and C_{90} the 90th percentile. In Germany, the regulatory odour dispersion model AUSTAL2000G (GIRL, 2009) uses the simple relationship $R_{90} = 4.0$, which is based on the work of Janicke and Janicke (2004). This assumption has been broadly being used in Austria, too. The advantages are its robustness, and its tendency to provide a conservative estimate for R_{90}, which is generally eligible when applying (simple) models for regulatory purposes. Nevertheless, one might suppose that the magnitude of overestimation increases substantially with distance to sources or in case of overlapping plumes.

Oettl and Ferrero (2017) developed a new method for calculating R_{90}, which is based on a simplified advection-diffusion equation for the concentration variance:

$$\frac{\partial \overline{c'^2}}{\partial t} = 2\sigma_{u_i}^2 T_{Li} \left(\frac{\partial \overline{C}}{\partial x_i} \right)^2 - \frac{\overline{c'^2}}{t_d} \qquad (2)$$

T_{Li} are the Lagrangian integral time scales, $\sigma_{u_i}^2$ the wind-velocity variances in each direction, and t_d is the dissipation time scale characteristic for the decay of the concentration variance. The model has been tested successfully against two datasets, where measurements of concentration fluctuations were available. In contrast to the German approach of using a constant R_{90}, the so-called concentration-variance model provides spatially inhomogeneous values for R_{90}, which depend strongly on the three-dimensional structure of the computed hourly-mean odour concentrations. Therefore, source geometries as well as mean wind and turbulence fields have a strong impact on computed R_{90}. Still, the proper determination of t_d is a matter of research, which has been addressed in a recent work by Ferrero and Oettl (2019). However, the development of a universal function for t_d that could be applied for all different kinds of sources is still to be done.

Apart from testing the models capability for computing R_{90}, Oettl et al. (2018a) demonstrated that computed odour-hour frequencies using the Lagrangian Particle Model GRAL (Oettl, 2019) in the vicinity of a pig shed agree well with observed frequencies based on the recently issued EN 16841-1 (2017). It should be emphasized that the main advantage of using odour hours in assessment studies is the possibility of using either dispersion modelling or field inspections, respectively.

NEW ODOUR GUIDELINE

The Austrian laws do not stipulate that any nuisance is to be prevented, but only unacceptable nuisance. However, the term unacceptable is not a scientific or medical term and, thus, requires further consideration. Up to now, no guideline was at hand in Austria, which would address this topic. Therefore, various threshold values for odour-hour frequencies are (still) in use. Some provinces prefer the usage of the odour standards established in Germany within the GIRL (2008), while others make use of threshold

issued in an elderly guideline in Austria (OAW, 1994). Though it is strongly felt that national harmonization is needed, Austrian experts in the field of odour assessment could not yet agree on common standards. Meanwhile the provinces of Styria and Salzburg agreed on establishing a common guideline (Oettl et al., 2018b).
The guideline took advantage of many well-established items of the German GIRL (2008) regulation. For instance, the regulation about the assessment area for dispersion modelling has been taken from the GIRL without any major changes. At the time when the GIRL was issued for the first time in Germany, the hedonic tone of odours was hardly considered. Only disgusting odours have been recognized for needing a special assessment, though, there is still no defined method provided. Later, backed by the study of Sucker et al. (2008), the GIRL has been revised and included so-called animal-specific factors to account for the different hedonic tones of odours from pigs, broilers, and cattle.
Weitensfelder et al. (2019) analysed resident complaints near various odour sources (livestock buildings, compost facilities) by means of dispersion modelling using the Lagrangian Particle Model GRAL. Resulting dose-response relationships impressively showed a strong influence of the hedonic tone of odours. Furthermore, various predictors for odour annoyance have been compared with regard to their ability to explain existing complaint rates. It was found that using a threshold of 1 odour unit per m³ in dispersion modelling and using annual mean odour frequencies is very well suited for assessing odour complaints, thus, confirming the German GIRL, which uses the very same method.
It is important to note that Weitensfelder et al. (2019) used emission factors for animal husbandry as reported in the German VDI 3894-1 (2011). As will be described in the next chapter, specifically the emission factors for pig- and chicken fattening were found too low compared to own observations and emission factors reported in literature. Hence, the corresponding dose-response relationships depicted in Weitensfelder et al. (2019) are quite certainly not yet representative. In this work, dispersion simulations have been repeated for pig and broiler sheds using new emission factors as reported in the next chapter.
Figure 1 and **Figure 2** illustrate dose-response relationships for various odours as found in literature and obtained from our own data. For very annoying odours (compost facilities) the curve is rather steep suggesting the need for a very strict threshold, while Sucker et al. (2006) found hardly any relationship between odour-hour frequencies and annoyance for cattle odours. Note, that the curves for chicken odours obtained by Sucker et al. (2006) and in this work are practically similar in their gradient.

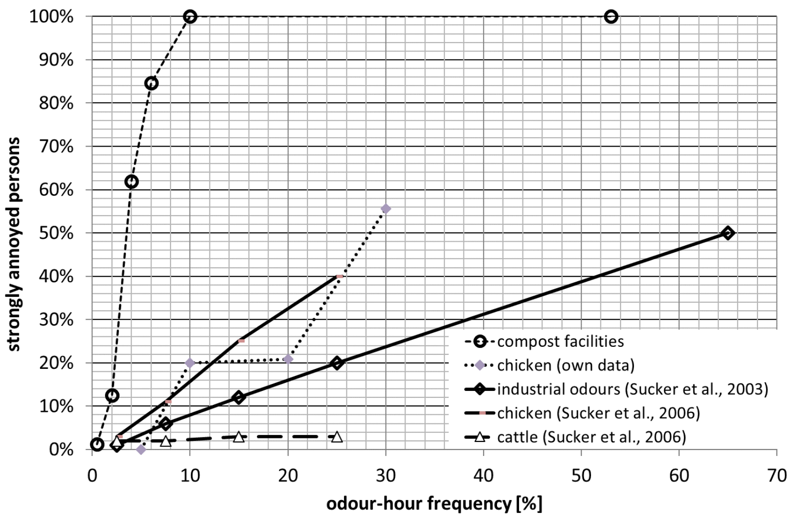

Figure 1. Dose-response relationships for different odours based on own data and literature

For swine odours, several studies were found in literature for comparison purposes. The relationship between odour-hour frequency and annoyance frequency obtained in this work is very similar to what was found in a study by Noordegraf and Bongers (2007), who used dispersion modelling, too. It should be stressed, that Noordegraf and Bongers (2007) used the 98th percentile of hourly-mean odour concentrations of a whole year. Based on GRAL simulations for a fictitious shed and by comparing resulting odour-hour frequencies with corresponding 98th percentiles, a relationship among these two measures were obtained and used to render the data of Noordegraf and Bongers (2007) into odour-hour frequencies. Though this method introduces quite some uncertainty, the relationships found by Noordegraf and Bongers (2007) seem to fit very well within the German studies (Gallmann, 2011; Sucker et al., 2006) and this work. It can be seen that the annoyance potential was found different depending on the character of the residential areas. In mixed agricultural/residential areas people seem to be less annoyed by swine odours than in predominantly residential areas.

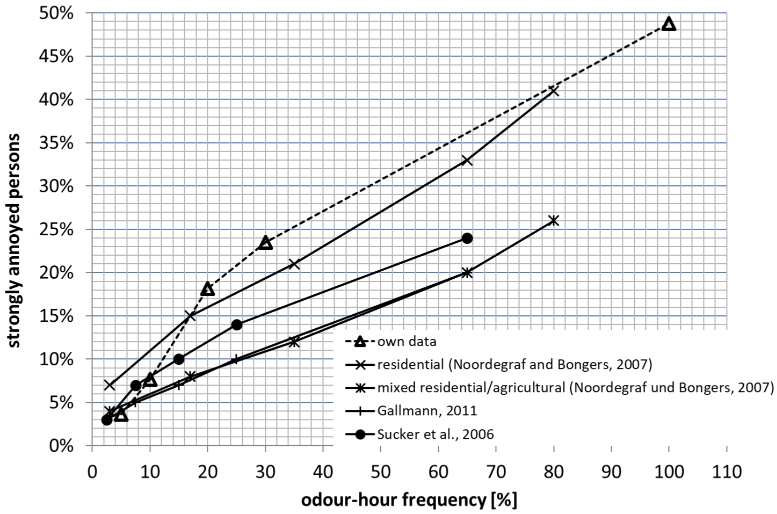

Figure 2. Dose-response relationships for pig-odour based on own data and literature

Based on these dose-relationships a set of threshold values have been established as listed in **Table 1** and **Table 2**.

Table 1. Recommended thresholds for odour-hour frequencies for agricultural odours

Annoyance potential	*examples*	*Pure residential, sensitive areas*	*Mixed agricultural/residential*	*Industrial, less sensitive areas*
Low	Cattle, Horses, Alpacas, Sheeps, Goats, Biofilters, Silages	40 %	50 %	-
Medium	Pigs	15 %	20 %	30 %
High	Broilers	10 %	15 %	20 %

Table 2. Recommended thresholds for odour-hour frequencies for non-agricultural odours

Annoyance potential	*examples*	
Low	Biofilters	40 %
Medium	Domestic heating, oil mills, breweries	15 %
High	„chemical“ odours like bitumen, VOCs	10 %
Very high	Odours from decay, rot, compost works without treatments, tanneries	2 %

NEW EMISSION FACTORS FOR ANIMAL HUSBANDRY

In the course of several measurements of odour emissions at livestock buildings, it became evident that the emission factors provided by the German VDI 3894-1 might be underestimating at least typical Austrian conditions. A further literature survey indicated that emission factors reported in other European countries apparently disagreed as well with the VDI 3894-1. In order to avoid an underestimation of odour burdens in the vicinity of livestock buildings, it was decided to set up own recommended emission factors, where observations and literature data were available in a sufficiently large number (Oettl et al., 2018c). This was the case for pig- and poultry husbandry (**Table 3**). In addition, reduction factors have been defined for various techniques such as protein-reduced feeding (not shown).

Table 3. Recommended emission factors for pig- and poultry husbandry in Styria, Austria

Animal	OU/s/500kg
Fattening pigs	140
Sows	50
Piglets < 25 kg	200
Laying hens	100
Fatting hens	200

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