CHEMICAL ENGINEERING TRANSACTIONS

VOL. 40, 2014

A publication of AIDIC

The Italian Association of Chemical Engineering
www.aidic.it/cet

Guest Editor: Renato Del Rosso

ISBN 978-88-95608-31-0; **ISSN** 2283-9216

DOI: 10.3303/CET1440030

National Odour Impact Criteria: Are the Modelled Separation Distances Between Sources and Receptors Comparable?

Elaine Sommer-Quabach [a], Martin Piringer [b], Erwin Petz [b], Günther Schauberger [a,*]

[a]WG Environmental Health, Unit for Physiology and Biophysics, University of Veterinary Medicine, Vienna, Austria
[b]Central Institute of Meteorology and Geodynamics, Vienna, Austria
* gunther.schauberger@vetmeduni.ac.at

To determine separation distances between odour sources and residential areas (in order to safeguard against nuisance and complaints), odour impact criteria (OIC) are adopted by the national regulatory authorities. There is a wide variety of OIC used for this purpose, which differ by the odour concentration threshold (between 0.12 ou m^{-3} and 10 ou m^{-3}), the averaging period (hourly or instantaneous) and by the tolerated exceedance probability of the adopted threshold (between 0.1% and about 35% of the time). Using two national OIC for the protection of rural residential properties (Ireland with a threshold of 6 ou m^{-3} and a tolerated exceedance probability of 2%) and Germany (with a threshold of 0.25 ou m^{-3} and a tolerated exceedance probability of 20%), the direction-dependent separation distances were calculated, and compared against those of 166 different OIC. It is interesting to investigate whether the large range of national OIC results in large differences in the modelled separation distances. For this investigation, the normalised mean standard error (NMSR) was selected as a statistical measure. There are two groups of OIC used in various jurisdictions: the first one with a low odour concentration threshold and a high tolerated exceedance probability (e.g. Germany); and the second group with a high odour concentration threshold and a low tolerated exceedance probability (e.g. Ireland). The modelled direction-dependent separation distances (using OIC which are supposed to offer the same protection level) can vary significantly. The OIC of the second group, considering higher ambient odour concentrations, show a much lower sensitivity to site-specific meteorological data. Therefore, a higher tolerated exceedance probability seems more appropriate for the determination of OIC. Even if the similarity of separation distances by various OIC could be determined, the direction-dependent separation distances differ considerably for the same protection level for a certain receptor type, e.g. rural residential properties.

1. Introduction

The annoyance potential of an odour source is reflected in the separation distance. The direction-dependent separation distance between an odour sources and the nearby residential area is used to define a zone beyond which nuisance should not occur. The protection level depends on the land-use category and its sensitivity to odour (e.g. residential, unpopulated); the higher the protection level, the larger the separation distance.

The calculation of the separation distance is carried out using a dispersion model, which predicts the ambient odour concentration on an hourly basis. This time-series of concentration values allows a calculation of the % of time in the year during which the threshold odour concentration (OIC) would be exceeded. This can be compared to the tolerated exceedence probability.

For the perception of odour, the time interval of one hour is not strictly speaking representative, because odour perception can occur over a few seconds. Therefore, the maximum ambient odour concentration for a single breath C_p can be estimated using a peak-to-mean factor F which modifies the modelled odour concentration (one hour mean C_m) using $C_p = C_m F$. The shorter the integration time for the ambient odour

Please cite this article as: Sommer E.N., Piringer M., Petz E., Schauberger G., 2014, National odour impact criteria; are the modelled separation distances between sources and receptors comparable?, Chemical Engineering Transactions, 40, 175-180
DOI: 10.3303/CET1440030

concentration, the higher the peak-to-mean factor F. It is assumed that this peak concentration C_p is more appropriate to describe the odour sensation of the human nose than the one-hour mean value (Piringer and Schauberger, 2013; Schauberger et al., 2012).

The direction-dependent separation distance between an odour source and the residential properties is the regulatory tool, which takes into account the entire chain starting from the odour emission rate (source strength), the dilution in the atmosphere (the dispersion model) and the evaluation of the predicted ambient concentration (the output of the dispersion model) against the OIC. In general, the OIC are set by the environmental agencies or other governmental institutions on a national basis. Therefore, various national odour impact criteria NOIC are available across different countries for the same receptor type.

This paper examines the NOIC of two selected countries, Germany and Ireland, for pig odours, and the protection of rural residential amenity.

The NOIC in Germany for pigs is defined by a low odour threshold of 1 ou m^{-3} as an hourly mean value, 0.25 ou m^{-3} as a peak concentration, and a high tolerated exceedance probability of 20%, taking into account the hedonic tone of the odour. In Ireland, a high odour threshold of 6 ou m^{-3} for rural areas with a low exceedance probability of 2% is used. This approach of OIC is used identically for all other odour sources like waste water treatment plants (Capelli et al., 2013) or municipal solid waste landfills (Sironi et al., 2005).

This paper aims to compare separation distances determined with various NOIC. The large differences in the calculated separation distances leads to a discussion of whether the protection of amenity is far greater in some countries compared to others.

2. Materials and Methods

2.1 Dispersion modelling

The calculations have been carried out for an odour emission rate of 13 000 ou s^{-1}, which represents a livestock flock of about 1 860 fattening pigs, or 91 000 laying hens, or 1 400 calves. The source geometry was assumed to be a single point source with a height of 6 m. The emission rate is assumed to be constant in time.

The separation distances are calculated using the Austrian Odour Dispersion Model (AODM) (Piringer et al., 2007; Schauberger et al., 2000, 2002). The meteorological data for the dispersion modelling were obtained from Wels, an observing site representative of the Austrian flatlands north of the Alps, with a temporal resolution of 30 minutes over a 2 year period between January 30, 1992 and January 31, 1994. Stability classes are determined as a function of half-hourly mean wind velocity and a combination of sun elevation angle and cloud cover. The cloud cover was monitored by the meteorological station at the airport Linz-Hörsching, in a distance of about 13 km.

2.2 Odour impact criteria OIC

The separation distances for 166 OIC were used for this analysis. These OIC were selected from 17 countries (e.g. Piringer and Schauberger (2013); Schauberger and Piringer (2012)) to cover the entire range of NOIC between 0.15 ou m^{-3} ≤ C_T ≤ 30 ou m^{-3} and 0.1 % ≤ p_T ≤ 20%. Two reference ROIC were applied which are used by the jurisdictions of Germany and Ireland. These two countries have been selected for the two fundamentally different approaches to OIC: either the use of a constant odour concentration threshold (as in Germany) or a constant tolerated exceedance probability (as in Ireland); the other parameter is in each case used to adjust the OIC to a certain protection level. The two OIC differ significantly as can be seen by the highlighted values in Fig. 1.

The first reference impact criterion ROIC R_1 is based on the German guideline (GOAA, 2008). This protection level is defined by an odour concentration threshold of C_T = 1 ou m^{-3} (as a peak value) with a peak-to-mean factor F = 4 which results in a one hour mean of C_T = 0.25 ou m^{-3} with a tolerated exceedance probability of p_T = 20%. The second ROIC R_2 is used as NOIC in Ireland (EPA Ireland, 2001). The protection level is defined by an odour concentration threshold C_T = 6 ou m^{-3} with a tolerated exceedance probability p_T = 2%, and a peak-to-mean factor F = 1.

Separation distances for the two reference values R_1 and R_2, are compared against the remaining 166 OIC for all 360 directions (1° sectors). The comparison of this paired set of direction-dependent separation distances is performed using the normalized mean square error $NMSE$.

The normalized mean square error $NMSE$ is defined by the squared differences of the reference separation distance $S_{i,k}$ and the separation distance $S_{j,k}$ of a certain OIC j, the mean reference separation distance $\overline{S_i}$, and the mean separation distance $\overline{S_j}$ of a certain OIC j for all directions k = 1 to 360 (1° sectors) by

$$NMSE_{i,j} = \frac{1}{N}\sum_{k=1}^{360}\frac{\left(S_{i,k} - S_{j,k}\right)^2}{\overline{S_i}\,\overline{S_j}} \qquad (1)$$

The $NMSE$ between the ROIC and all other OIC is used to find those OIC with the most similar separation distance compared to one of the two ROIC.

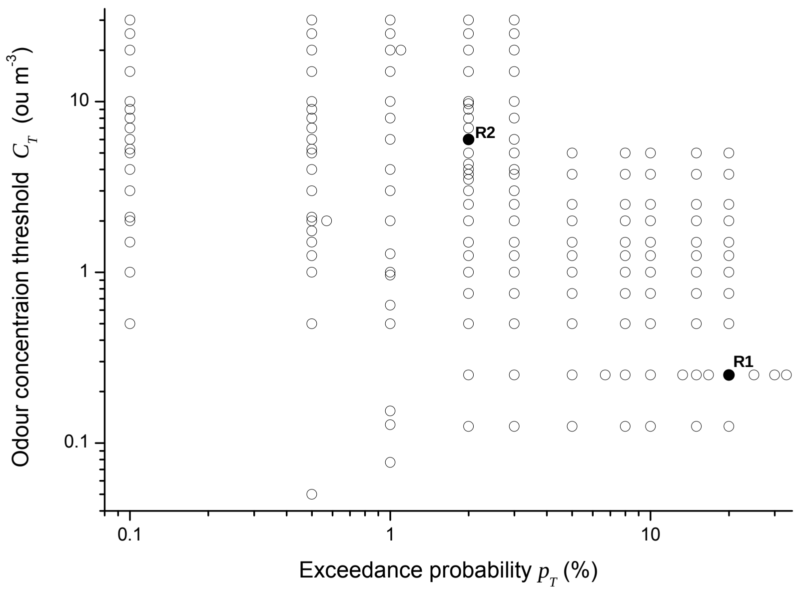
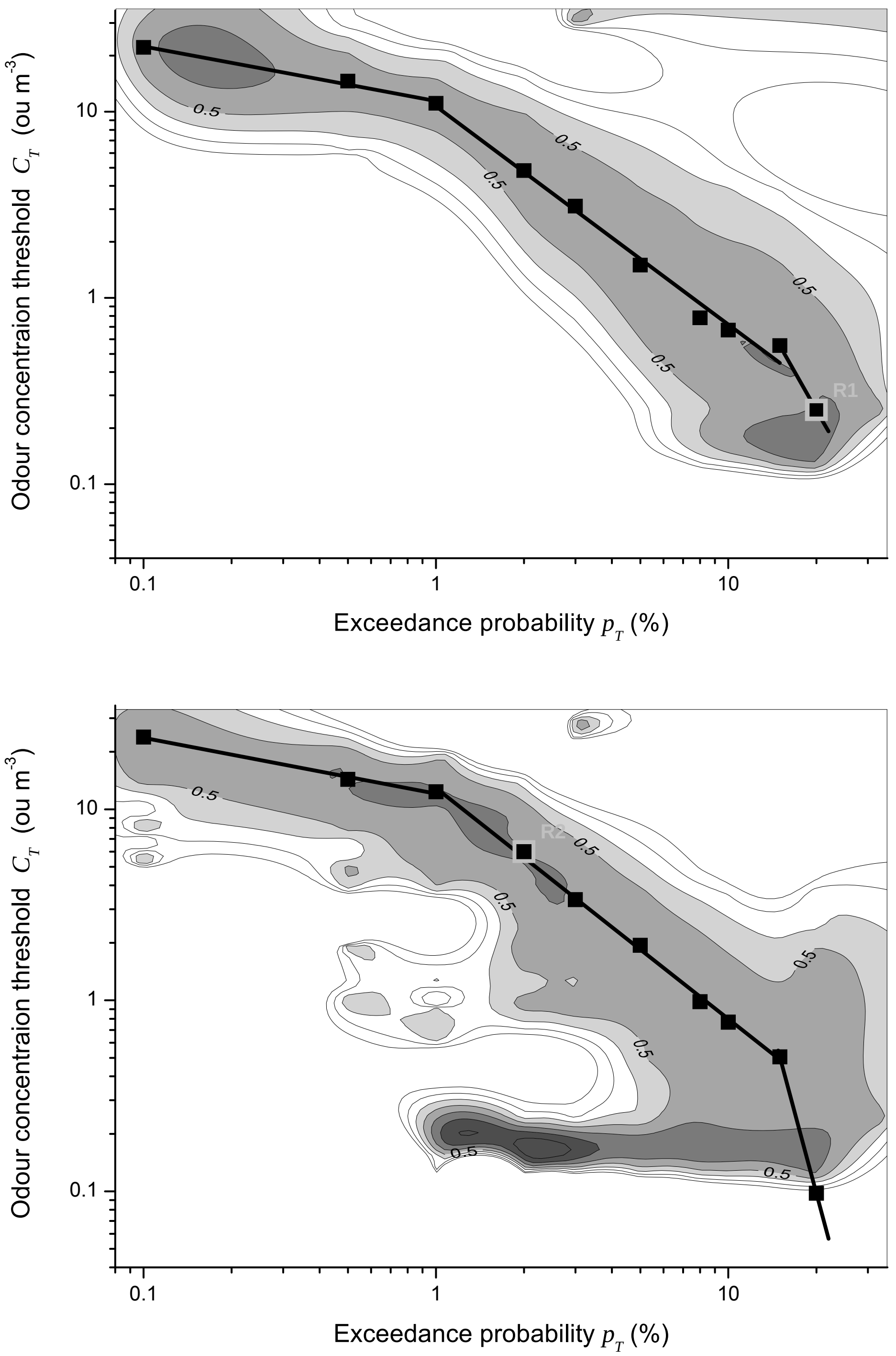


Fig. 1 Selection of odour impact criteria OIC defined by the odour threshold concentration C_T for a one hour mean value and the tolerated exceedance probability p_T. For each of these 166 OIC, the direction-dependent separation distances are calculated. Two reference OIC for rural residential areas (R_1 and R_2), which are used in Germany (Index 1) and Ireland (Index 2) as NOIC for pig odour, are highlighted.

3. Results and Discussion

The $NMSE$ as a means of comparing the direction-dependent separation distances of each of the two reference scenarios against the other 166 OIC is graphically represented as contour maps in Fig. 2. The contour lines are shown in intervals of 0.25. Areas with a higher similarity ($NMSE$ < 0.75) are shaded. Besides the contour map of the $NMSE$, the local minima of the $NMSE$ (shown as filled black squares) are also depicted to define the isopleth of a certain protection level. In each figure, two regression lines connect the local minima of the $NMSE$, one with a shallow slope below p_T = 1% and one with a steeper slope above this limit. Along these lines, the similarity of separation distances is highest. Independent of the reference scenario and the land-use, a similar pattern of separation distances is obtained for an increase of the tolerated exceedance probability from 1 to 10 % and the concurrent decrease of the odour concentration threshold from about 10 to 1 ou m^{-3}. The shapes of the two contour maps show a similar pattern.

The regression lines of the local minima of the $NMSE$ represent isopleths of a certain protection level in Fig. 2. These isopleths of the two ROIC are compared to other NOIC. Besides single values describing an odour impact criterion, functions are in use to describe the relationship between the tolerated exceedance probability p_T and odour concentration threshold C_T for a certain protection level.



A

B

Fig. 2 Contour map of the NMSE *of 166 OIC compared to the reference scenario German NOIC* R_1 *(A) and Irish NOIC* R_2 *(B) (light squares) and the local minima of the* NMSE *of the protection level for rural residential areas (black line) for fattening pigs.*

The NOIC show a wide variety of different parameter combinations of the odour concentration threshold C_T and the tolerated exceedance probability p_T as well as the peak-to-mean factor F (Piringer and Schauberger, 2013; Schauberger and Piringer, 2012).

Some countries (Germany, Ireland, and Belgium) distinguish between various animal species taking into account the hedonic tone. Nearly all countries select different OIC depending on the protection level, mainly defined by the zoning of the residential areas. The adaption of the OIC to a certain protection level is done in two ways. In Germany, the odour concentration threshold C_T is taken as a constant value, whereas the exceedance probability p_T is used to adjust the OIC to a certain protection level. All other countries use a constant exceedance probability p_T and modify the odour concentration threshold C_T to adjust the OIC to the protection level. If peak-to-mean factors $F \neq 1$ are used to assess the peak concentration, all countries except Austria use a constant factor.

The odour concentration threshold of the Irish NOIC lies in the range between C_T = 1.5 ou m^{-3} and C_T = 9.7 ou m^{-3} for a one-hour mean value, depending on the protection level. By applying the German peak-to-mean factor F = 4, the stimulus concentration can be assessed between C_T^* = 6 ou m^{-3} and C_T^* = 39 ou m^{-3}. Taking into account the relationship between odour concentration and odour intensity (Bundy et al., 1997; Piringer and Schauberger, 2013; Sarkar and Hobbs, 2002) this gives an intensity clearly above the odour threshold, verbally described as 'weak' to 'strong' odour intensity. The tolerated exceedance probability of this concentration with a distinct odour perception is then limited to 2%.

For a low tolerated exceedance probability of p_T = 2% or less, only few distinct meteorological situations will determine the separation distance. For p_T = 0.1% (e.g. the NOIC of West Australia) only 9 hours of a year are used to determine the separation distance. This means that for each wind direction at least nine hours per year of a certain meteorological situation with a very low dilution can be found which leads to a nearly circular separation distance. In contrast, for a high exceedance probability in the range of 10 to 20%, nearly all stability classes contribute to the separation distance as could be shown by Schauberger et al. (2006).

4. Conclusions

In many countries, odour impact criteria OIC are in use defined as the combination of odour concentration threshold (in ou m^{-3}) and tolerated exceedance probability (in %). There exists a wide variety of OIC (Table 1); the preferred combinations are either low odour concentration thresholds/high tolerated exceedance probabilities or vice versa. The main purpose of OIC is the determination of separation distances between the odour source and the nearest neighbours to avoid odour nuisance.

In this paper, two ROIC based on regulations in Germany and Ireland for rural areas have been selected for which direction-dependent separation distances have been determined. These are compared to those derived from 166 other OIC (Fig. 1). As a measure of similarity of the paired set of direction-dependent separation distances, the normalized mean square error $NMSE$ is used.

The two ROIC represented by the selected German and Irish regulations differ significantly. The German odour concentration threshold C_T^* = 1 ou m^{-3} means that even very sensitive individuals who perceive odour with this low stimulus are taken into account. Especially in the field this odour concentration threshold will seldom lead to odour perception. On the other hand, for a low tolerated exceedance probability of p_T = 2% or less, only a few distinct meteorological situations will determine the separation distance. From these findings one might argue that a combination of a threshold for a distinct odour recognition and a tolerated exceedance probability of more than 2 % might work as an effective OIC. Variations in either parameter to account for the different protection levels of land use classes are then still possible.

References

Bundy, D., Chen, Y.C., Hoff, S.J., Zhu, J., 1997. Modelling odour intensity for swine units, in: Voermans, J.A.M., Monteny, G.J. (Eds.), Ammonia and Odor Emission from Animal Production Facilities Rosmalen, The Netherlands, pp. 677-684.

Capelli, L., Sironi, S., Del Rosso, R., Guillot, J.-M., 2013. Measuring odours in the environment vs. dispersion modelling: a review. Atmos. Environ. 79, 731-743.

EPA Ireland, 2001. Odour Impacts and Odour Emission Control Measures for Intensive Agriculture, Environmental Research, R&D Report Series No. 14. Environmental Protection Agency, Ireland.

GOAA, 2008. Guideline on Odour in Ambient Air (GOAA). Detection and Assessment of Odour in Ambient Air.

Piringer, M., Petz, E., Groehn, I., Schauberger, G., 2007. A sensitivity study of separation distances calculated with the Austrian Odour Dispersion Model (AODM). Atmos. Environ. 41, 1725-1735.

Piringer, M., Schauberger, G., 2013. Dispersion modelling for odour exposure assessment, in: Belgiorno, V., Naddeo, V., Zarra, T. (Eds.), Odour Impact Assessment Handbook. Wiley, pp. 125-176.

Sarkar, U., Hobbs, S.E., 2002. Odour from municipal solid waste (MSW) landfills: A study on the analysis of perception. Environment International 27, 655-662.

Schauberger, G., Piringer, M., 2012. Assessment of separation distances to avoid odour annoyance: interaction between odour impact criteria and peak-to-mean factors. Chemical Engineering Transactions 30, 13-18.

Schauberger, G., Piringer, M., Petz, E., 2000. Diurnal and annual variation of the sensation distance of odour emitted by livestock buildings calculated by the Austrian odour dispersion model (AODM). Atmos. Environ. 34, 4839-4851.

Schauberger, G., Piringer, M., Petz, E., 2002. Calculating direction-dependent separation distance by a dispersion model to avoid livestock odour annoyance. Biosystems Engineering 82, 25-37.

Schauberger, G., Piringer, M., Petz, E., 2006. Odour episodes in the vicinity of livestock buildings: A qualitative comparison of odour complaint statistics with model calculations. Agriculture, Ecosystems and Environment 114, 185-194.

Schauberger, G., Piringer, M., Schmitzer, R., Kamp, M., Sowa, A., Koch, R., Eckhof, W., Grimm, E., Kypke, J., Hartung, E., 2012. Concept to assess the human perception of odour by estimating short-time peak concentrations from one-hour mean values. Atmospheric Environment 54, 624-628.

Sironi, S., Capelli, L., Centola, P., Del Rosso, R., Grande, M.I., 2005. Odour emission factors for assessment and prediction of Italian MSW landfills odour impact. Atmos. Environ. 39, 5387-5394.