


ABT15 – Air pollution control

# Project SaLu\_T

**Surveys of odour and ammonia emissions in the vicinity of an animal welfare stable for pig fattening**



## Project SaLu\_T: Surveys of odour and ammonia emissions in the vicinity of an animal welfare stable for pig fattening

Author and Project Manager	Mag. Dr. Dietmar Öttl, Amt d. Stmk. LR, A15
Monitoring of the meteorological measuring network, data control	Martin Tantscher, Amt d. Stmk. LR, A15 Mario Innerhofer-Ambros, Amt d. Stmk. LR, A15 Ing. Heinz Gressenberger, Amt d. Stmk. LR, A15
Odor inspections	Jörg Lukanz Ing. Robert Mair (Organisation) Hannah Öttl Magdalena Öttl Miriam Öttl Michael Rodler Melanie Schober Robert Seidl Reiner Sorko Markus Walter
Responsible for the content	Dipl. Ing. Dr. Thomas Pongratz, Amt d. Stmk. LR, A15
Map basics	GIS Styria 

Responsible for layout and content:  
Division 15 – Energy, Housing and Technology  
Air Pollution Control Unit  
Mag. Dr. Dietmar Öttl  
Email: [dietmar.oettl@stmk.gv.at](mailto:dietmar.oettl@stmk.gv.at)

<http://www.umwelt.steiermark.at>

publishers  
Office of the Government of Styria  
Division 15 – Energy, Housing and Technology  
Landhausgasse 7  
8010 Graz

Telephone: +43/(0)316/877-2931  
Air quality control centre: +43/(0)316/877-2172  
Fax: +43/(0)316/877-4569  
E-mail: [luft@stmk.gv.at](mailto:luft@stmk.gv.at)

© September 2022

# Table of Contents

Table of Contents .....	1
Summary .....	2
1. Introduction .....	3
2. Short description of the animal welfare stable .....	4
3. Odour Surveys .....	9
4. Ammonia measurements .....	15
5. Propagation modelling .....	16
5.1. Model description .....	16
5.1.1. Suitability of the model .....	16
5.1.2. Odour modelling .....	17
5.2. Model parameters used .....	17
6. Determination of emission factors .....	20
6.1. Determination of the odour emission factor .....	20
6.1.1. Propagation conditions during odour surveys .....	20
6.1.2. Results .....	22
6.2. Determination of ammonia emission factors .....	25
6.2.1. Spread conditions for the period of NH <sub>3</sub> measurements .....	25
6.2.2. Results .....	27
7. Literature .....	30

## Summary

In the present study, emission factors for an animal welfare stable equipped with state-of-the-art techniques to reduce emissions were determined on the basis of odour surveys according to EN16841-1 and passive collector measurements of ammonia. The emission factors, which were determined on the basis of dispersion calculations using the GRAL model, were significantly lower than the base factors currently applied in Styria in approval procedures for fattening pigs. For odor, a factor of 8 GE/GVE/s was determined, which means almost a 95% reduction compared to the standard factor of 140 GE/GVE/s. The corresponding factor for ammonia is 0.73 kg/TP/a, which corresponds to a reduction of around 80% compared to the standard factor of 3.64 kg/TP/a. The massive emission reductions compared to conventional housing technology with full-column flooring, single-phase feeding and closed housing are mainly due to the following emission-reducing measures in housing and feeding technology:

- Multiphase feeding
- Outdoor climate/open front stable
- Minimization of faeces
- Feces-urine separation

The investigation method used on the basis of immission surveys in the vicinity of the stable and propagation simulations does not allow the observed emission reductions to be directly assigned to the individual techniques.

# 1. Introduction

The SaLu\_T project – Clean Air in Animal Production deals with measures and technologies to reduce emissions and increase animal welfare in agricultural practice. A major focus of this project is the reduction of ammonia emissions (NH<sub>3</sub>), which is particularly important for compliance with the NEC Directive [NEC 2016]. The focus is on the development and testing of the first low-emission animal welfare stable for fattening pigs in Austria, which is technically breaking new ground in the areas of animal husbandry and emissions. The combination of emission reduction and optimisation of production is developed through the use of modern techniques and their evaluation by several research teams. The emission reduction also has a positive effect on odour emissions. The overall scientific management is in the hands of HBLFA Raumberg-Gumpenstein. Other project partners are the Austrian Society for the Environment and Technology, Schauer Agrotronic GmbH, Lorber & Partner, the Department of Animal Husbandry and Animal Welfare, TÜV Austria, the Bavarian State Institute for Agriculture, the German Agricultural Society and the Medical University of Graz. The operator of the animal welfare stable is the Fam. Neuhold in Leitersdorf in southern Styria.

The studies available so far in the literature on such housing systems – in particular on removal methods with feces/urea separation in the fattening pig area – are manageable. Dynamic flag inspections and model calculations with the GRAL model by TÜV Austria (2018) at an open-front stable with multi-phase feeding, permanent removal and feces-urea separation yielded an average emission factor of 20 GE/GVE/s. Investigations by LUFA Nord-West, Oldenburg (Broer, 2021) using the tracer gas method according to the VERA protocol revealed factors between 54 and 132 GE/GVE/s.

In the present study, in contrast to the above-mentioned work, the elaborate method of scanning according to EN16841-1 was used. The collected odour hour frequencies at eight points in the vicinity of the animal welfare stable were subsequently used to determine the emission factors for odour by means of a propagation simulation using the GRAL model. In addition, ammonia measurements were carried out at ten points in the vicinity of the stable, which were also available for the determination of a corresponding emission factor via a propagation simulation with GRAL.

## 2. Short description of the animal welfare stable

The research stable is located northeast of the village of Leitersdorf in the district of Leibnitz in a single location in the Schwarzaual (and Abb. 1 Abb. 2). The stable is functionally separated into three bays:

- Stable interior: Rest area
- Planned outdoor area: Activity area and feed intake (Abb. 6)
- Column area outside: Area of excretion

From an emission perspective, the following abatement measures have been implemented:

- Supply air cooling by means of cool-pads (Abb. 5)
- Functional separation of activity areas (Abb. 6)
- Multiphase feeding (Abb. 7)
- Dust removal of bedding (Abb. 8)
- Feces-urine separation (Abb. 9)

With the exception of the supply of cooled outside air via a horizontal ventilation shaft in the centre of the aisle indoors, the ventilation and venting takes place via natural convection. The resulting emissions are transported diffusely into the open air via the lateral openings (Abb. 3). In addition, emissions can also escape via two vertical surfaces above the stable building due to the special roof shape (Abb. 4). According to the operator, the side-mounted windbreak nets in the form of roller blinds are closed, especially in the three winter months and at night. During these periods it can therefore be assumed that the emissions are mainly released via the vertical openings above the stable. For the remainder of the period, it is assumed that 2/3 of the emissions will escape to the ground and 1/3 to the open air via the vertical surfaces above the stable mentioned above.

The maximum number of animal places is 850 fattening pigs with an average weight of about 75 kg. The resulting liquid manure is regularly pumped into a closed slurry storage, whereby emissions occur in the area of the inlet opening during the pumping process. Solid manure is transported several times a week, whereby odour emissions are also released here for relatively short time intervals (Abb. 10).

Abb. 1 Location of the animal welfare stable northeast of the village Leitersdorf in the district Leibnitz

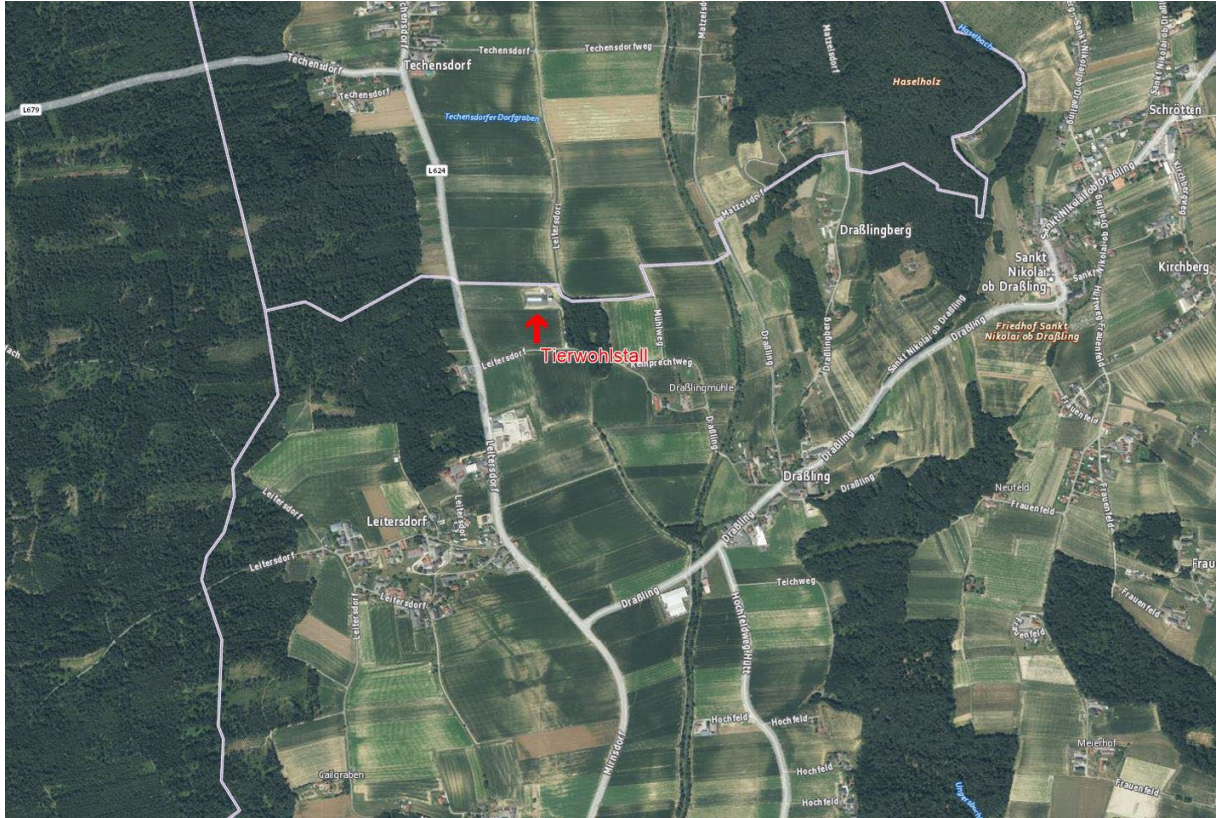


Abb. 2 Sites in the vicinity of the research stable

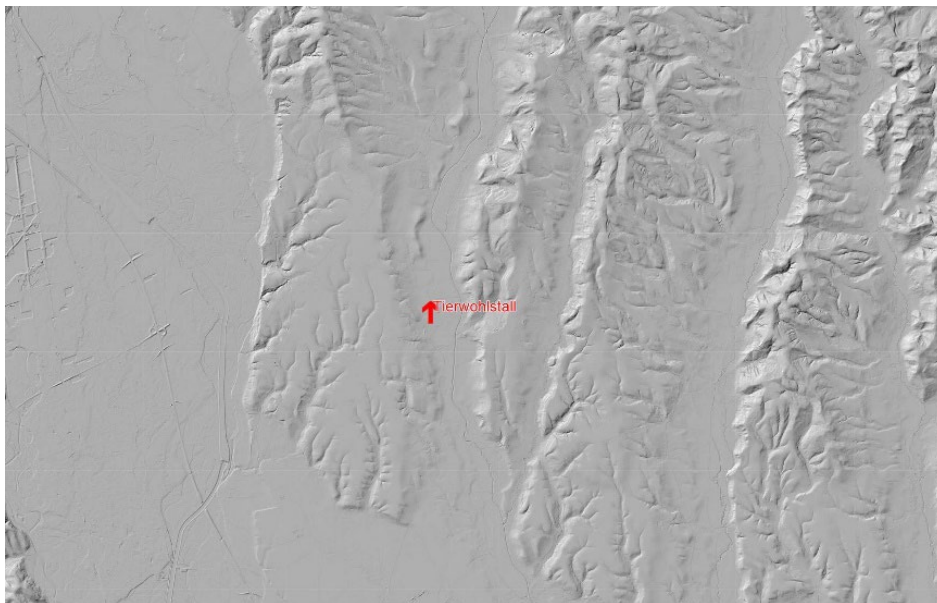


Abb. 3 View of the animal welfare stable from the south



Abb. 4 Outdoor area with ventilation openings in the ridge area



Abb. 5 Cool pads for  
Supply air cooling

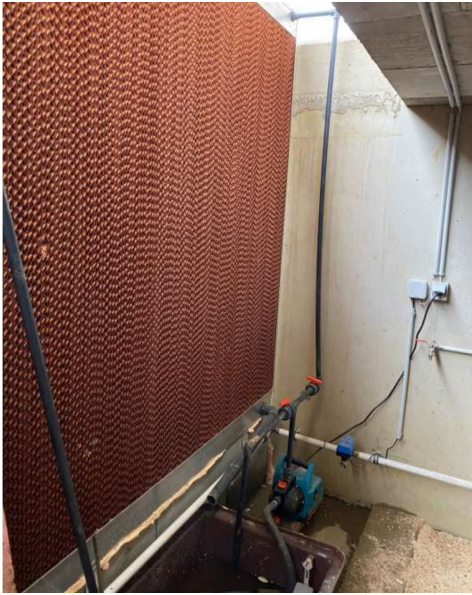


Abb. 6 Outdoor area for feeding  
and excretions



Abb. 7 Multiphase feeding



Abb. 8 Dust removal system for bedding



Abb. 9 Disposal (scrapers)  
with fecal urine separation



Abb. 10 removal of the mooring;  
left in the picture: closed manure pit



### 3. Odour surveys

The essential resource for field inspections is a sufficiently large pool of subjects whose sense of smell was previously determined under normative conditions. The specification of the corresponding ÖNORM EN 13725 is the selection of suitable persons whose sense of smell is not too sensitive or too insensitive. In order to ensure repeatability, the olfactory sensitivity of the examiners must be within a defined range, which is much narrower than the range of variation in the population. The standard-compliant selection of the test persons on the olfactometer (Abb. 11) was carried out by TÜV Austria under the direction of Mr. Ing. Robert Mair. The reference odour was n-butanol (CAS 71-36-3) in nitrogen.

Abb. 11 Test persons at the olfactometer (symbol photo)



In order to determine whether the participants - within the meaning of ÖNORM EN 13725 - are suitable, at least 10 individual threshold estimates must be made with the reference odour. The data of each subject shall be collected on at least three measurement days, with an interruption of at least one day in between. Finally, in order to obtain normative approval as a test subject for a field visit, the following two criteria must be met (see also Abb. 12):

- the standard deviation of the total number of threshold estimates shall be less than 2,3;
- the geometric mean of the individual threshold estimates shall be between 0,5 times (20 ppb) and 2 times (80 ppb) the reference value of the reference odour n-butanol;

Abb. 12 Result of the test subjects tested with n-butanol and suitable

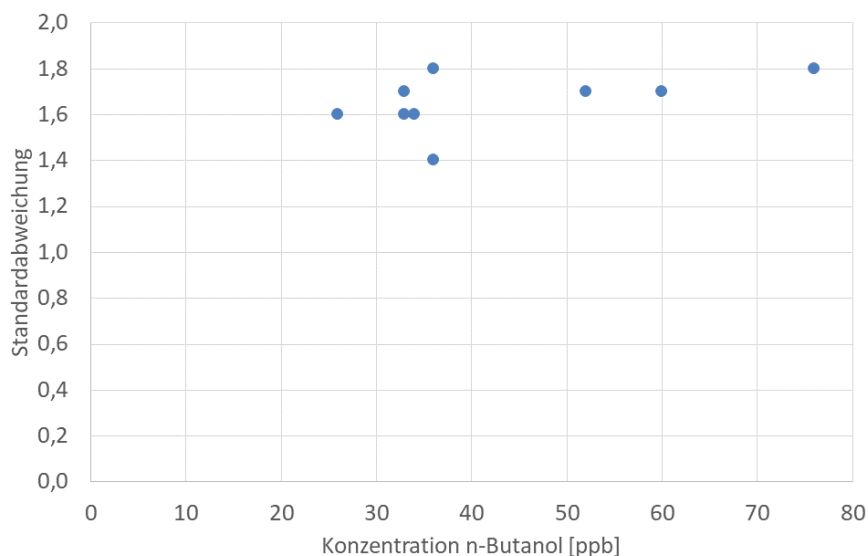


Abb. 13 Team of the odour surveys at the enrolment on 16.12.21 at the research stable



The field inspections to determine the odour frequencies at the 8 survey points (Abb. 14) were planned and carried out in the period from 10.1 to 12.7.2022 on the basis of standard EN16841-1. The standard stipulates that the odour impression is recorded by a calibrated subject every 10 seconds for a period of 10 minutes per survey point. The protocol used for this is Abb. 15 shown in. The odour impressions 'Schweinstall' and 'Güllegrube' were combined to calculate the odour frequencies. Odours caused by 'slurry application' and other odours were not taken into account. The participants were enrolled on 16.12.21 directly at the research stable (Abb. 13).

Abb. 14 Location of the survey points for the odour inspections

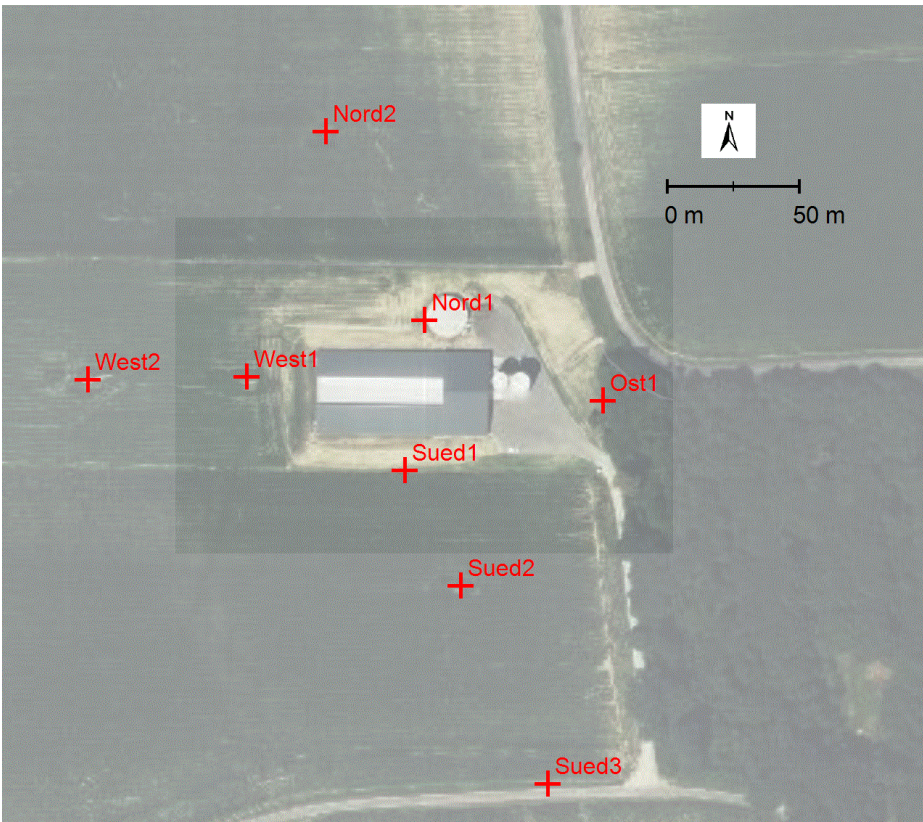


Abb. 15 Odour log used during inspections

## GERUCHSPROTOKOLL – SALUT

MESSPUNKT:    N1   N2   O1   S1   S2   S3   W1   W2

NAME:

DATUM:

BEGINN:

ENDE:

1. Minute

--	--	--	--	--	--

2. Minute

--	--	--	--	--	--

3. Minute

--	--	--	--	--	--

4. Minute

--	--	--	--	--	--

5. Minute

--	--	--	--	--	--

6. Minute

--	--	--	--	--	--

7. Minute

--	--	--	--	--	--

8. Minute

--	--	--	--	--	--

9. Minute

--	--	--	--	--	--

10. Minute

--	--	--	--	--	--

**GERUCHSARTEN:**

- 0    kein Geruch
- 1    Schweinestall
- 2    Gülleausbringung
- 3    Andere Gerüche

**WINDSTÄRKE:**

- kein Wind
- leicht
- mäßig
- stark
- stürmisch

**WOLKEN:**

- keine
- wenig
- bedeckt

**NIEDERSCHLAG:**

- kein
- Niesel
- Regen
- Schnee
- Bodennebel
- Graupel/Hagel

As Abb. 16 Abb. 17 can be seen, the requirements of EN16841-1 with regard to the most even distribution of the 53 survey dates over weekdays and daytime hours could be met and very well. Several

sick leave (mainly Covid-19) and short-term scheduling collisions led to the need to correct the inspection plan several times, making it impossible to divide the inspections evenly among the team of subjects (Abb. 18). In order to comply with the 10 second cycle as precisely as possible, an electronic device was developed that set the cycle both acoustically and visually (Abb. 19).

Abb. 16 Number of surveys per weekday

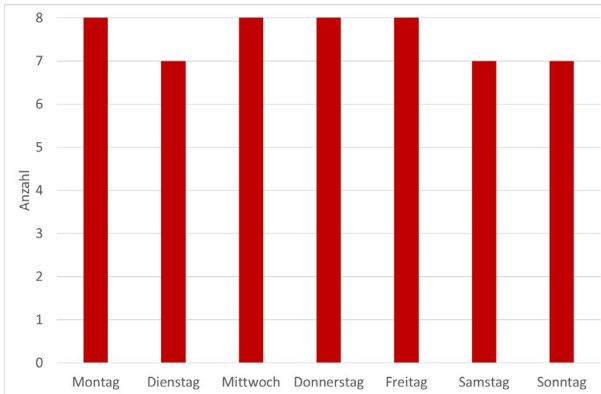


Abb. 17 Number of surveys over the course of the day

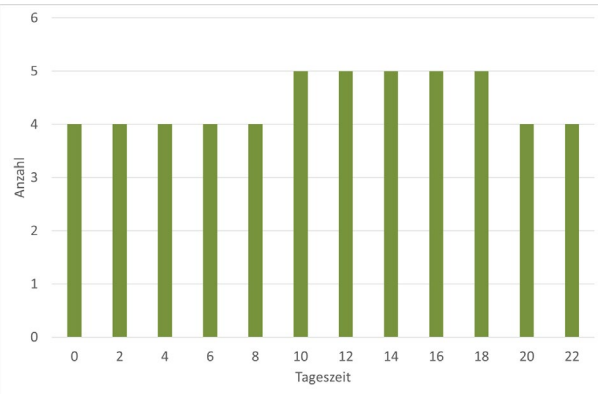


Abb. 18 Number of surveys per subject

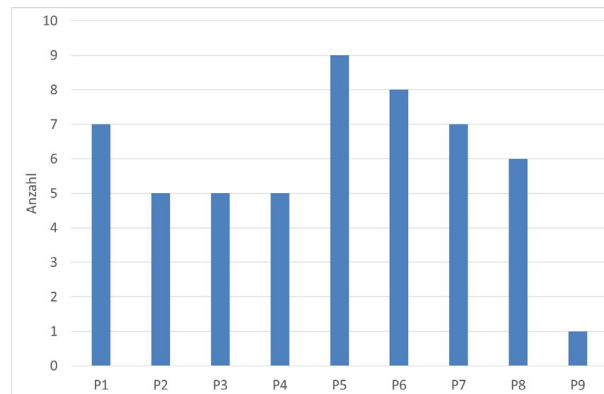


Abb. 19 Acoustic and optical 10 s clock (developer: Ing. Heinz Gressenberger, A15)



For each survey point, a plausibility check was carried out on the basis of locally collected wind direction data at the time of the survey. The individual odour protocols were evaluated according to the criteria  $\geq 6$  odour perceptions,  $\geq 3$  odour perceptions (upper uncertainty limit) and  $\geq 9$  odour perceptions (lower uncertainty limit). While the VDI 3940-1 explicitly indicates the sampling error of an odour survey based on a binomial distribution, the EN 16841-1 specifies a method for estimating the uncertainty due to the different odour perception of the subjects. An upper and lower uncertainty limit is determined by evaluating the odour frequencies with the above criteria ( $\geq 3$  and  $\geq 9$  perceptions per point). In fact, both assessments of uncertainties must be considered completely independently of each other. It should be noted that the sampling error caused by the choice of a 10-minute observation period instead of an entire hour is not addressed in VDI 3940-1 or EN 16841-1.

The error estimation of EN 16841-1 to take into account the different odour sensitivities within a team of subjects does not represent any uncertainty of the survey. In fact, in dispersion models to calculate odour hours, this fact is taken into account by integrating the product of the simulated distribution function of the odour concentrations and the perceptual function of the respective odour type and then determining the odour hour ( $\kappa \geq 0,1$ ):

$$\kappa = \int_0^{\infty} P_0(c)f(c)dc$$

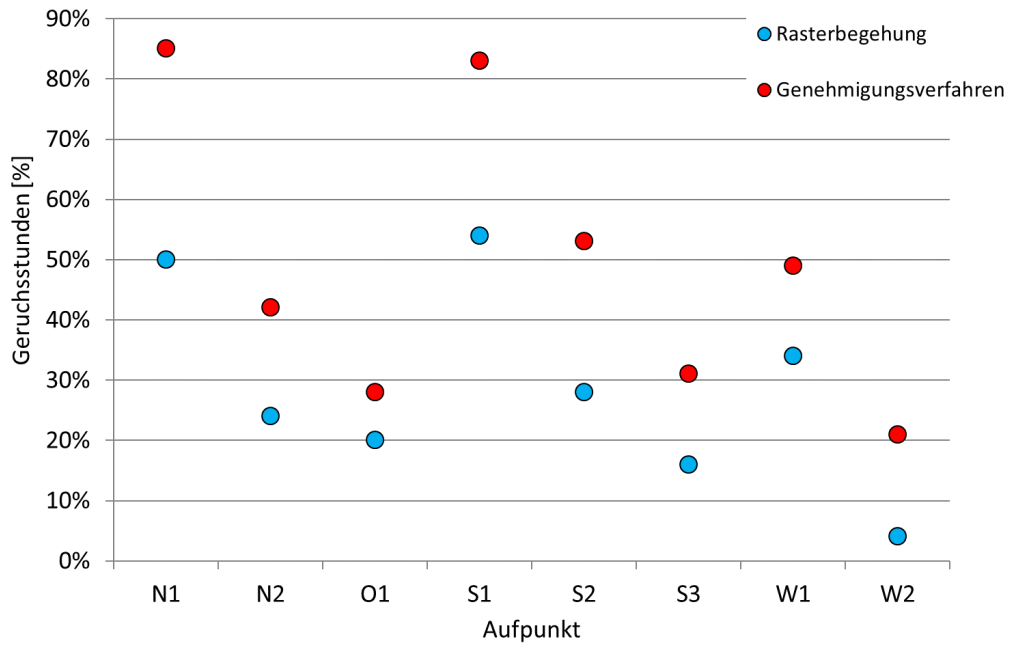
$P_0(c)$  is the probability of odour perception for a certain concentration  $c$  and  $f(c)$  the distribution function of the concentration fluctuations. The function  $P_0(c)$  can be determined in the context of olfactometry and is usually described by a logarithmic normal distribution. The odour model implemented in GRAL (Öttl and Ferrero, 2017) implicitly takes into account the different odour perceptions of the subjects (Öttl et al., 2018). A correction of the inspection results or the indication of an uncertainty range is therefore not necessarily expedient for a comparison with model results.

The Tab. 1 determined odour frequencies for the eight survey points are listed in. The highest values are found in the immediate vicinity of the stable building at points S1 and N1 with 54% and 50% odour hours, respectively. Both points are only about 10 m from the stable building. The survey points W1 and O1, which are in the close range (less than 50 m to the emission sources), but outside the main wind directions, have significantly lower frequencies of 34% and 20%, respectively. The decrease in the determined odour frequencies with increasing distance to the stable is very clear. For example, the values for points S2 and S3 dropped sharply from 28% to 16% at a distance of around 60 m and 140 m respectively from the stable. Particularly positive is the fact that the odour frequencies collected ( $\geq 6$  perceptions) are at all points significantly lower than the odour frequencies forecast in the course of the official approval procedure (Bachler, 2019) (Abb. 20). The emission abatement measures therefore work even better than those adopted in the investigation procedure at the time.

Tab. 1 Results of the odour surveys for the individual points for stable odours

# perceptions	N1	N2	O1	S1	S2	S3	W1	W2
$\geq 6$	50%	24%	20%	54%	28%	16%	34%	4%
$\geq 3$	64%	32%	28%	68%	34%	26%	44%	16%
$\geq 9$	48%	24%	16%	50%	24%	10%	20%	2%

Abb. 20 Comparison of the collected odour frequencies based on field inspections with the forecasted frequencies from the submission project (Bachler, 2019)



## 4. Ammonia measurements

At a total of ten points, NH<sub>3</sub> measurements with passive collectors (type 'Radiello') were carried out by the LFL – Institute of Agricultural Engineering and Animal Husbandry (Bavaria) (Abb. 21). A double sampling was carried out at a height of about 3 m above ground (Abb. 22), whereby the mean value was used for the further evaluations. The measurement period covered the period from October 2020 to February 2022, with the change of passive collectors taking place on a monthly basis.

The results of the immission measurements are Tab. 2 listed in. There was a clear decrease in the measured NH<sub>3</sub> concentrations with increasing distance to the stable building, with the lowest values recorded at site W3 at 3 µg/m<sup>3</sup>. In addition to the greater distance to the stable, this is mainly due to the fact that the most common wind directions are north and south. The highest concentrations of around 28 µg/m<sup>3</sup>, on the other hand, were measured at point S1, as this was positioned closest to the stable building on the one hand and directly in the main wind direction on the other. The influence of the stable building on the NH<sub>3</sub> immissions is therefore clearly visible from the measurement results.

Tab. 2 Measuring averages of NH<sub>3</sub> measurements in [µg/m<sup>3</sup>] for the evaluation period from January to November 2021

	N1	N2	N3	E1	S1	S2	S3	W1	W2	W3
MEAN	25,6	6,8	6,1	7,8	28,4	9,9	7,3	7,2	4,0	3,0

Abb. 21 Location of survey points for ammonia measurements

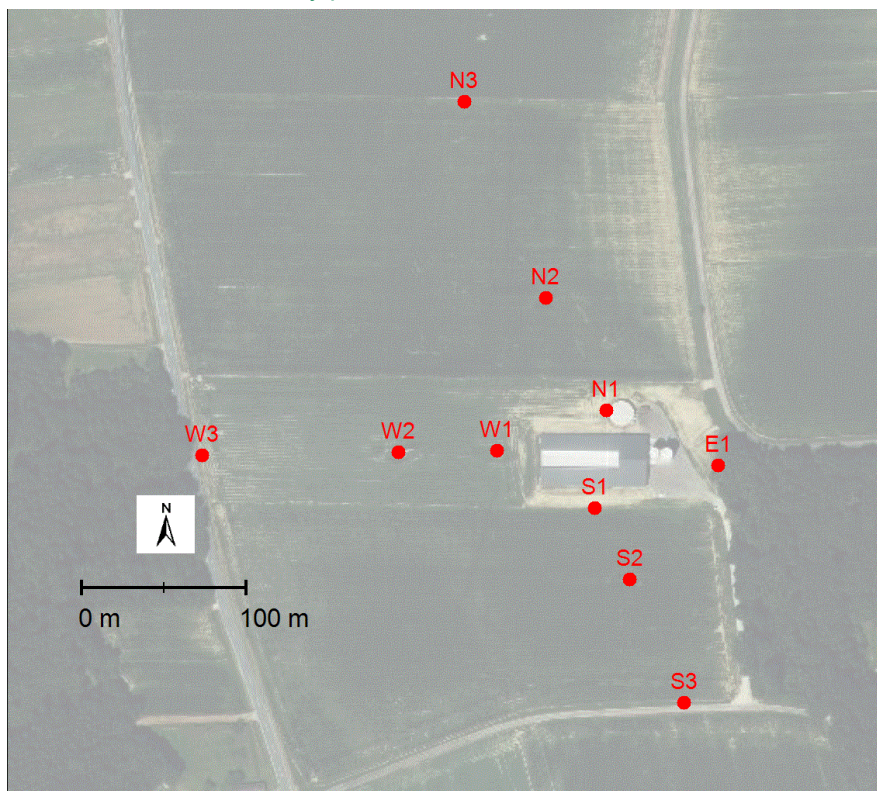


Abb. 22 Collector's equipment for NH<sub>3</sub> measurement



## 5. Propagation modelling

### 5.1. Model description

For the propagation calculation, the Lagrange propagation model GRAL was used. A comprehensive description of the model, including evaluation based on numerous propagation experiments, can be found in Öttl (2020). The propagation of air pollutants is determined by spatial flow and turbulence processes. In addition to the propagation conditions, these are also dependent on the terrain structure, constructions and different land uses for near-ground sources. With Lagrange's particle models, diffusion can also be simulated physically correctly in the close range of emission sources, which, in contrast, is not possible with prognostic Euler models. In Lagrange's particle models, the dispersion of pollutants is simulated by a large number of particles, the movement of which is determined by the predetermined mean wind field and superimposed turbulence. In addition, inhomogeneous wind and turbulence conditions and any forms of pollutant sources can be taken into account.

#### 5.1.1. Suitability of the model

In Austria, there are no legally binding rules for the use of a specific propagation model. Therefore, the technical basis 'Quality Assurance Spread Calculation' (BMWfJ, 2013) and the ÖNORM M9440 set out the following requirements with regard to proof of model suitability:

- Presentation of model physics, preferably in peer-reviewed journals
- Presentation of evaluation studies, in particular if buildings or vegetation, odour, flue gas plume elevations, wind-weak weather conditions, terrain influence, sedimentation, deposition or air-chemical reactions are important for the application.

Evaluation studies using the GRAL propagation model have been published so far in 21 scientific papers in internationally peer-reviewed journals. In particular, scientific evidence has been provided in the following specialist areas:

#### Weak weather conditions:

Weather conditions with low wind speeds lead to large wind direction rotations, which cannot be modelled with sufficient precision by many available models. The algorithm implemented in GRAL is based on scientifically recognized methods, which have been published in several articles (e.g. Öttl et al., 2005).

#### Development:

Construction can lead to significant changes in the small-scale spread of pollutants and odours. To take these effects into account, the GRAL model has an upstream microscale flow model. This prognostic, non-hydrostatic model was developed on the basis of VDI guideline 3783 sheet 9 'Prognostic microscale wind field models. evaluation for building and obstacle flow.'; The results can be found in detail in the documentation of the GRAL model or have been published partly scientifically (Öttl, 2015).

#### Foliage:

The influence of vegetation on microscale flow conditions is taken into account according to Green's (1992) proposal. Here, the flow resistance is calculated by vegetation areas over the leaf area density and the vegetation height, separated by trunk and crown area.

### 5.1.2. Odour modelling

The assessment of odours in Austria is based on so-called annual odour hours. An hour of smell is defined in such a way that in 10% of an hour smell must be perceptible. Thus, it is necessary to determine the 90 percentile of the concentration distribution within one hour. This is calculated individually for each grid point depending on the mean total odour concentration distribution at each hour of the year and the turbulence state of the atmosphere and is thus spatially and temporally variable (Öttl and Ferrero, 2017).

The odour threshold used in the calculations for the 90th percentile of the odour concentration distribution within one hour means that odour concentrations within one odour hour must be higher than this specified odour threshold in 10% of the time. If the odour threshold is 1 GE/m<sup>3</sup>, this means in the worst case that significantly higher odour concentrations often occur in 10% of the time, which not only lead to odour perception but also to odour detection. It could be demonstrated that this method achieves a very good agreement between model calculation and field inspection according to EN16841-1.

## 5.2. Model parameters used

Tab. 3 Methodology and input parameters for the GRAL propagation model used

Model version	GRAL 20.1
terrain	Not taken into account
Terrain - GRAL	Not taken into account
Buildings, vegetation	Microscale non-hydr. prognostic flow model, mixing path turbulence model Horizontal resolution: 3 m Vertical resolution: 1 m, vertical spread factor 1.00
	Min. time steps: 100 Max. time steps: 500 Model upper edge for obstacle flow: 26 m Roughness of building walls: 0.001 m
Counting grid for concentration	3 m horizontally, 1 m layer thickness, evaluation height 2 m above ground
Area size	540 m x 490 m
Number of particles	360,000 per hour

Soil roughness 0.1 m

Abb. 23 Input parameters for GRAL

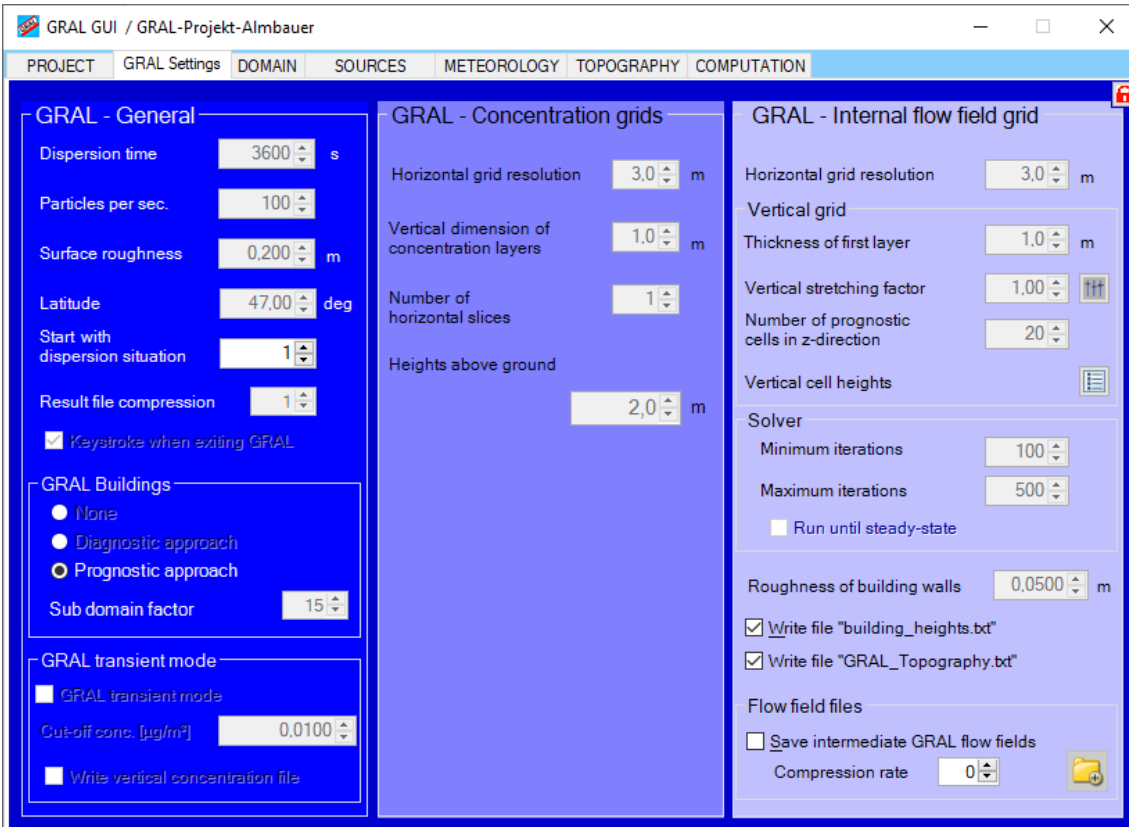
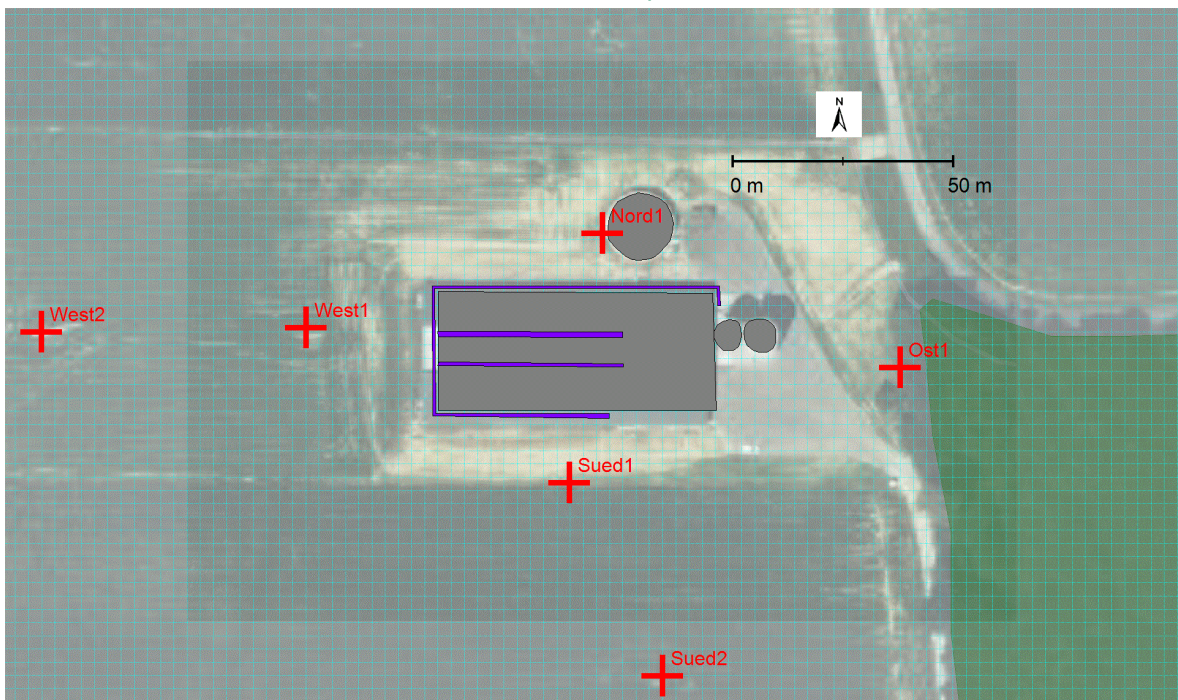


Abb. 24 Model area, building, vegetation and location of the stable



Abb. 25 Distribution of diffuse emission sources for dispersion calculations

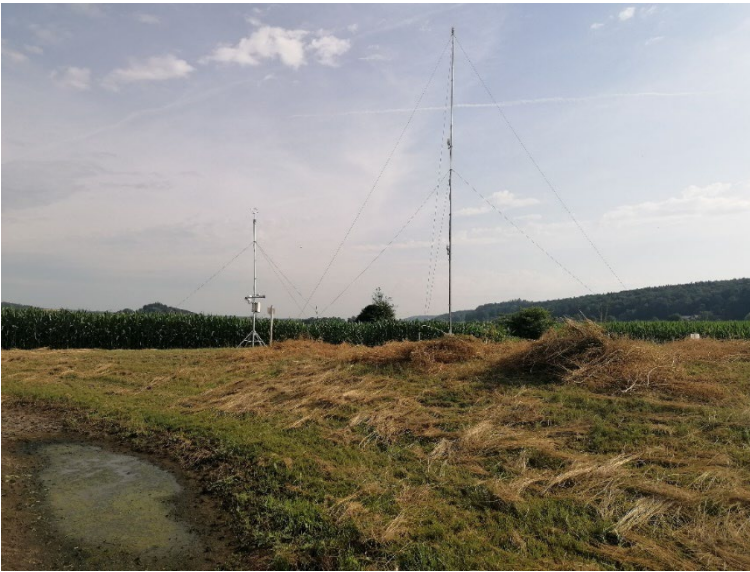


## 6. Determination of emission factors

At the beginning of the odour inspections on 10.1.2022, the surrounding arable land lay fallow. Until the end of the ascents on 12.7.2022, these were predominantly covered with maize (approx. 3m height). As a roughness length 0.1 m was used uniformly in the propagation calculations.

Over the entire survey period, meteorological measurements (278 m above sea level) were carried out on site (Abb. 26). The wind speed and direction were measured with several ultrasonic anemometers at different altitudes, as well as the air temperature at three altitudes and the global radiation. From these data, ÖNORM M9440 dispersion classes (GRAL method) were determined. Temperature values of the Klösch station at 415 m above sea level were used to determine the necessary nocturnal inversion.

Abb. 26 Meteorological measurements at the operating site



### 6.1. Determination of the odour emission factor

#### 6.1.1. Propagation conditions during odour surveys

As already mentioned, meteorological measurements were carried out at the site of the research stable from 10.1. to 12.7.22. As expected, the measured wind direction distribution has a north-south distribution due to the terrain structure. The average wind speed is 1.2 m/s and the calving frequency (wind speeds below 0.5 m/s) is almost 30%. At night, almost exclusively northern wind directions occur, during the day southern valley winds dominate.

Abb. 27 Measured wind direction and wind speed distribution at 8 m above ground at the farm site (top: Total, middle: Tag, below: night)

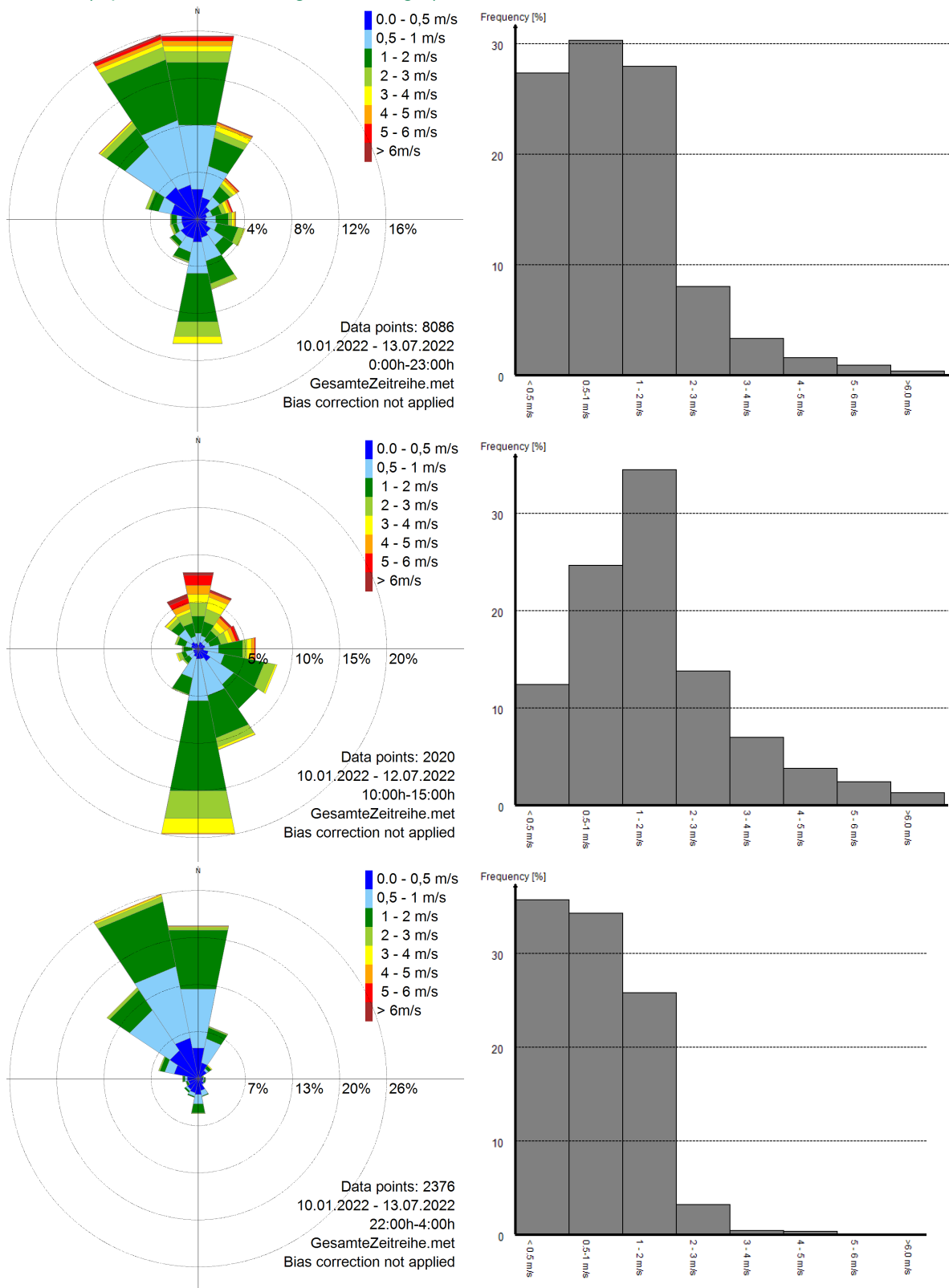


Abb. 28 Measured frequency of selected wind directions and mean daily wind speed in 8 m above ground

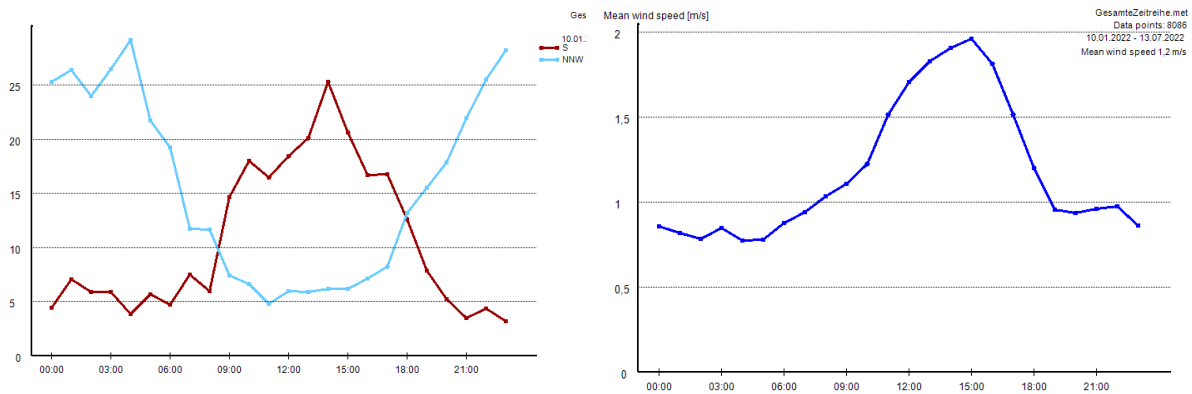
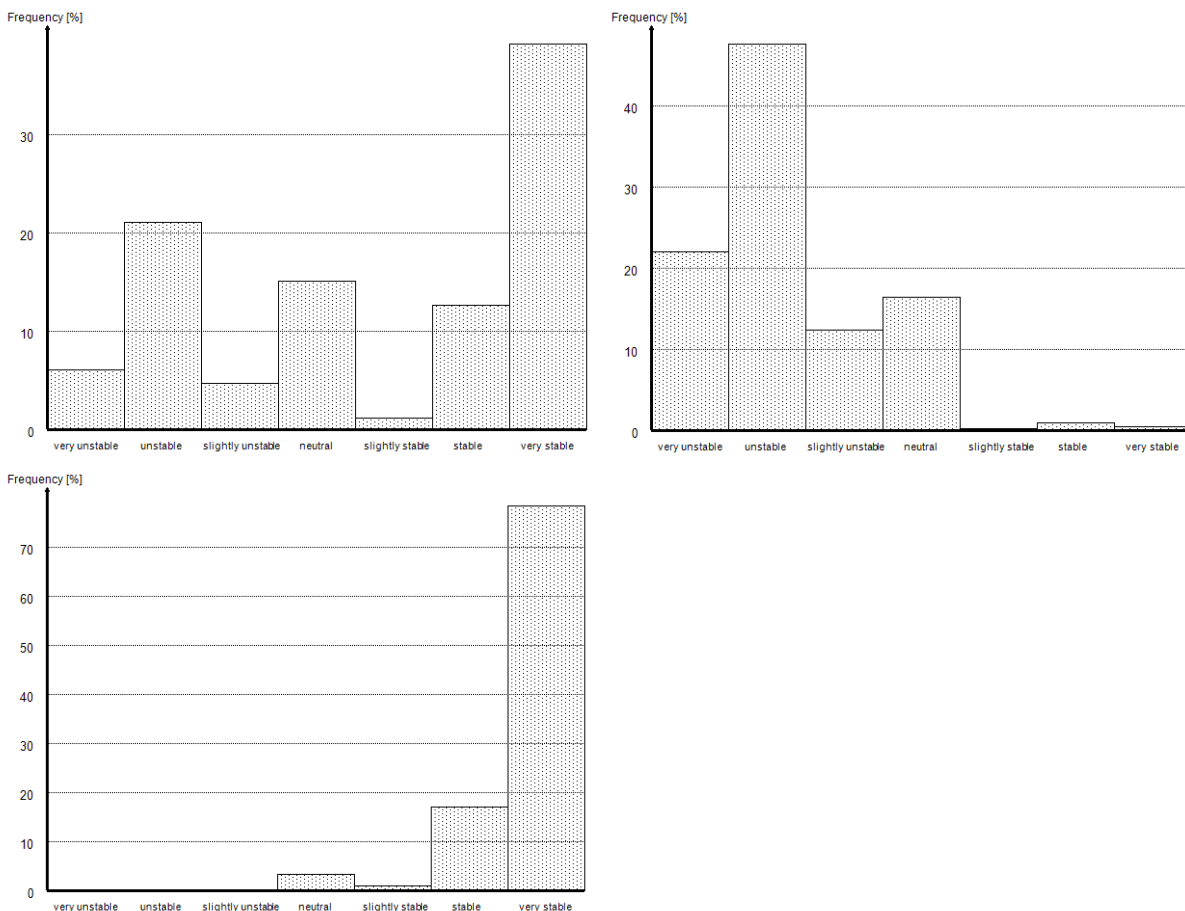


Abb. 29 Frequency of propagation classes (top left: Total, top right: Tag, lower left: night)



## 6.1.2. Results

For the determination of the mean odour load over the observation period of the odour ascents from 10.1. to 12.7.22, the measured meteorological data of the same period were used for the propagation calculation. The initial emission load was 1 MGE/h. This emission load was changed in post-processing until the best possible agreement between collected and modelled odour frequencies was achieved. The mean absolute deviation between collected and modelled frequencies was used for the error calculation, taking into account the uncertainty of the surveys according to VDI 3940-1. This means that simulated frequencies, which were within the 95% confidence interval of the visits, were taken into account with 0% deviation. The minimum error over all eight points (2% deviation) was achieved for an odour load of 3.5 MGE/h (Abb. 30). In principle, there is a very good spatial correlation

between modelled and elevated odour frequencies. A conspicuous underestimation can be seen in points N2 and O1. In particular, the underestimation at point N2 could be explained by background contamination from existing livestock farms north of the research stable.

Based on the mean number of animals for fattening of 850 pigs and the mean weight of 75 kg during the odour survey period, an emission factor of around 8 GE/GVE/s is obtained. State government, 2021), this is a reduction of almost 95%.

The guideline value for pig odours in the open air (30% annual odour hours) according to the Styrian Odor Immunity Directive (Öttl et al., 2021) is already complied with in the main wind direction at a distance of 120 m and in less than 40 m outside the main wind directions (Abb. 31). The corresponding guideline value for village areas (20% annual odour hours) is no longer exceeded in the main wind direction from a distance of 170 m.

Abb. 30 Collected and modelled odour frequencies with an average emission load of 3.5 MGE/h

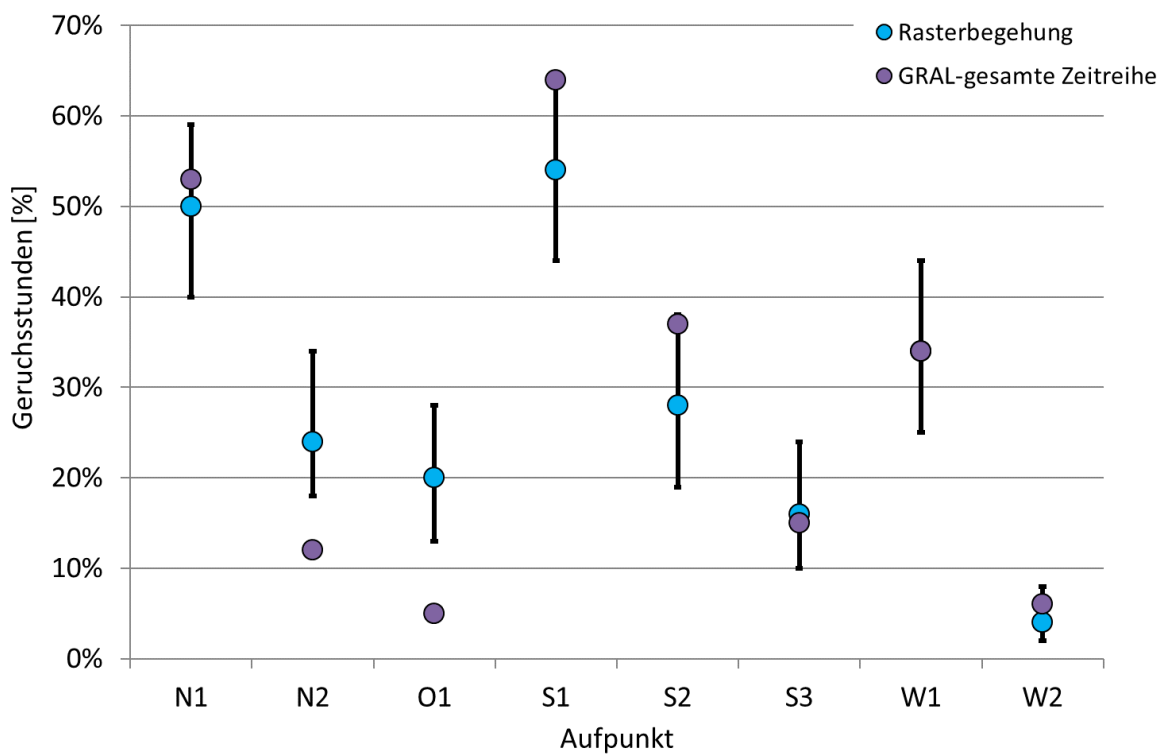
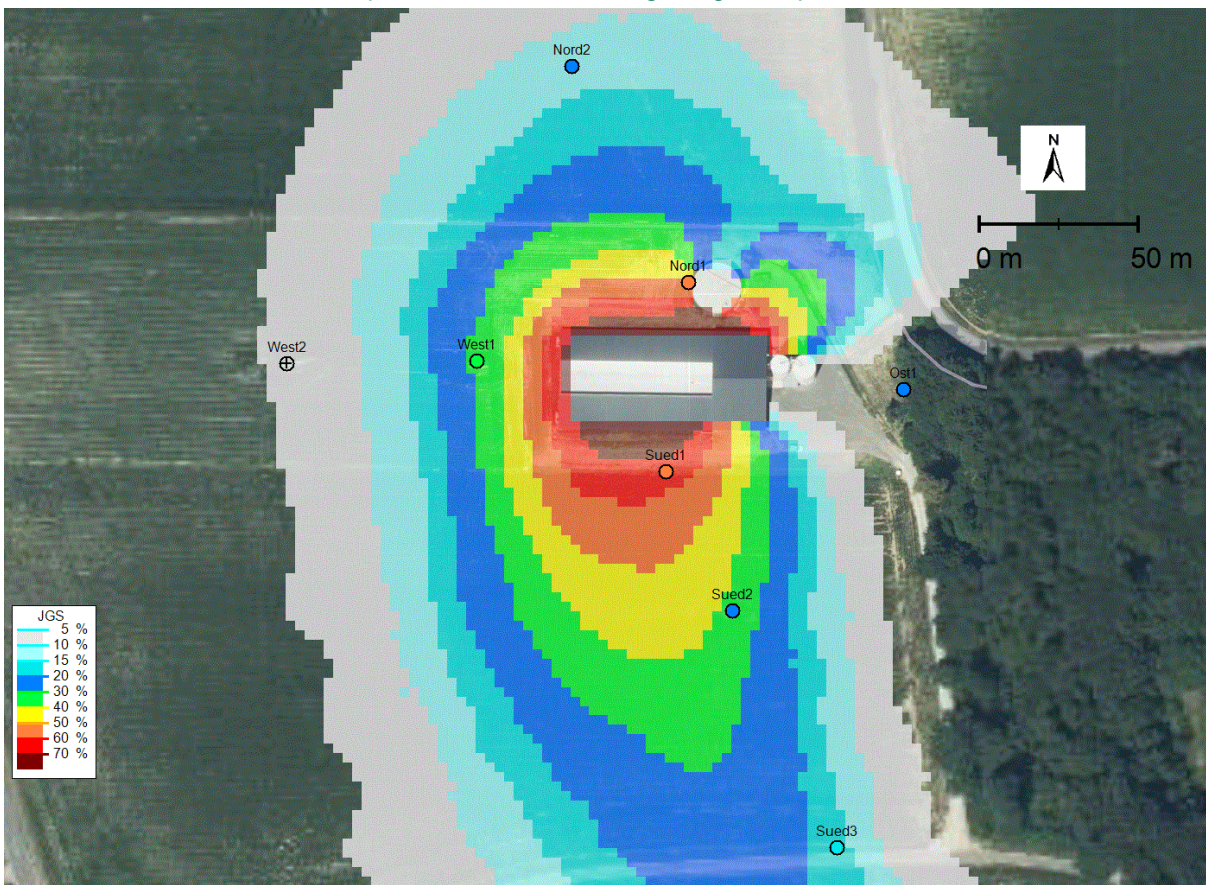


Abb. 31 Result of the dispersion calculation for an average emission load of 3.5 MGE/h and comparison with the odour frequencies collected during the grid inspection



The chosen methodology for determining the emission factors for odour and ammonia on the basis of immission measurements and dispersion calculations is not suitable for determining the reduction effects of the individual mitigation measures in the research stable.

For conventional fattening pig houses in Styria, an emission reduction of 10% is usually assumed by the use of cool pads. Due to the separate functional areas in the research barn, the cooled supply air acts exclusively in the area of the resting bays inside the barn, where the animals do not fade. For this reason, it cannot be assumed that the cooled supply air can reduce emissions. Supply air cooling is therefore of exclusive importance for animal welfare and, in particular, has an impact on the behaviour of the animals in the summer, in the sense that the pigs increasingly visit the rest area during the day.

In Styria, it is currently assumed that outdoor climatic housing will have a 20% reduction effect compared to closed housing systems due to the lower annual average temperature and the associated lower evaporation rate (Eurich-Menden et al 2011, VDI 3894-1).

The reduction factor for two- and three-phase feeding in the pig fattening area of 20% was determined by the studies of Öttl et al. (2018), Mösenbacher et al. (2011), Studies by Le et al. (2007) and the NH<sub>3</sub> reduction data of VDI 3894-1 estimated, assuming that the odour reductions are about half of the corresponding measured NH<sub>3</sub> reductions, such as comparative measurements of odour and NH<sub>3</sub> reductions in feed additives (e.g. Mösenbacher et al., 2011; Zentner et al., 2010).

The functional separation of the activity areas is accompanied by a reduction of the area for the feces. Based on the studies of Ogink and Lens (2001), a reduction potential of about 50% is indicated in Holland for limited emission areas.

Field inspections and model calculations by TÜV Austria (2018) at an open-front stable with multi-phase feeding, permanent removal and feces-urea separation yielded an average emission factor of 20 GE/GVE/s.

It should be noted that the average temperature during the ascent periods was 15.8°C. On the other hand, the average annual average temperature in the examination room is 9.4°C. As stated in the report of TÜV Austria (2018), the actual odour emission in the annual average, based on studies by Schrade et al. (2013), is 50% lower, which corresponds to an annual average emission factor of 10 GE/GVE/s. This factor is in very good agreement with the determined emission factor in this study, which already corresponds to the annual average emission factor due to the long investigation period.

## **6.2. Determination of ammonia emission factors**

The input data for the determination of the NH<sub>3</sub> emission factors were the measured monthly mean values of the NH<sub>3</sub> concentrations from January to November 2021. For this period, the required meteorological input data were also available as 10-minute averages.

### **6.2.1. Spread conditions for the period of NH<sub>3</sub> measurements**

In contrast to the meteorological measurements carried out by the A15 – Air Pollution Control Unit, which only started at the beginning of 2022, the HBLFA Raumberg-Gumpenstein used locally measured data for the period from January to November 2021. In order to be able to determine the propagation classes according to ÖNORM M9440, global radiation values from the Klöch station had to be used. The nocturnal temperature gradient was formed between the measured data in 15 m and 5 m.

As expected, the measured wind direction distribution has a northwest-southeast distribution due to the terrain structure. The average wind speed is 1.4 m/s and the calving frequency (wind speeds below 0.5 m/s) is 10%. At night, almost exclusively northwesterly wind directions occur, during the day southeasterly valley winds dominate.

Abb. 32 Measured wind direction and wind speed distribution at a height of 10 m above ground at the farm site (top: Total, middle: Tag, below: night)

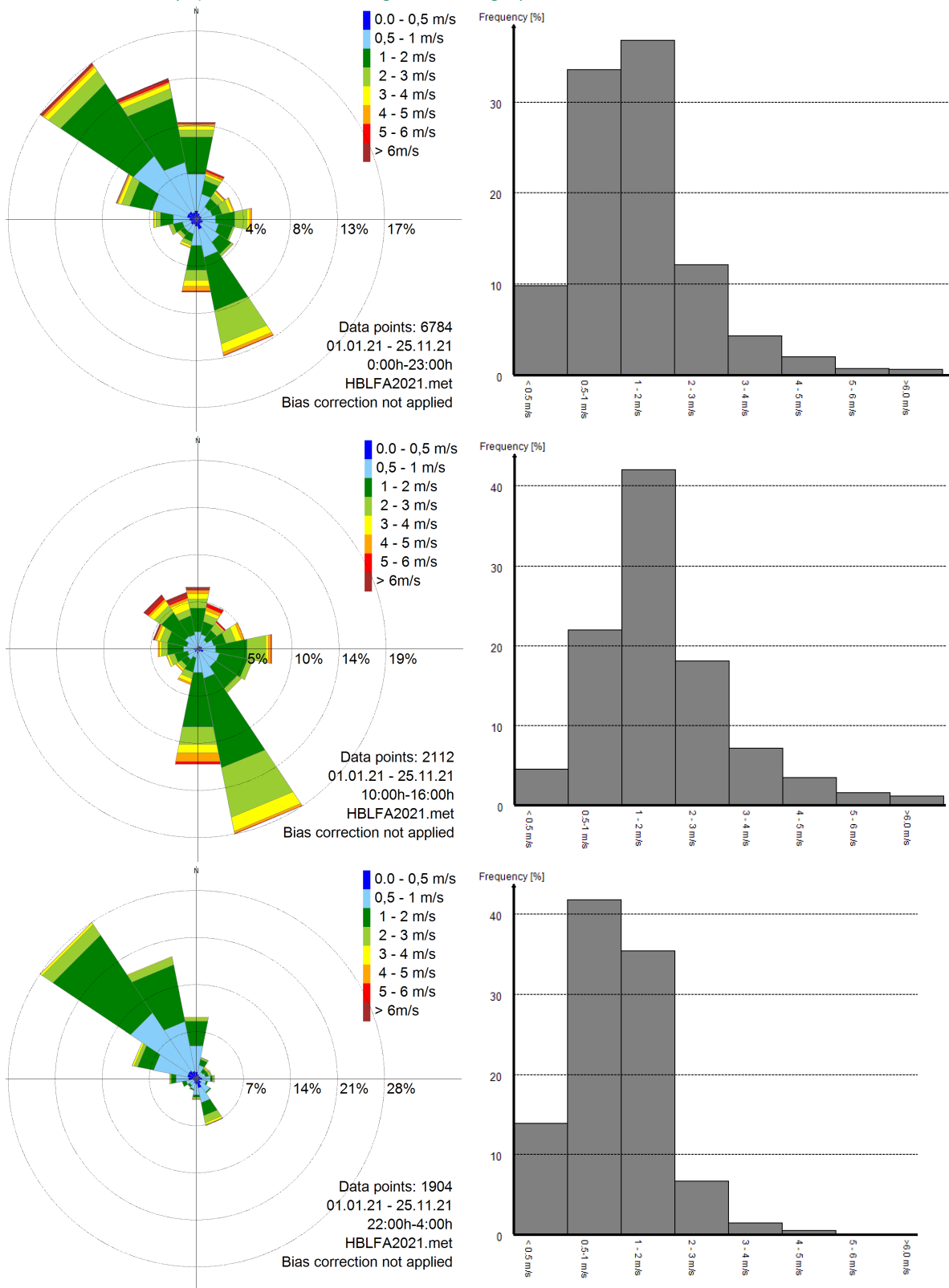


Abb. 33 Measured frequency of selected wind directions and mean daily wind speed in 10 m above ground

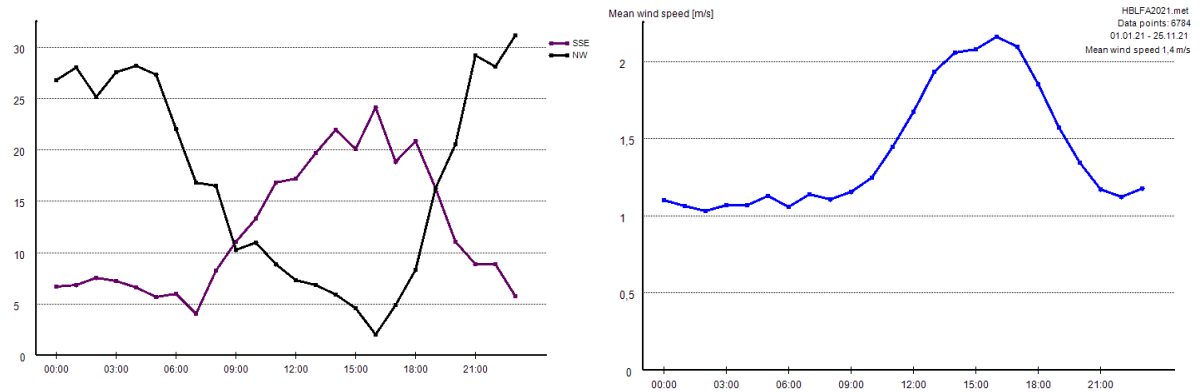
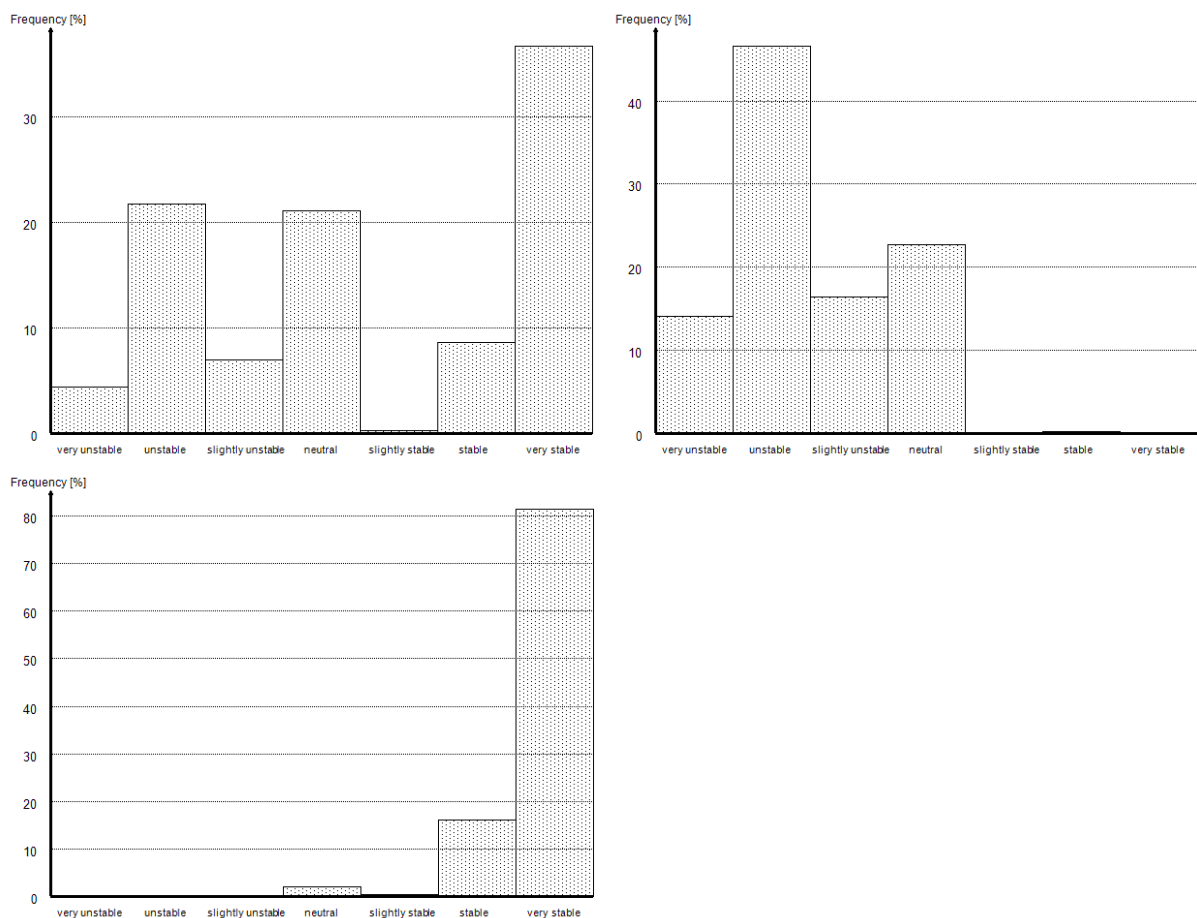


Abb. 34 Frequency of propagation classes (top left: Total, top right: Tag, lower left: night)



## 6.2.2. Results

Similar to the odour modelling, an initial emission load of 1 kg/h was assumed. This emission load was subsequently optimised to achieve the best possible agreement (minimum *Bias*) with the measured concentrations:

$$Bias = \sum_k \sum_i \sum_n |B_n - (M_n \cdot f_i + H_k)|$$

Here,  $B_n$  the respective month-average measured concentration at the measuring point  $n$ ,  $M_n$  the month-average concentration at this measuring point modelled by GRAL,  $f_i$  the modulated emission

and  $H_k$  the modulated background load, which was assumed spatially homogeneously. The latter hypothesis represents a certain simplification of the actual circumstances, since a certain inhomogeneity due to existing surrounding holdings must be assumed.

Abb. 35 shows the total spatial load modelled in this way and the corresponding measured average values for the period from January to November 2021. The modelled and measured values at the individual measuring points are also Abb. 36 shown in. It can be seen that with the optimised values  $\bar{f}_i = 0.07$  of kg/h averaged over all months, and  $\bar{H}_k = 4.0 \mu\text{g}/\text{m}^3$  very good matches can be achieved. This corresponds to an average emission factor of 0.73 kg/a/TP for 850 fattening pigs. Compared to the corresponding base factor of VDI 3894-1 of 3.64 kg/TP/a, this results in a factor of around 80% lower.

Abb. 35 Comparison of the modelled  $\text{NH}_3$  immission load for an average emission load of 0.07 kg/h and an average background load of  $4.0 \mu\text{g}/\text{m}^3$  with the measured  $\text{NH}_3$  concentrations

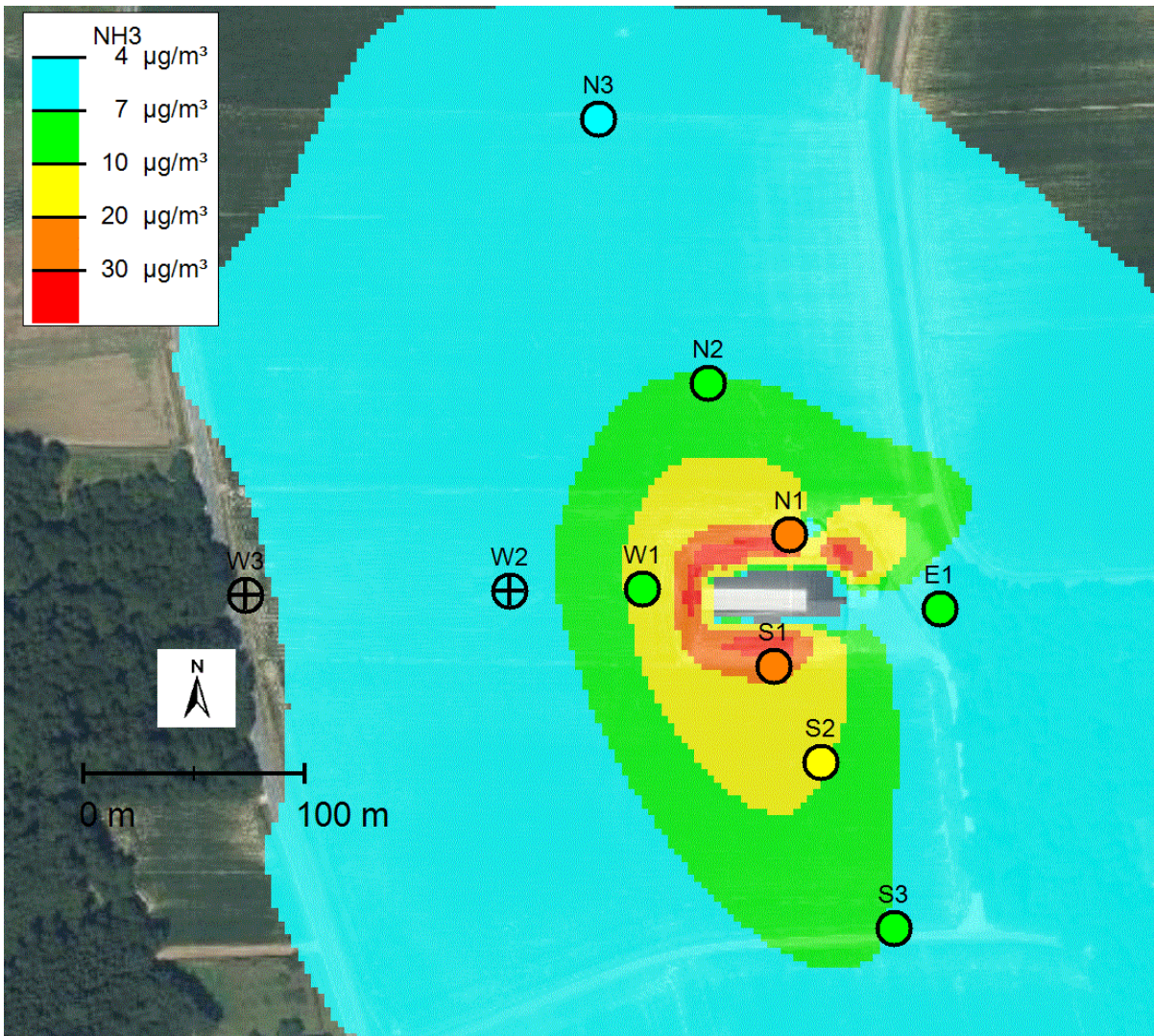
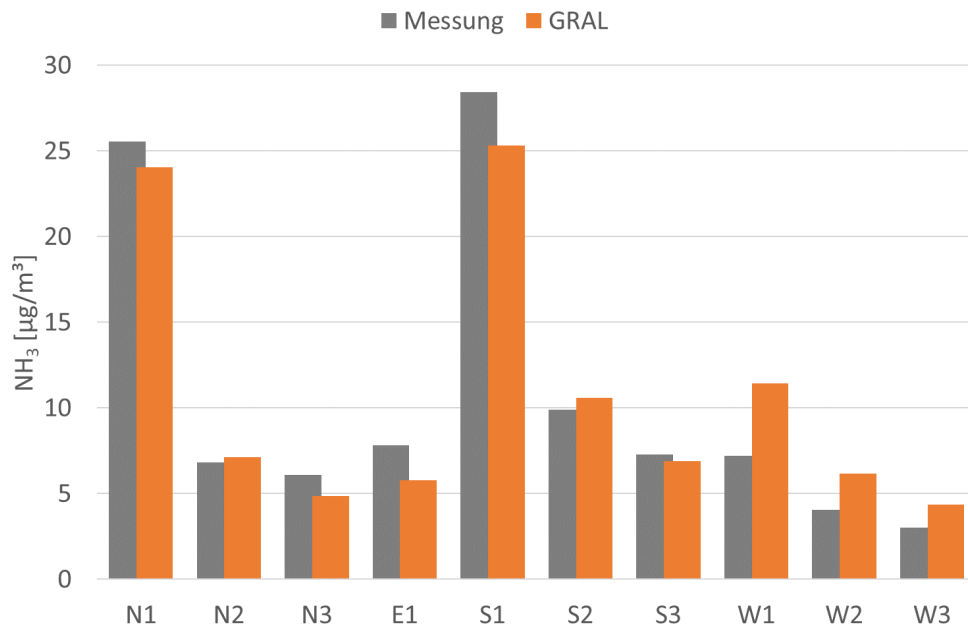
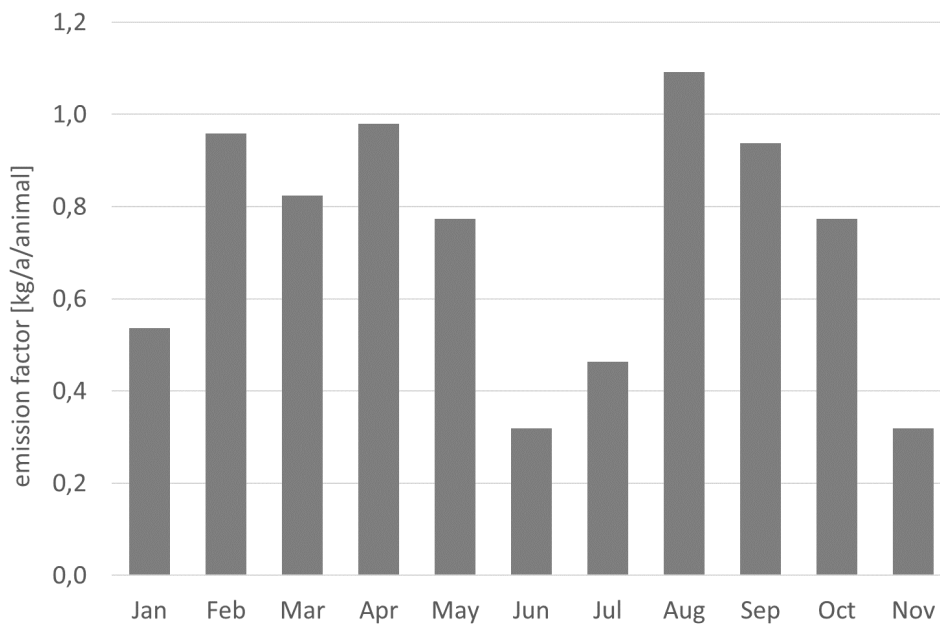


Abb. 36 Comparison between measured and simulated NH<sub>3</sub> concentrations at the individual measuring points



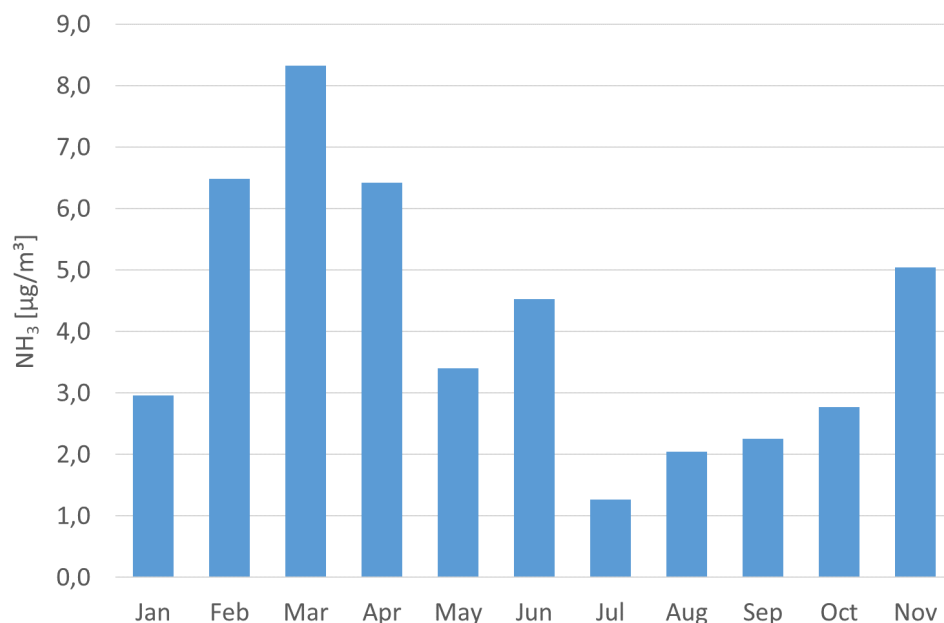
The calculated monthly averages of the emission factors Abb. 37 are shown. The low values in the months of June and July are particularly striking.

Abb. 37 Calculated emission factors for each month



The seasonal course of the simulated background loads can be Abb. 38 seen in. As expected, this shows that higher background loads occur in spring and late autumn, which is due to the application of manure to the surrounding fields. The mean value of 4.0 µg/m<sup>3</sup> for background load is in very good agreement with recent measurement results in southern and eastern Styria.

Abb. 38 Calculated monthly averages of NH<sub>3</sub> background concentration



## 7. Literature

- Office of Stmk. Provincial Government (2021): Odour emissions from animal husbandry. Report No LU-01-21, 12 p.
- Bachler (2019): Odour assessment for the construction of a stable building with 850 fattening pig places from 27.5.2019 (GZ: ABT15-98401/2018-8)
- BMWFJ (2013): Technical basis for quality assurance in the air pollutant dispersion calculation. Federal Ministry for Economic Affairs, Family and Youth, Vienna, 27 S
- Broer, L. (2021): Odour emission measurements on free-ventilated pig houses. VDI Conference on Odours in the Environment, Wiesbaden 24.-25.11.21, Report No. 2383, 31-40
- EN 16841-1 (2016): Ambient air – Determination of odour in ambient air by using field inspection – Part 1: Grid method. Draft version. 53 pp
- Eurich-Menden, B., H. Döhler, H. Van den Weghe (2011): Ammonia emission factors in agricultural emission inventories - Part 2: Poultry and fattening pigs. *Agricultural technology*, 66, 60 - 63
- Green, S.R. (1992): Modeling Turbulent Air Flow in a Stand of Wide-Spaced Trees. *The PHOENICS Journal of Computational Fluid Dynamics and its Applications* 5, 294 – 312, Wimbledon
- Le, P.D., A.J.A. Aarnink, A.W. Jongloed, C.M.C. Van der Peet-Schwering, N.W.M. Ogink, and M.W.A. Verstegen (2007): Effects of dietary crude protein level on odour from pig manure. *Animal*, 1, 734-744
- Mösenbacher, I., G. Huber, J. Gasteiner, Ch. Bachler, M. Mayer, J. Zainer, S. Brettschuh, B. Rudorfer, A. Schauer, R. Kitzler, J. Kaufmann, B. Steiner (2011): Investigation of a feed additive with regard to emission reduction and performance data taking into account the IEP (IPPC) Directive. *HBLFA Raumberg-Gumpenstein*, 3594, 32 S
- Ogink, N.W.M., P.N. Lens (2001): Odour emissions from livestock operations (original title: Geuremissie uit de veehouderij. Overzichtsrapportage van geurmetingen in de vakrenshoudrij,

- pluimveehouderij en rundveehouderij). Institute for Agricultural and Environmental Engineering IMAG-DLO, Netherlands
- ÖNORM EN 13725 (2006): Air quality – Determination of odour concentration with dynamic olfactometry (consolidated version), 74 S
- ÖNORM M9440 (2019): Propagation of air pollutants in the atmosphere. Calculation of immission concentrations. Vienna, 22 p.
- Öttl, D. (2015): Quality assurance of the prognostic, microscale wind-field model GRAL 14.8 using wind-tunnel data provided by the German VDI guideline 3783-9. *Journal of Wind Engineering & Industrial Aerodynamics*, 142, 104-110
- Öttl, D. (2020): Documentation of the Lagrangian Particle Model GRAL Vs. 20.1. Office of Stmk. Provincial Government, Graz, 208 p. <http://lampz.tugraz.at/~gral/>
- Öttl, D., A. Goulart, G. Degrazia, D. Anfossi (2005): A new hypothesis on meandering atmospheric flows in low wind speed conditions. *Atmos. Environ.*, 39, 1739 - 1748
- Öttl, D., and E. Ferrero (2017): A Simple Model to Assess Odour Hours for Regulatory Purposes. *Atmospheric Environment*, 155, 162-173
- Öttl, D., H. Moshhammer, M. Mandl, L. Weitensfelder (2021): Directive on the assessment of odour immissions. Office of Stmk. Provincial Government, Report No LU-02-21, 20 pp. [http://app.luis.steiermark.at/Reports/Download/Technical Reports/ABT15\\_Lu\\_02\\_2021\\_Odour Guideline.pdf](http://app.luis.steiermark.at/Reports/Download/Technical Reports/ABT15_Lu_02_2021_Odour Guideline.pdf)
- Öttl, D., M. Kropsch, and M. Mandl (2018): Odour assessment in the vicinity of a pig-fattening farm using field inspections (EN 16841-1) and dispersion modelling. *Atmos Environ*, 181, 54-60
- Schrade, S., B. Steiner and M. Keck (2013): Ammonia emissions from dairy farms and mitigation measures. In: *Bautagung Raumberg-Gumpenstein 2013*, 33-40, <https://www.researchgate.net/publication/264155543>
- TÜV Austria (2018): Odour ascents and dispersion calculations at the outdoor climate pig stable Langdorf 3, 4714 Meggenhofen. Report No 17-IN-AT-UW-WE-EX-267, 97 p.
- VDI 3894-1: Emissions and immissions from livestock farms. Farming methods and emissions pigs, cattle, poultry, horses. Düsseldorf (2009) S 46
- VDI 3940-1: Determination of odour immissions by inspection – Determination of the frequency of immission of identifiable odours – Grid measurement. Düsseldorf 2006
- Zentner, E., G. Huber, I. Mösenbacher-Molterer, J. Gasteiner, Ch. Bachler, S. Brettschuh, M. Mayer, J. Zainer, Th. Guggenberger, A. Leithold, A. Schauer, M. Urdl, M. Velik, J. Kaufmann, B. Steiner, R. Kitzer (2010): Final report Biomin feed additive. Examination of a feed additive with regard to emission reduction and performance data. LFZ Raumberg-Gumpenstein, 27 S



Das Land  
Steiermark

→ Energie, Wohnbau, Technik