An empirical model to estimate the separation distance between livestock buildings and residential areas: An improved version of the Austrian guide line

M. Piringer*, G. Schauberger** and E. Petz*

* Central Institute for Meteorology and Geodynamics, Department of Environmental Meteorology, Hohe Warte 38, A 1190 Vienna, Austria (E-mail: *martin.piringer@zamg.ac.at; erwin.petz@zamg.ac.at)*
** Institute of Medical Physics and Biostatistics, University of Veterinary Medicine Vienna, Veterinärplatz 1, A 1210 Vienna, Austria (E-mail: *gunther.schauberger@vu-wien.ac.at)*

Abstract In this paper, separation distances between livestock buildings and residential areas calculated by the Austrian guide line are compared to those of a new empirical model. This comparison is necessary as the guide line is currently under revision. The calculation of the separation distance in the guide line is based on a power function with an exponent of 0.5. The new empirical approach to be tested uses a power function $S = a\,E^b$ with the separation distance S, the odour emission flow E and the two parameters a and b, These two parameters depend on the relative frequency of the wind direction h_w and the protection level, a combination of the threshold of the odour concentration of 1 OU/m³ and the exceedance probability h_G for odour sensation. The new approach generally delivers larger separation distances with a stronger dependence on wind direction compared to the guide line.

Keywords Gauss model, guide line, separation distance, peak-to-mean ratio, livestock, odour

INTRODUCTION

Complaints by the neighbourhood due to odour emissions of livestock buildings are a major concern in rural areas. Therefore, some countries have already developed guide lines to address odour from livestock. These guide lines are in use to assess the necessary separation distances between livestock buildings and residential areas such that odour is not felt as an annoyance. In all of the guide lines, the separation distance is calculated as a function of the odour emission rate, sometimes parameterised by the number of animals. The calculation of the separation distance in most of these guide lines is based on a power function with an exponent between 0.3 (Germany), 0.5 (Austria; The Netherlands; Indiana, USA) and 0.6 (USA) (Piringer and Schauberger (1999)).

As the Austrian guide line is in use since 1996 (Schauberger et al., 1997), a revision is currently undertaken. This revision is necessary because of several reasons: quantification of the odour flow (currently, a dimensionless odour number is used to characterize the odour flow); application to increased numbers of animals; inclusion of new techniques to reduce the generation of odour in animal husbandry. To revise the guide line, new empirical approaches to calculate the separation distance are tested. The calculations will be performed for several sites in Austria to evaluate the necessity of a regionalisation of the parameters of the regression model.

In this paper, first results of the new empirical approach for the area of Wels in the Austrian Northern Alpine foreland will be shown and discussed.

MATERIAL AND METHODS

Determination of the separation distances

The new empirical approach to be tested uses a power function $S = a E^b$ with the separation distance S, the odour emission flow E and the two parameters a and b. These two parameters depend on the relative frequency of the wind direction h_w (resolved to 1°, i. e. determined for each of the 360 wind directions and therefore given in ‰) and the protection level. The protection level is expressed by the threshold of the odour concentration of 1 OU/m³ and the exceedance probability h_G for odour sensation.

The Austrian Odour Dispersion Model (AODM)

The separation distances to test the approach are calculated with the Austrian Odour Dispersion Model (AODM). The model calculations are performed for the area of Wels in the Austrian Northern Alpine foreland. The model calculations are done for three odour emission rates (500, 2000 and 8000 OU/s) and four exceedance probabilities (0, 3, 8 and 15 %). The model is described in detail in Schauberger et al. (2001, 2002). AODM is a Gaussian-based model to predict odour sensation, by estimating the daily and seasonal variations of the odour emission, the average ambient odour concentration and the momentary (peak) concentration for the time interval of a single human breath (approx. 5 seconds). Peak concentrations further downwind are modified by an exponential attenuation function (Piringer et al., 2007).

The Austrian guide line

The Austrian guide line (Schauberger et al., 1997), to determine the separation distance, uses a constant exponent b of 0.5. Instead of frequencies for h_w and h_G, the guide line operates with factors. The wind direction frequencies of the eight cardinal wind directions representing each a 45° sector are converted to the meteorological factor f_M of the guide line varying between 0.6 and 1, and exceedence probabilities are converted to the land use factor f_R of the guide line. The guide line discerns between three land use categories: pure residential areas ($f_R = 1$), common residential areas ($f_R = 0.7$), and areas of mixed residential/commercial activity ($f_R = 0.5$). In the guide line, the separation distance $S = 25\, f_M\, f_R\, O^b$, where O is the dimensionless odour number depending on the number of animals and on the conditions how they are kept.

RESULTS AND DISCUSSION

Parameters of the power function

Values of parameters a and b obtained with the new empirical approach are given in Table 1. The exponent b decreases with increasing exceedence probability from about 0.7 to 0.4 and increases slightly with the frequency of the wind direction. Most of the factor a ranges from 5 to 6, with the exception when frequencies of the wind direction are less than 2 ‰. Here some irregularities occur, and these values should therefore be treated with caution. The overall result of this dependence of a and b is a general increase in separation distances with increasing exceedence probability and increasing frequency of the wind direction.

Table 1. Factor *a* and exponent *b* of the empirical model

Exceedence probability, h_G (%)		Frequency of the wind direction (‰) 0.5	1.5	2.5	3.5	4.5
0	*a*	4.997	5.451	5.427	5.570	5.323
	b	0.731	0.723	0.723	0.720	0.726
3	*a*	6.232	5.037	5.081	5.176	4.781
	b	0.410	0.483	0.504	0.502	0.518
8	*a*	11.359	7.306	5.534	5.552	6.028
	b	0.256	0.358	0.433	0.455	0.452
15	*a*	77.388	18.665	8.381	5.844	5.651
	b	-0.028	0.182	0.322	0.394	0.416

Table 1. (continued)

Exceedence probability, h_G (%)		Frequency of the wind direction (‰) 5.5	6.5	7.5	8.5	9.5	10.5
0	*a*	5.350	5.520	5.552	5.572	5.469	5.538
	b	0.725	0.721	0.720	0.720	0.723	0.721
3	*a*	4.191	3.763	4.451	4.232	4.017	3.928
	b	0.546	0.569	0.539	0.553	0.565	0.563
8	*a*	6.019	6.271	6.679	6.540	6.466	6.717
	b	0.458	0.458	0.450	0.453	0.456	0.451
15	*a*	5.265	5.885	6.764	6.576	6.404	6.812
	b	0.440	0.440	0.428	0.433	0.437	0.430

Comparison of the separation distances

In the following, the separation distances obtained by the new empirical approach are compared to those of the Austrian guide line. In the following figures, the solid lines show the separation distances of the empirical model, and the dashed lines show that for the guide line. The curves of the same colour can be compared.

Generally, the new empirical model delivers larger separation distances than the guide line. For pure residential areas (Fig. 1), there is a factor of 2 to 2,5 between the separation distances calculated by the guide line and that of new empirical model. The factor slightly increases with odour flow and h_w.

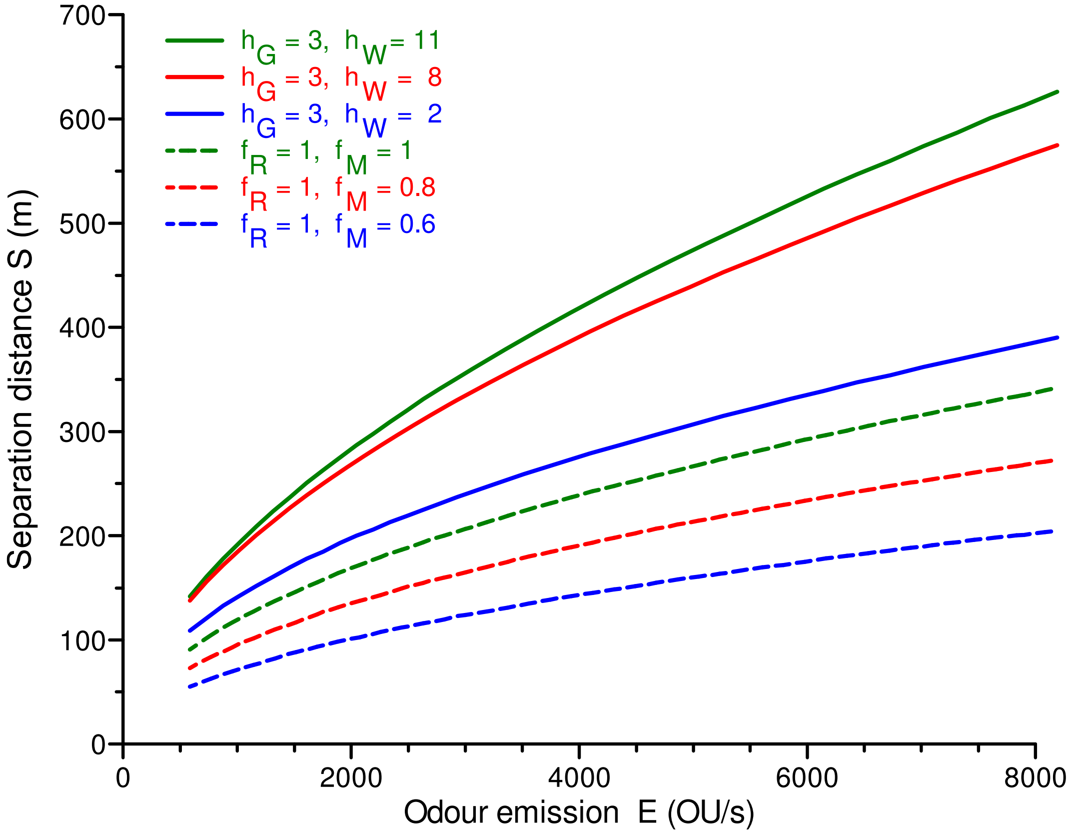

Figure 1. Comparison of the separation distances for pure residential areas (empirical model: h_G=3%, solid lines, guide line: f_R =1, dashed lines)

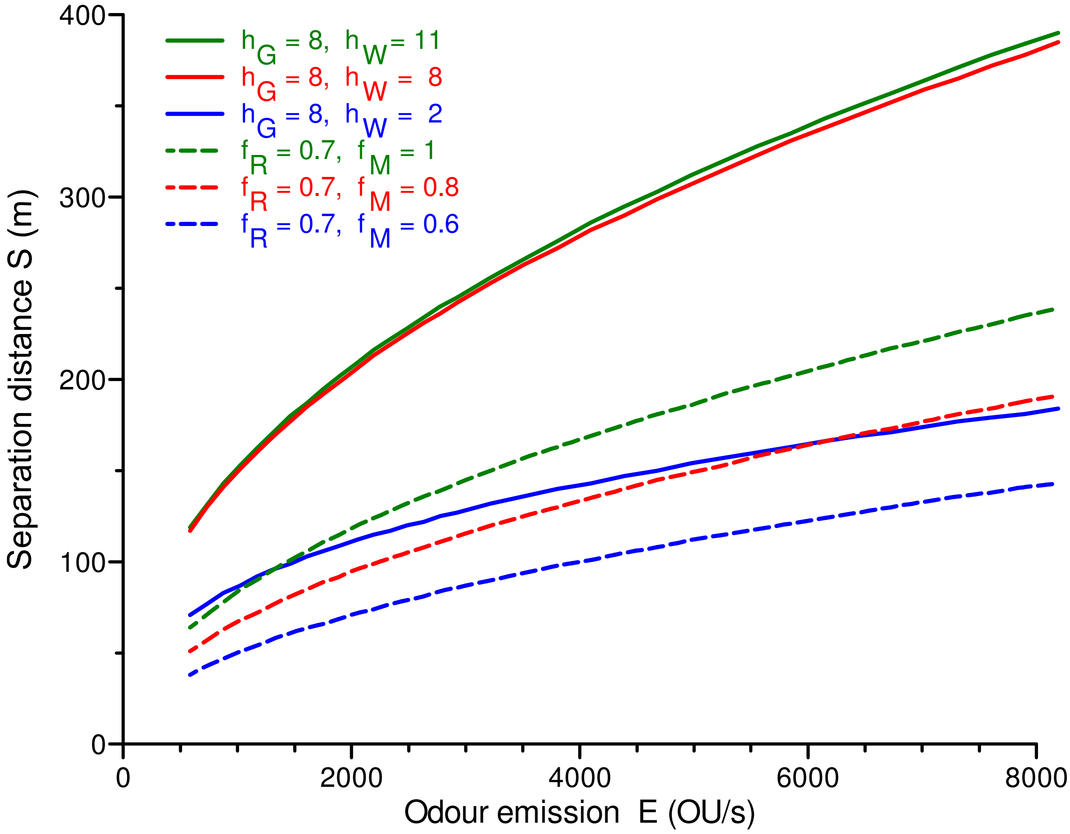

Figure 2. Comparison of the separation distances for common residential areas (empirical model: h_G=8%, solid lines; guide line: f_R =0.7, dashed lines)

For common residential areas with an average level of protection (h_G = 8%, Fig. 2), separation distances are generally lower than for those with a high protection level (Fig. 1). The comparison of the separation distances at this protection level indicates a factor of 1.5 higher for the model compared to the guide line, taking low wind direction frequencies into account (blue lines in Fig. 2). For larger wind direction frequencies (red and green curves), the separation distances are again a factor 2 to 3.5 larger for the empirical model, generally increasing with increasing odour flow.

For the lowest protection level investigated (areas of mixed residential/commercial activity, h_G = 15%, Fig. 3), separation distances are the smallest, as expected. There is not much difference between the blue lines, representing cases with a low frequency of wind direction. For larger wind direction frequencies for which the described process of regression analysis gives more reliable results, there is not much change compared to Fig. 2: for small odour flows, the separation distances of the empirical model are about twice as large as those of the guide line, and this factor increases up to 3.5 for large odour flows.

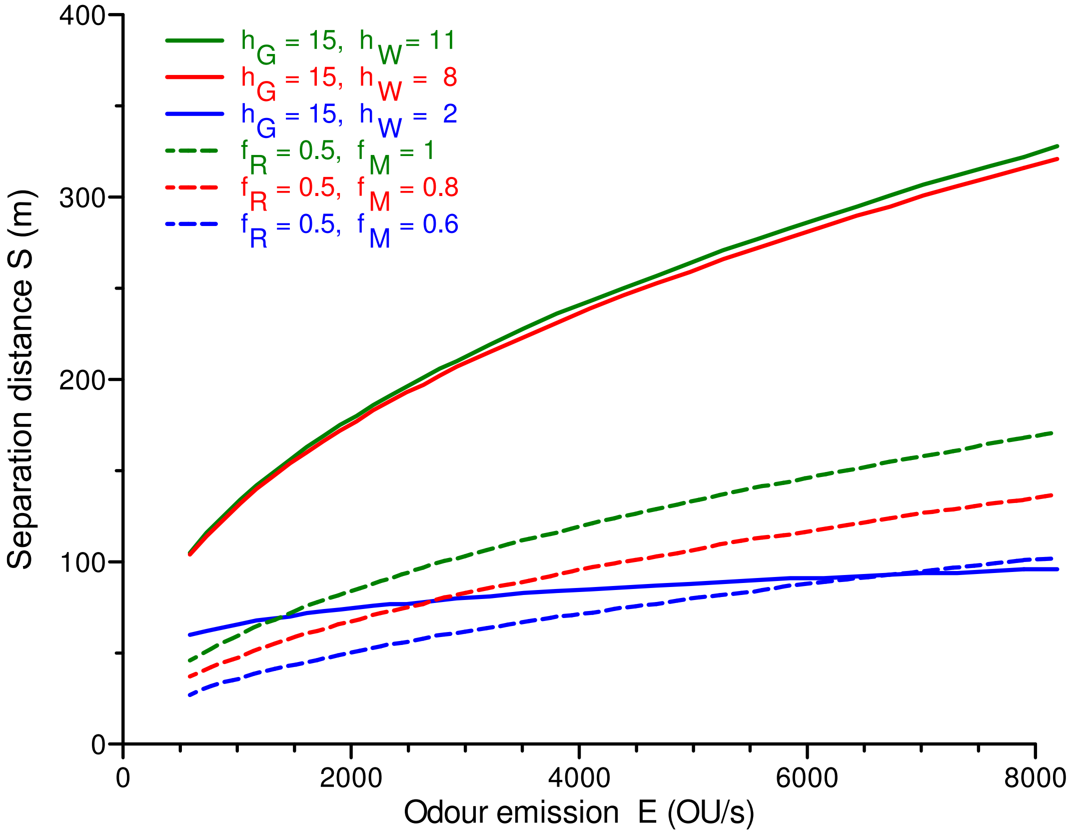

Figure 3. Comparison of the separation distances for areas of mixed residential/commercial activity (empirical model: h_G=15%, solid lines; guide line: f_R =0.5, dashed lines)

Directional dependence of separation distances

In the following, the two approaches (guide line and empirical model) are applied to compare direction-dependent separation distances, which are the final outcome of the guide line. This comparison is undertaken for the meteorological conditions at Wels, an area characteristic for the North-Alpine foreland in Austria. The calculation is done for livestock units of 100, 350 and 1400 fattening pigs, corresponding to odour flows of 585, 2048 and 8190 OU/s, respectively.

The calculations are done for pure residential areas (Fig. 4 with f_R =1 and h_G=3%), for common residential areas (Fig. 5 with f_R =0.7 and h_G=8%) and for areas with mixed residential/commercial activity (Fig. 6 with f_R =0.5 and h_G=15%). The results show that, as expected, the separation distances calculated by the empirical model show a much larger dependence on wind direction than those of the guide line. Whereas the guide line discerns only the eight cardinal wind directions, separation distances with the empirical model were calculated for wind direction sectors of 10°, which allows for far more details.

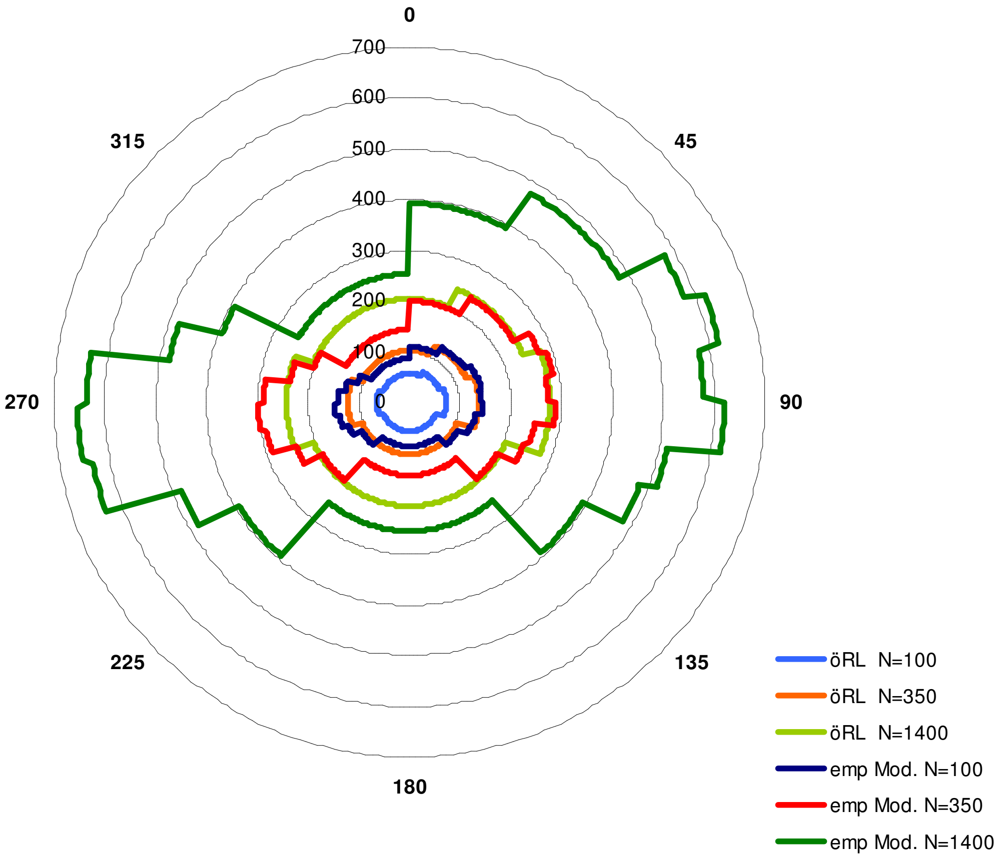

Figure 4. Comparison of separation distances for pure residential areas (f_R =1) between the Austrian guide line (öRL) and the empirical model (h_G=3%) for three livestock units (N = number of fattening pigs)

For a high level of protection (Fig. 4), separation distances of the guide line for small and medium-sized livestock units are almost circular, i.e. show only a marginal dependence on wind direction; for large livestock units, they vary between 200 and 300 m. For the empirical model, the dependence on wind direction increases with the number of animals; for 1400 fattening pigs (dark green line), they vary between 250 and 650 m. Note that the two approaches calculate the maximum separation distances for different (opposite) wind directions: the guide line for winds from the west, the empirical model for winds from the east, also best discernible for large livestock units.

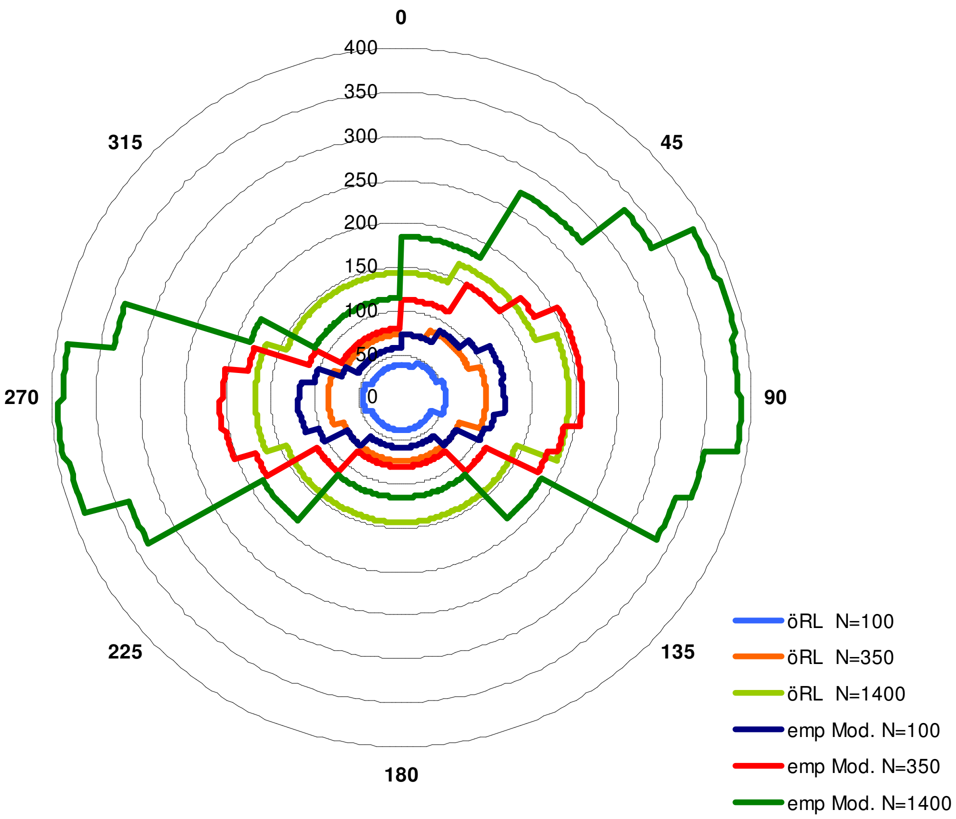

Figure 5. Comparison of separation distances for common residential areas (f_R =0.7) between the Austrian guide line (öRL) and the empirical model (h_G=8%) for three livestock units (N = number of fattening pigs)

As the protection level decreases (Figs. 5 and 6), there is also a general decrease of separation distances, but the dependence on wind direction does not change much compared to Fig. 4. The only main difference is that there are now wind direction sectors for which the empirical model gives shorter separation distances than the guide line. This occurs for the less frequent northerly and southerly winds. This is due to the finer resolution of the wind directions in the empirical model. Less data per wind direction sector are kept in the empirical model, and with the higher exceedence probabilities, cutting off 8 or 15 % of the data result in smaller separation distances in these cases.

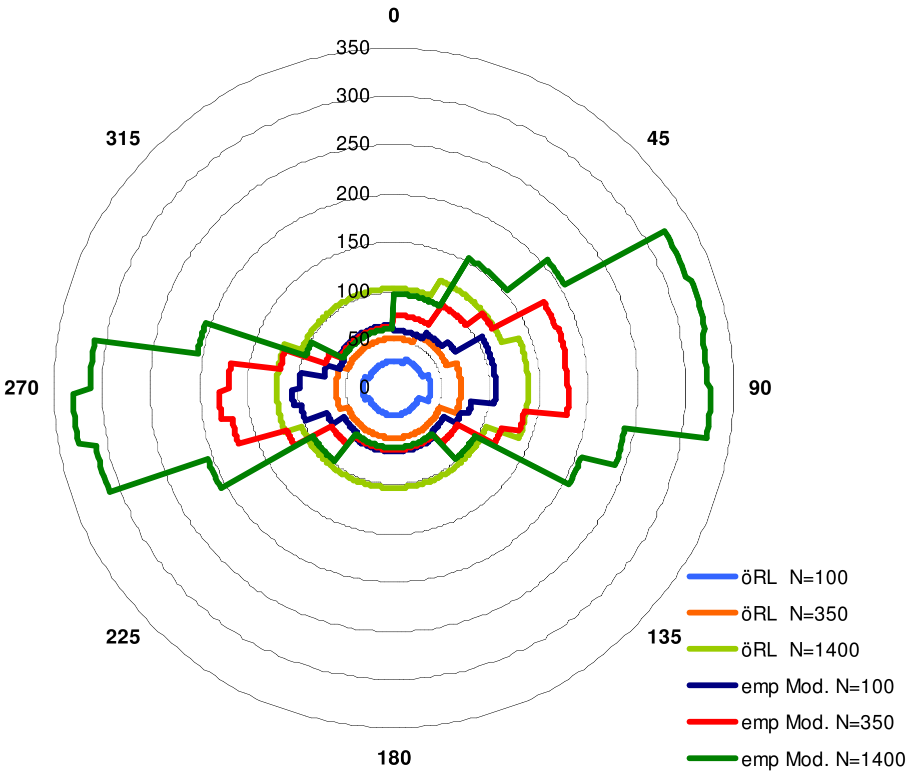

Figure 6. Comparison of separation distances for areas of mixed residential/commercial activity (f_R =0.5) between the Austrian guide line (öRL) and the empirical model (h_G=15%) for three livestock units (N = number of fattening pigs)

Table 2 summarizes the statistics of the quotient of the separation distances between the empirical model and the guide line for the three different protection levels and livestock units. On average, the separation distances of the empirical model are by a factor of 1,24 to 2,42 larger than those of the guide line.

Table 2. Quotient of the separation distances of the empirical model and the guide line for pure residential areas (f_R =1.0 and h_G=3%), common residential areas (f_R =0.7 and h_G=8%) and areas of mixed residential/commercial activity (f_R =0.5 and h_G=15%) for livestock units of 100, 350 and 1400 fattening pigs (N)

	Pure residential			Common residential			Mixed res./comm.		
N	100	350	1400	100	350	1400	100	350	1400
Max	2.32	2.49	2.73	2.64	2.50	2.35	3.24	2.99	2.74
Ave	1.84	1.79	1.76	1.90	1.63	1.39	2.42	1.71	1.24
Min	1.55	1.39	1.22	1.51	1.11	0.79	1.86	1.22	0.59

CONCLUSIONS

Currently, the Austrian guide line (Schauberger et al., 1997) to address odour from livestock is under revision. The calculation of separation distances between livestock or poultry farms and the neighbours is based on a power function with an exponent of 0.5. To revise the guide line, new empirical approaches to calculate the separation distances are tested. The new empirical approach uses a power function $S = a E^b$ with the separation distance S, the odour emission flow E and the two parameters a and b, These two parameters depend on the relative frequency of the wind direction h_w and the protection level. The protection level is expressed by the threshold of the odour concentration of 1 OU/m³ and the exceedance probability h_G for odour sensation. The new approach results in an exponent varying with wind direction.

The separation distances to test the approach are calculated with the Austrian Odour Dispersion Model (AODM). The model calculations were performed for the area of Wels in the Austrian Northern Alpine foreland. The model calculations were done for three odour emission rates (500, 2000 and 8000 OU/s) and four exceedance probabilities (0, 3, 8 and 15 %). The model is described in detail in Schauberger et al. (2001, 2002).

The new empirical model generally delivers larger separation distances than the guide line (Figures 1 to 3). This is especially true for medium and large wind direction frequencies and for large odour flows. As the protection level expressed in land use categories decreases, also the separation distances decrease, both in the empirical model and in the guide line.

When applied to the area of Wels (Figures 4 to 6), there is much more variation in the separation distances with the empirical model compared to the guide line. The variation increases with the level of protection and the number of animals. With both being high (Figure 4), separation distances of the guide line are between 200 and 300 m, whereas those of the empirical model vary between 250 and 650 m.

More modelling and comparison will be conducted for several sites in Austria (including Alpine valleys and basins), to evaluate the necessity of a regionalisation of the parameters of the regression model.

REFERENCES

Piringer, M., Schauberger G. Comparison of a Gaussian diffusion model with guidelines for calculating the separation distance between livestock farming and residential areas to avoid odour annoyance. *Atmospheric Environment* **33** (14): 2219-2228.
Piringer, M., Petz, E., Groehn, I., Schauberger, G. (2007). A sensitivity study of separation distances calculated with the Austrian Odour Dispersion Model (AODM). *Atmospheric Environment*
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. (2001). Predicting odour impact using the Austrian odour dispersion model (AODM). *Water Science and Technology* **44**, 197-204.
Schauberger G., Piringer M., Eder J., Fiebiger H., Köck M., Lazar R., Pichler-Semmelrock F., Quendler T., Swoboda M., Thiemann G., Teufelhart J. (1997). Österreichische Richtlinie zur Beurteilung von Immissionen aus der Nutztierhaltung in Stallungen. *Gefahrstoffe - Reinhaltung der Luft* **57**, 399-408.