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Towards a Harmonized Odour Guideline for Some Austrian Provinces

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Currently some provinces in Austria attempt to set up a harmonized regulation for assessing odour nuisance. The Austrian laws do not stipulate that any nuisance is to be prevented, but only “unacceptable” nuisance. “Unacceptable” is not a scientific or medical term but needs to be interpreted in a legal context. In the new guideline different odour impact criteria (OIC) are set up with regard to the hedonic tone of odours. For each category a maximally allowed frequency is defined. Frequencies are to be assessed on the total number of hours of a year, where the computed 90th percentile within one hour is above a certain threshold concentration (e.g. 1 odour unit [ou] per m³). Such is termed an odour hour. Dispersion modelling is the major methodology for odour assessments. Unlike in Germany, no specific model is prescribed, but model developers need to prove the capability of their model to accurately simulate the 90th percentile odour concentration of an hour. For instance, the Lagrangian particle model GRAL, which is frequently used in Austria, offers a new module to compute the 90th percentile based on the work of Oettl and Ferrero (2017a). The 90th percentile is thereby a function of the three dimensional odour-concentration field and the atmospheric turbulence, thus, the model is able to take into account the effects of overlapping odour plumes, too. It could be demonstrated that modelled odour-hour frequencies using this novel approach are in very good agreement with observed odour hours assessed by field inspections following the new European standard EN 16841-1. Field inspections, therefore, may also be used for odour assessment, whenever modelling is not possible (e.g. unknown source strengths). OICs are derived upon dose-response relationships, which were established by evaluating historical citizen’s complaints using the dispersion model GRAL. Relationships between the percentage of annoyed residents and modelled odour-hour frequencies were found to be quite different for odorants having a very high potential of offensiveness and such with a moderate potential. Discontinuous odour sources are assessed by using OICs based on the 0.5th percentile evaluated for concentrations larger than 1 ou m^{-3}. The corresponding concentration thresholds for the four distinguished hedonic tones were derived by matching the affected non-attainment areas resulting from the regulations for continuous sources with those resulting from the 0.5th percentile regulation.

1. Introduction

In Austria odour nuisance is regulated in qualitative terms (e.g. unacceptable odour is not permitted) but not quantitatively yet. Following the German GOAA (2008), odour assessment is carried out based on odour hours defined by at least 6 minutes of detectable odour concentrations within one hour. Unfortunately, no harmonized thresholds for maximum allowed odour hours are used in Austria, but each of the nine provinces developed its own standard. Some follow the suggestion of utilizing 8 % odour hours for weak odours and 3 % odour hours for strong ones (OAW, 1994). However, the terms “weak” and “strong” were not quantitatively defined at that time. Others apply the German regulation (GOAA, 2008), or use a mixture of both OAW (1994) and GOAA (2008). The aim of this work is to provide a basic concept of harmonized odour assessments for Austria. Several Austrian provinces have already signalled their interest.

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2. Odour impact criteria (OIC)

2.1 General remarks

OIC are based on odour hours. According to VDI 3788 the correct calculation of odour-hours is carried out by taking into account the individual odour sensitivity of qualified panel members, which is usually approximated by a log-normal distribution

$$P_0(c) = 0.5\left[1 + erf\left(\frac{\ln\left(c/c_{OT}\right)}{\sqrt{2}\alpha}\right)\right], \qquad (1)$$

with *erf* being the error function, *c* the odour concentration, c_{OT} the odour concentration detected by 50 % of the qualified panel members, and α a scale parameter. Hence, $P_0(c)$ describes the fraction of qualified panel members, which are able to detect a certain odour concentration. In this way, an odour hour can be defined more precisely by computing

$$\kappa = \int_0^\infty P_0(c) f(c) dc\ , \qquad (2)$$

whereby $f(c)$ is the probability density function of odour concentrations at some observational point within one hour. An odour hour is defined by $\kappa \geq 0.9$, i.e. in 10 % of the time odour will be detected by qualified panellists.

A commonly accepted basis for the development of jurisdictional criteria of environmental odours are the so-called FIDOL factors (e.g. Brancher et al., 2017), which stand for frequency (F), intensity (I), duration (D), offensiveness (O), and location (L). The German guideline GOAA (2008) discriminates OIC according to frequency and location. The offensiveness only comes into play when assessing odour impacts from animal husbandry. Odours related to industrial facilities are all judged upon the very same criteria, i.e. a maximum of 10 % odour hours in a calendar year in residential areas. This criterion is deduced from a dose-response relationship (Figure 1) for unpleasant industrial odours stemming from oil and grease production, and a foundry (Sucker et al., 2003).

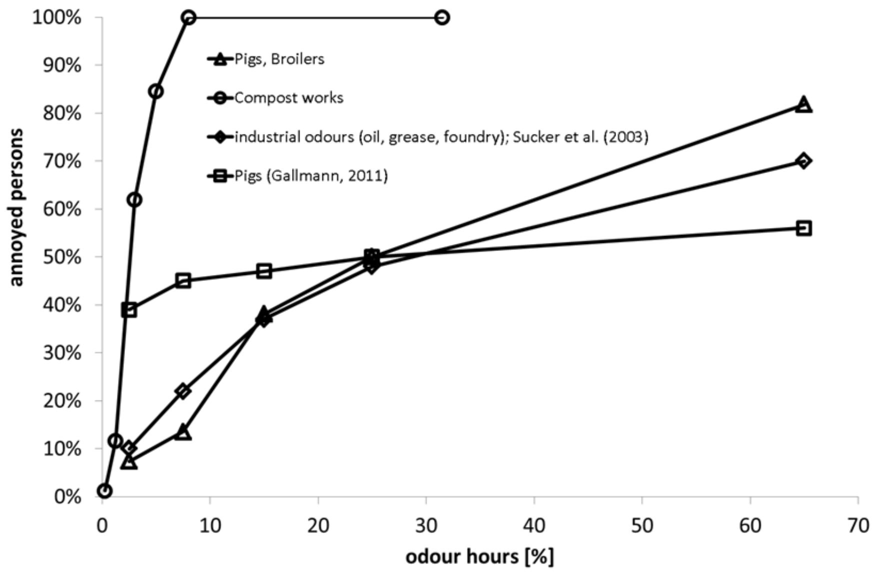

Figure 1: Comparison of some dose-response relationships based on literature and own investigations

2.2 Dose-response relationships based on odour-hour frequencies

Over the past decade odour complaints in the province of Styria, Austria, have been analysed by means of dispersion modelling. For the flow-field simulations in complex terrain, the prognostic, non-hydrostatic mesoscale model GRAMM (Oettl, 2017a) was applied. The flow fields were subsequently taken as input to the Lagrangian particle model GRAL (Oettl, 2017b) for computing the odour dispersion. GRAL in particular has been validated for applications covering all wind speeds including calm winds, which are very frequent in Styria, and especially for the calculation of odour hours (Oettl et al., 2018). For the latter, Oettl and Ferrero (2017a) developed a new odour-hour model, which, unlike existing other ones (e.g. Janicke and Janicke, 2004; Piringer et al., 2016), is able to take into account atmospheric turbulence, but also overlapping odour plumes.

Modelled odour-hour frequencies for a calendar year were evaluated at the residential buildings of both complaining and non-complaining neighbours in the vicinity of odour sources. Two distinct dose-response relationships for compost works and animal husbandry (pigs, broilers) have been derived from this data (Figure 1). Especially, the curve for compost works differs significantly from the relationship found by Sucker et al. (2003) obviously indicating that complaints arising from industrial odour nuisance can't be assessed using a single OIC. The difference between the dose-response relationship of Sucker et al. (2003) and the one presented herein for composting activities, can be explained by the fact that odours from organic-waste treatment is more offensive than from oil and grease production, or foundries.

Apparently, odours from broiler and pig sheds are less annoying than those from compost works. While the dose-response relationship found for broiler and pig sheds almost coincides with the one of Sucker et al. (2003), the relationship for pigs reported in Gallmann (2011) has almost no dependency on odour-hour frequencies. This would indeed indicate that odour-hours frequencies are not useful for assessing odour nuisance at all.

Based on the existing dose-response relationships, the following criteria for odour assessments are proposed, whereby in case of modelling, the threshold for the 90th percentile odour concentration c_{90} has to be set to 1 ou m^{-3}.

- Low offensiveness: 30 % odour-hours
- Moderate offensiveness: 15 % odour-hours
- High offensiveness: 10 % odour-hours
- Very high offensiveness: 2 % odour-hours

Still, the criteria will have to be discussed among the Austrian's provinces, thus, alterations might occur in the future.

It should be noted that no distinctive threshold is apparent. Therefore, the definition of corresponding assessment criteria is subject to a commonly accepted fraction of complaints. Here, about 30 % of potentially annoyed people have been taken as limit for deducing the odour-assessment criteria listed before. These include above-average sensitive persons and persons that complain about odour, though, in reality other or additional (e.g. noise) conflicts trigger the nuisance. In Austria the assessment has to be carried out for "normal, healthy people". Therefore individual sensitivities must be ignored in the evaluation of odours.

Examples for odours with low offensiveness could be cattle, biofilters, for odours with moderate offensiveness pigs and some industrial sources, for odours with high offensiveness chemical industry, and for odours with very high offensiveness composting activities.

The criteria for low and high offensive odours are equal to those of GOAA (2008), while the province of Quebec (Canada) has implemented just the same criterion for composting and biogas activities as in this work (Brancher et al., 2017). It should be noted, that for instance the 2 % criterion for compost works has been applied in the province of Styria since around 2009 (Oettl, 2009). Not only did it help to avoid odour complaints for newly installed compost works, but it was also possible to solve existing conflicts by prescribing measures to reduce the odour burden below 2 % odour hours per calendar year.

2.3 Discontinuous odour sources

Even more difficult is the assessment of odour nuisance in case of discontinuous sources. Quite obvious, criteria based on yearly statistical measures are not particularly useful in this case. Generally, thresholds for very low frequencies will be better applicable. Currently, no dose-response relationships are available for establishing criteria for discontinuous sources. In order to set up a reasonable framework for odour assessment, it is suggested to use a maximum frequency of 0.5 % for a calendar year not to be exceeded. The threshold for the odour intensity, expressed in ou m^{-3}, is defined for each odour category such that modelled areas using the corresponding criterion (section 2.2) coincide as much as possible with the modelled areas based on the 0.5 % frequency criterion. To do so, many different source configurations have been modelled and compared with each other. The following odour intensities have been found to provide a satisfying representation for each odour category:

- Low offensiveness: c_{90} = 5 ou m^{-3}
- Moderate offensiveness: c_{90} = 4 ou m^{-3}
- High offensiveness: c_{90} = 2,5 ou m^{-3}
- Very high offensiveness: c_{90} = 1,5 ou m^{-3}

2.4 Mixed odour assessment

The usage of four different odour categories and corresponding assessment criteria creates the problem of assessing overlapping odour plumes from different kinds of sources. The criterion for mixed odours has been defined by

$$\sum_i \frac{h_i}{B_i} \leq 1 , \qquad (3)$$

where h_i are the odour-hour frequencies for each source at some point, and B_i are the corresponding odour-assessment criteria. For instance, if the odour-hour frequency from cattle is 20 % and the contribution from a pig shed is 10 %, the odour criteria for mixed odours is not met, while each individual source is not violating the corresponding assessment criterion.

2.5 Assignment of odour-criteria to a specific odour source

Currently, the greatest challenge is to objectively assign an odour criterion to a specific odour. Some countries, using multiple odour-assessment criteria, do not provide any method for categorizing odours (e.g. UK). Others establish lists of odour sources and assign an OIC for each list (e.g. Netherlands).

Methods aiming at providing objectively distinguished nuisance potentials are not yet implemented in any country (Brancher et al., 2017). The polarity-profile method outlined in VDI 3940-4 (2010) is a candidate for this purpose.

In an effort to test the applicability of this method for categorizing different odours according to their hedonic tone, more than 700 polarity profiles for more than 20 different odours (e.g. pigs, broilers, cattle, composting activities, volatile organic compounds) have been statistically analyzed. While the method is well suited for discriminating between pleasant and unpleasant odours, it completely failed for further separating unpleasant odours. On the one hand, it was found that the odour intensity strongly influences the outcome of the polarity profile, and on the other hand, correlation factors for unpleasant odours all showed very similar correlations with idealized profiles for stench. Therefore, the current conclusion is that polarity profiles are not suitable for that purpose, and the only way for establishing multiple odour criteria for unpleasant odours will be to work out commonly accepted lists of odour sources linked to a certain criterion as outlined in section 2.2 and 2.3.

3. Methods for assessing and measuring odour exposure

The great advantage of using odour-hour frequencies as assessment method is the possibility to use either dispersion modelling or field inspections. In GOAA (2008) both methods are considered to be equivalent, thus, they should provide similar results when following the prescribed methodological approaches therein. However, several comparison studies have indicated that there might be a general tendency that dispersion modeling according to GOAA (2008) overestimates odour-hour frequencies (e.g. Grotz and Zimmermann, 2015; Hartmann and Borcherding, 2015; Oettl and Oitzl, 2015). Other studies have shown that sometimes the GOAA (2008) approach may lead to good agreement with results obtained by field inspections (Oettl and Ferrero, 2017b; Oettl et al., 2018). A possible explanation can be derived from the work of Oettl and Ferrero (2017a), who developed a new odour-hour model, which in most cases results in lower odour-hour frequencies compared to the simplistic approach in GOAA (2008), which sets $c_{90} = 4c_{mean}$, whereby c_{mean} is the hourly average odour concentration. Depending on the distance to the source, the way how multiple odour plumes overlap, the source strengths, etc. modelled odour hours following GOAA (2008) either overestimate or agree well with field inspections. In contrary, simulation results based on the more sophisticated model of Oettl and Ferrero (2017a) provides very good agreement with field inspections in the majority of cases (Oettl and Ferrero, 2017b; Oettl et al., 2018). It should be noted that there is a general need to adequately take into account odour emission variability in modelling, since oversimplification of emission patterns can heavily affect the results of odour dispersion modelling (e.g. Oettl, 2014).

It is important to note that a new European standard for carrying out field inspections has been established in 2017 (EN 16841-1, 2017). At least eight qualified panellists (EN 13725, 2003) are required for conducting either 52 inspections over half a year or 104 inspections over a full year. As field inspections are extremely

costly with regard to time and staff, it is not recommended in the upcoming guideline as the primary method for odour assessments. Instead, dispersion modelling is the preferred method, but it has to be assured that the dispersion model and methods are validated for that purpose. Therefore, modellers need to provide evaluation studies, preferably published in international peer-reviewed journals.
Growing research activities in the field of instrumental monitoring of odours (electronic nose) will hopefully add a third method to detect odours in the near future (e.g. Giuliani et al., 2012, Viccione et al., 2012).

4. Conclusions

Austrian experts from academia and administration have started to cooperate in a working group to propose a national guideline document for a harmonised procedure for the evaluation of environmental odours. There is still a lot to be done and some burning issues must still be resolved. One example is how to deal with a situation when existing sources already exceed the proposed guideline values. Although they are obviously causing odours that can produce considerable and unacceptable annoyance, when enterprises have a valid license any improvements and amendments can only be enforced when economically feasible and efficient. This is often difficult to prove. Measures could be enforced when the exposures not only cause annoyance, but also risks to health. Generally speaking severe and prolonged annoyance is a mental stressor that is believed to have adverse health consequences. But how frequent and how intensive must the exposure be before a health risk can be stated?
What if the guideline values are already reached by existing enterprises? Is then no additional source to be permitted, even when that additional source will only have a minor impact on the overall situation? What signifies a relevant additional contribution?
The way forward is clear, but it is still a long way ahead and we expect long and – as past experience shows – also some quite heated discussions. In the end we hope to achieve a national guideline that takes into account the special geographical situation of Austria with the special meteorological conditions of an Alpine country and the diverse and scattered land-use structure where living areas are in close proximity with industrial and agricultural uses. The finalisation of such a guideline is a difficult but nevertheless much needed task.

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