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Assessment of Odour and Ammonia Impacts for a Novel Fattening Piggery Tailored for Animal Welfare and Low Emission Rates

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Abstract: According to the European Commission, Austria is obliged to reduce ammonia emissions by 12% between 2005 and 2030. Agriculture, in particular livestock buildings and the spreading of manure, is the predominant source of ammonia in most countries, calling for stringent mitigation measures in this area. This study investigated a combination of measures implemented in a newly constructed fattening piggery in Styria (Austria) for reducing ammonia, particulate matter (not subject of this publication), and odour emissions. Additionally, the livestock building should meet standards to enhance animal welfare as well. Based on observed ammonia concentrations at several locations in the vicinity of the farm as well as field inspections for odour according to EN 16841-1, corresponding emission factors were derived using the Lagrangian particle model GRAL and in situ measurements of meteorology. The resulting emission factor for ammonia was found to be 80% lower compared to the standard emission factor of 3.64 kg a^{-1} for fattening piggeries according to the German guideline VDI 3894-1. Moreover, the emission factor for odour was 95% lower than the standard factor of 0.180 ou_E kg^{-1} s^{-1} used in Styria for conventional fattening piggeries without any reduction techniques.

Keywords: Salu_T; GRAL; fattening piggery; ammonia; odour; emission factor; animal husbandry

Citation: Oettl, D.; Zentner, E.; Zentner, A.; Mair, R.; Oettl, H.; Kropsch, M. Assessment of Odour and Ammonia Impacts for a Novel Fattening Piggery Tailored for Animal Welfare and Low Emission Rates. *Atmosphere* **2023**, *14*, 75. https://doi.org/10.3390/atmos14010075

Academic Editors: David Janke, Sabrina Hempel, Chaoyuan Wang and Yunhua Chang

Received: 24 October 2022
Revised: 15 December 2022
Accepted: 23 December 2022
Published: 30 December 2022

1. Introduction

In recent years, globalization has set Austria's fattening-pig production under economic pressure due to the comparably small farm sizes. According to the Austrian Federal Ministry for Agriculture, Forestry, Regions and Water Management, roughly 2.8 million pigs are kept by 24,200 farmers (https://info.bml.gv.at/en/topics/agriculture/agriculture-in-austria/animal-production-in-austria/pig-keeping-in-austria.html accessed on 24 October 2022) resulting in an average of little more than 100 pigs per farm. The high share of mountainous regions in Austria often sets natural limits for expanding farms towards very large animal numbers. In Styria, which is among the most productive regions in Austria concerning fattening pigs, only a few farms hold more than 1500 fattening pigs. Therefore, alternative forms of production emphasizing animal welfare are on the rise. Aside from that, the European Commission issued target values for 2030 for reducing ammonia emissions in each member state [1]. As agriculture is responsible for more than 90% of ammonia emissions in the European Union [2], stringent abatement strategies mainly within this sector must be developed. Moreover, complaints about odour nuisance arising from livestock buildings are among the most frequent issues regional authorities must deal with. Hooiveld et al. [3] found that odour annoyance can be associated with reduced general health and increased reporting of respiratory, gastrointestinal, neurological and stress-related symptoms. As ammonia emissions from fattening piggeries are partly correlated with odour emissions, reducing them would help to minimize this problem as well.

To deal with these difficulties, a new kind of livestock building for fattening pigs has been erected in southeaster Styria. Several novel technologies for reducing ammonia, odour, and dust emissions have been implemented. In autumn 2020, pig production started as well as the collection of meteorological (e.g., temperature, humidity, wind) and air-quality data (e.g., particulate matter, ammonia), which has been collected within the livestock building and in the surroundings of the fattening piggery. In the next section, the abatement measures implemented in the livestock building are highlighted and in Section 3 the methodology used for deriving emission factors for ammonia and odour is outlined. Results are presented in Section 4, followed by a discussion of emission rates found in previous studies in Section 5. Finally, conclusions are drawn in Section 6.

2. Description of the Fattening Piggery

The livestock building for fattening pigs offers three compartments to foster animal welfare: (i) a rest zone inside the shed with reduced light and a thin straw layer (approximately 50 g per animal and day), (ii) a zone for taking up food and water outside, and (iii) a small excretion area with a perforated floor made of plastic (Figure 1). The whole area outside is covered by a roof and can optionally be protected from intense irradiation or adverse weather conditions (e.g., strong winds, high relative humidity) by roller blinds. The temperature inside can be conditioned either by an underfloor heating system for the winter months or fresh air cooled by heat exchangers at the inlets (so-called ‘cool pads’). In this way, a maximum degree of comfort for the pigs should be guaranteed, which in addition shall keep the animals from excreting inside. Moreover, a mixture of organic oil and water is sprinkled regularly via numerous nozzles in the compartments inside for minimizing airborne particulate matter concentrations. The straw is initially cleaned using dust filters before application.

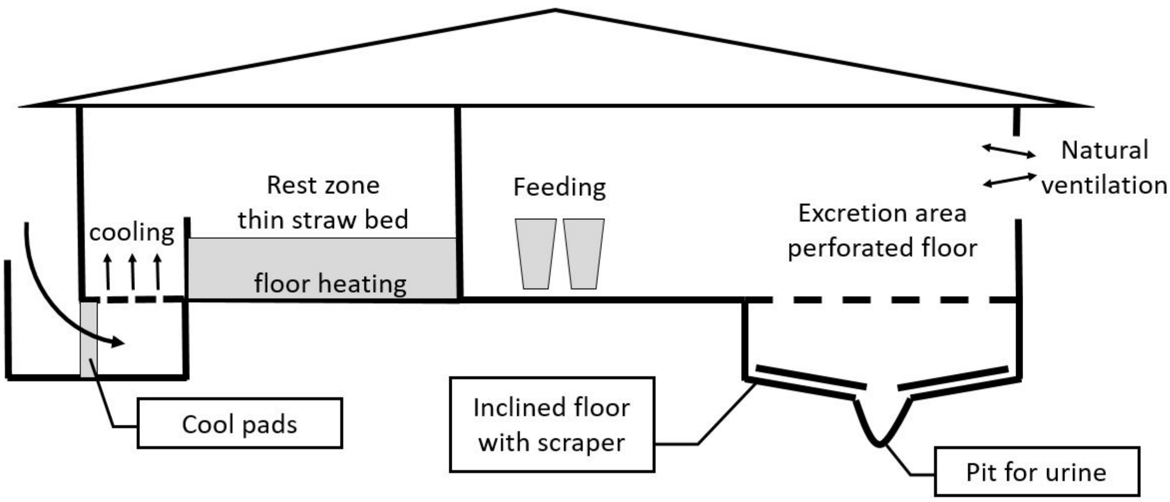

Figure 1. Sketch of the fattening piggery with the various areas for resting, feeding and excretion.

One of the key techniques for reducing ammonia and therefore odour emissions is the separation of the liquid and solid fraction of excrements for avoiding urease. A mechanical scraper under slats for the solid fraction of excrement operated every 2 h in combination with a pit allowing the liquid phase to run off efficiently accomplishes this. Loussouarn et al. [4] observed a reduction in ammonia emissions of at least 40% using a V-shaped scraper in a fattening piggery. The share of protein in the fodder is automatically adjusted according to the growing rates of the pigs in each partition, which is also a well-known technique for reducing ammonia emissions, too (e.g., [5]).

The rest zone inside is flexible in size offering typically 0.20–0.46 m^2 per animal. The corresponding areas per animal for feeding is 0.40 m^2 and for dunging 0.24 m^2. A total of 36 pens are used to separate the animals into smaller groups, whereby the time for moving the piglets in varies from pen to pen (i.e., an all-in-all out system is not practiced). The initial weight of the piglets is 30 kg while at the end a weight of 120 kg is reached. The whole livestock building comprises space for 850 fattening pigs with an average weight of 75 kg, which did not vary significantly during the observational period.

Multiphase feeding has been applied over the investigation period using five different feed compositions during the growing phase. Table 1 lists some important components differentiated according to animal weight. As can be seen, the share of raw protein, which is the dominant source of potential ammonia emissions, is reduced from 15.90% at the beginning down to 13.83% at the end of the fattening period. The metabolizable energy is being kept rather constant, while lysine is also reduced over the fattening cycle.

Table 1. Composition of the feeding stuff dependent on animal weight for a dry mass of 880 g.

	<35 kg	**35–45 kg**	**45–70 kg**	**70–90 kg**	**>90 kg**
Dry mass [g]	880	880	880	880	880
Raw protein [%]	15.90	15.18	14.77	14.15	13.83
Metabolizable energy [MJ]	12.83	12.91	13.00	12.96	12.99
Lysine [g]	11.77	11.41	11.01	10.24	9.25

3. Methodology

As the livestock building is naturally ventilated via lateral openings causing fugitive emissions, it is impossible to measure the source strengths of ammonia and odour in a direct manner. In this study, dispersion modelling has been used for assessing the corresponding source strengths (e.g. [6]). Therefore, ammonia concentrations have been observed at ten monitoring sites in the vicinity of the livestock building at distances of approximately 15 m, 130 m, and 250 m (Figure 2). According to the observed wind-direction distribution (note that the wind measurements started prior to the ammonia observations), sampling points have been placed along the axis of the main wind directions, which is approximately north-south orientated (Figure 3). Two additional samplers (W2 and W3) have been placed lateral to this axis to capture background concentrations.

Source strengths in the dispersion model have been varied until the mean absolute bias (MAB) between observed (O_n) and modelled concentrations (M_n) had become a minimum.

$$MAB = \frac{1}{n}\sum_{n}|O_n - M_n| \quad (1)$$

Ammonia was measured using passive samplers ([7]) at 2.5 m above ground level. The exposure time was four weeks and analyzation was carried out following the German standard VDI 3869-4 [8] by means of ion chromatography. At each monitoring site, two passive samplers have been placed in parallel for quality control. The average difference between each pair was 0.2 µg m^{-3} over the entire period. In addition, blind samples have been analyzed for each period. The concentration for these samples was <0.1 µg m^{-3} in all cases.

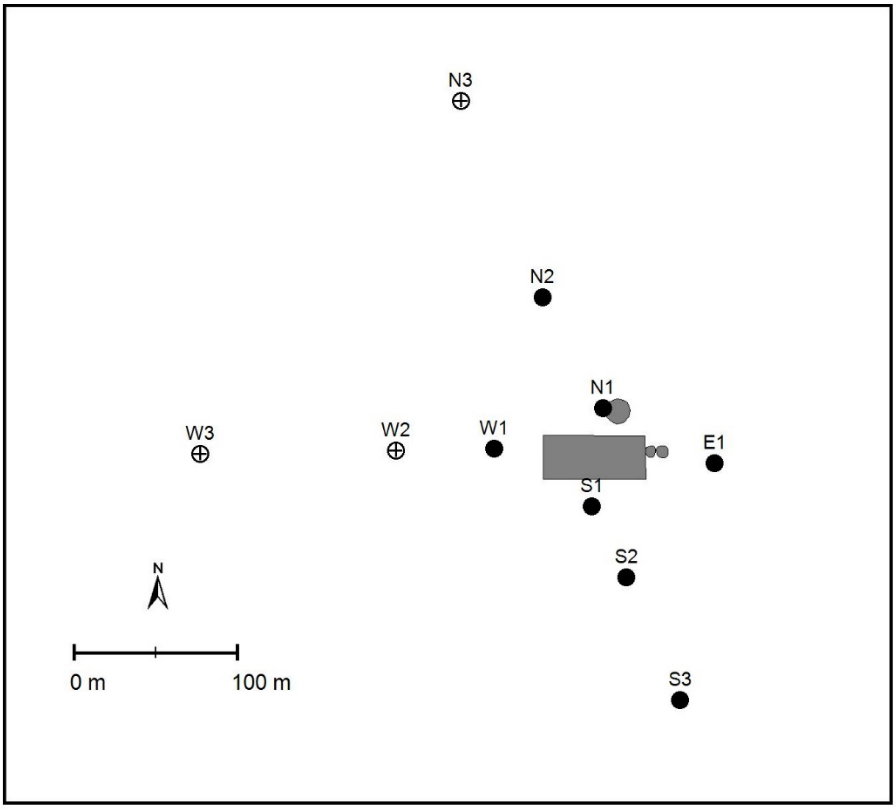

Figure 2. Sitemap of the monitoring sites for ammonia, the fattening piggery including two silos at the east side of the building, and the closed slurry pit north of the livestock building. The modelling domain is marked by the grey rectangle.

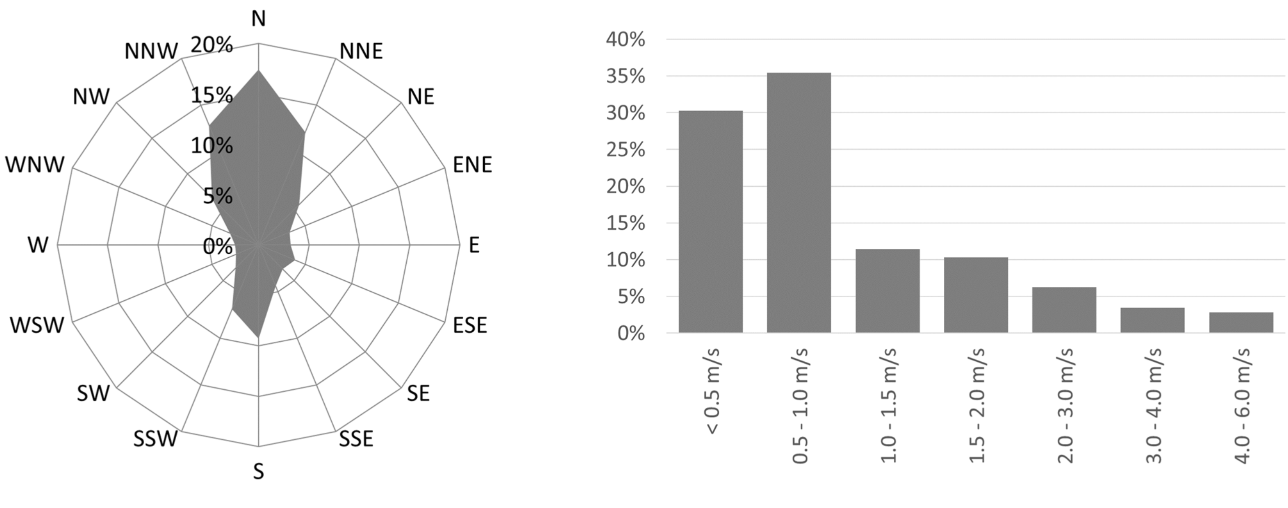

Figure 3. Observed wind-direction and wind-speed frequencies averaged over the period of the field inspections (10 January–12 July 2022).

Odour concentrations cannot be measured by any technical device. Therefore, a different approach had to be adopted for assessing the source strength. The European standard EN 16841-1 outlines how field inspections by trained panellists must be carried out for obtaining odour-hour frequencies. To keep field inspections in a reasonable frame, the time a panellist must evaluate odours at each location is limited to 10 min and the observation frequency is strictly 10 s according to the EN16841-1. At least six odour detections are necessary for the identification of an odour-hour. Simply explained, an odour-hour can be described as the recognition of odour for at least six minutes within an hour by at least 50% of the people exposed to it. A more detailed definition is provided in the German guideline VDI 3788 [9] for instance.

Odour-hours can also be simulated by suitable dispersion models. Based on the work of [10] and [11], 1 OU_E m^{-3} was taken as threshold for the 90th percentile. In other words, if the simulated odour concentration of the 90th percentile is above this threshold, an odour-hour is counted. Using the aforementioned *MAB* it is possible to derive a source strength for odour in a similar way for ammonia. The Lagrangian particle model GRAL (Graz Lagrangian Model [12]) has been used for the dispersion modelling. It is particularly suited for assessing odour-hour frequencies [11,13,14], taking into account horizontal wind meandering in low wind speed conditions [15], and the influence of buildings and/or vegetation on the microscale flow field [16,17]. For a comprehensive discussion about the implementation of methodologies for assessing odour-hours in a dispersion model the reader is referred to [18] or [14].

It should be noted that it is not possible to provide an estimate of the uncertainty of the derived emission factors introduced by the dispersion modelling. However, GRAL has been thoroughly evaluated using various tracer experiments carried out in different environmental settings regarding meteorology, source configurations, and building geometries. Chang and Hanna [19] suggested using an upper bound for the normalized mean square error below 4, and a max. fractional bias of $+/-0.3$ as criteria to define acceptable model performance. GRAL fulfils these criteria in 28 out of 29 experiments used for model evaluation [12]. Moreover, the GRAL model has also been tested using data from a field inspection according to EN16841-1 for a fattening piggery [11]. In this study, no bias was found between computed odour-hour frequencies and observed ones. Brancher et al. [14] evaluated the concentration-variance model used in GRAL for computing odour-hours and found a fractional bias of -0.25 for the computed 90 percentile of the concentration distribution, which were observed at some sampling points in the surroundings of a fattening piggery in Germany [20]. Based on these studies one might expect that the emission factors derived by dispersion modelling with GRAL have a bias of less than $\pm 30\%$.

Another issue that might contribute to the uncertainty is existing background odour concentration, which cannot be readily taken into account in the modelling because of non-linear effects in the calculation of odour-hours. For instance, if an odour-hour is triggered by the emissions from the fattening piggery at a particular location, an existing background odour concentration would not contribute to this odour-hour anymore and vice versa, although it does so regarding the odour concentration. Therefore, observed odour-hour frequencies at greater distances from the fattening piggery, could not be used as background value and added to modelled ones. To take background odour concentrations in the modelling into account, one would need to know the odour-emission strengths from all sources in the surroundings including their temporal patterns. For the estimation of the source strengths information about the activity, feeding, manure handling, etc. for each livestock is required. However, such data were not available for this study.

A total of 53 field inspections have been carried out between 10 January and 12 July 2022 at the same locations where ammonia has been observed, except at the sites N3 and W3 which were not deemed necessary for assessing the odour-emission factor due to the low expected odour impact at these locations. The European standard for field inspections EN 16841-1 [21] requires at least a pool of eight panel members qualified according to EN 13725 [22]. This means that each participant must be able to detect a reference odorant (n-butanol) within a prescribed concentration range (20–80 ppb in the case of n-butanol), which is calculated as an average over at least 10 but not exceeding 20 tests. In addition, the standard deviation needs to be lower than 2.3. Eventually, eight panellists were selected and an additional one was picked as a standby in case of illnesses etc. The panellists have been trained beforehand to make them familiar with the type of odour and the site itself according to the suggestions in EN 16841-1. Surveys must be distributed evenly over the days, hours, and the panellists, which required a lot of planning, particularly in cases of illnesses or other unforeseeable events preventing a field inspection at a scheduled date and time. As can be seen from Table 2, the distribution of the inspections over time and day was in accordance with the requirements of the EN16841-1, while the distribution of the panellists was not. This was due to some COVID-19 cases that complicated the whole study enormously.

Table 2. Sampling frequencies separated for staff, weekday, and time of the day of sampling.

	Staff	Samples	Day	Samples	Time	Samples
	P1	7	Monday	8	0 a.m.	4
	P2	5	Tuesday	7	2 a.m.	4
	P3	5	Wednesday	8	4 a.m.	4
	P4	5	Thursday	8	6 a.m.	4
	P5	9	Friday	8	8. a.m.	4
	P6	8	Saturday	7	10 a.m.	5
	P7	7	Sunday	7	12 a.m.	5
	P8	6			2 p.m.	5
	P9	1			4 p.m.	5
					6 p.m.	5
					8 p.m.	4
					10 p.m.	4
Total		53		53		53

A two-dimensional sonic anemometer was set up northeast of the livestock building about 40 m away and 7 m above ground level. The in situ observed wind speed and direction accompanied by measured air temperature (2 m above ground level) and incoming solar radiation have been used for the model simulations. As mentioned previously, GRAL uses a non-hydrostatic prognostic model to take into account the effects of buildings and vegetation on the microscale flow field. At the inflow boundaries, a first-guess wind field is prescribed, while at the outflow lateral boundaries homogeneous Neumann conditions are imposed to avoid the reflection of waves [23]. Whether any lateral side of the modelling domain is classed as an outflow or inflow boundary is determined at the beginning of any simulation by the direction of the wind component normal to the specific boundary. The first-guess wind field is a simple vertical profile determined by the wind observation at 7 m above ground level and using a power-law function as suggested by US-EPA [24]. The power-law exponent is computed as a function of the aerodynamic roughness length z_0 and the Obukhov length [12]. The latter is derived from the stability class as outlined in the VDI 3783-8 [25]. For more information about the solution techniques used in the microscale flow-field model the reader is referred to [15,16]. After a wind-field computation has been completed, tracer dispersion is modelled with the Lagrangian dispersion module of GRAL until a steady-state concentration field is achieved. Based on the Obukhov length, roughness length and wind speed, turbulence quantities such as friction velocity, standard deviations of wind-speed fluctuations, dissipation rate of turbulent kinetic energy are calculated. For a comprehensive description of the turbulence parameterizations used in GRAL the reader is referred to the model documentation [12].

The average wind-direction and wind-speed frequencies are shown in Figure 3. During nighttime winds from the north prevail, while during daytime wind directions were mainly from the south. Low wind speeds ($\leq$1.5 m s^{-1}) dominated more than 70% of the time emphasizing the need for a dispersion model suitable for treating horizontal wind meandering in such conditions. GRAL requires turbulence information, which has been provided by stability classes derived according to the Austrian standard ON M9440 [26]. In 32% of the time convective conditions predominated, neutral conditions made up 17%, and stable conditions were found in 51% of the time. Figure 4 shows the same as Figure 3 but exactly for the times of the field inspections. It can be seen that the meteorological conditions were comparable. Therefore, no significant bias between modelled and observed odour-hours due to the underlying meteorological conditions is to be expected.

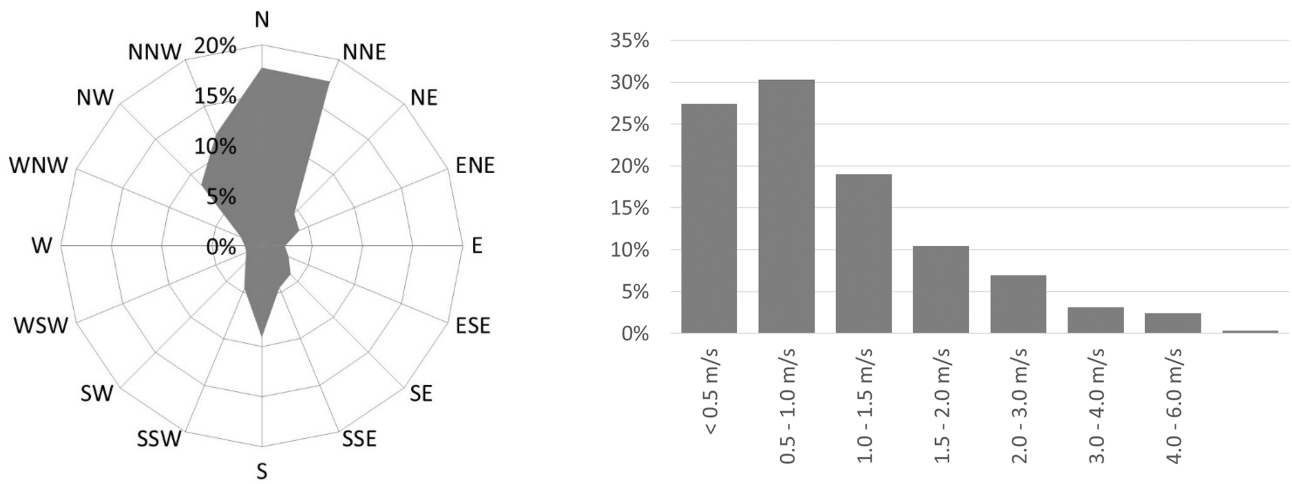

Figure 4. Observed wind–direction and wind–speed frequencies exactly at the times of the field inspections.

The surroundings of the fattening piggery are very flat, hence, topography has been neglected in the simulations. A small forested area is situated approximately 40 m east of the stable, which has been taken into account in the dispersion modelling as well as the livestock building itself by applying a non-hydrostatic prognostic flow-field model prior to dispersion modelling [12,16].

4. Results

4.1. Odour

Figure 5 depicts modelled and observed odour-hour frequencies for the observation period. The vertical bars indicate the 95% confidence interval of the field observations evaluated according to the German guideline VDI 3940-1 [27]. Equivalence of modelled and observed odour-hour frequencies is assumed when modelled values fall within the 95% confidence interval of the field inspections, which is the case for all observational sites except for N2 and E1. Here, the model significantly underestimates observed odour-hour frequencies. The discrepancy might be partly reasoned by occasional odour impacts from other fattening piggeries located approximately 700 m north of the study site. An elaboration of observed wind directions for all cases, where an odour-hour has been detected by panellists at site N2, indicated that in two cases wind directions were exclusively from the north. Excluding these two cases would lower the percentage of odour-hours from 24% to 20% and considering the 95% confidence interval would lead to an overlapping with the corresponding modelled odour-hour frequency. It should be emphasized that odour impacts of other fattening piggeries north of the study area are not likely to increase the odour-hours perceived by panellists south of the livestock building, because in most of the cases the stable itself would trigger an odour-hour even without any background odour concentration caused by these farms.

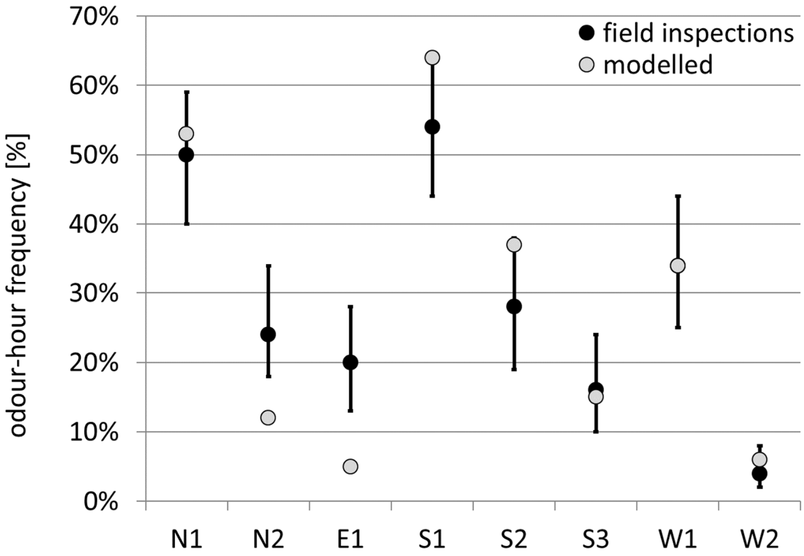

Figure 5. Observed and modelled odour–hour frequencies in the vicinity of the fattening piggery. Vertical bars indicate the 95% confidence interval of the observations.

The simulated pattern of odour-hour frequencies is depicted in Figure 6. An emission rate of 3.5 MOU_E h^{-1} (OU_E = European odour unit) provides the minimum *MAB* (Equation (1)). Due to the frequent northerly wind directions the odour plume extends mainly towards the south. The corresponding odour-hour frequencies derived from the field inspections are depicted by the circles. Modelled odour-hour frequencies exhibit particularly strong gradients close to the fattening piggery, thus, equal magnitudes of modelled and observed odour-hour frequencies can be found just within a few metres around the sites S1 and S2.

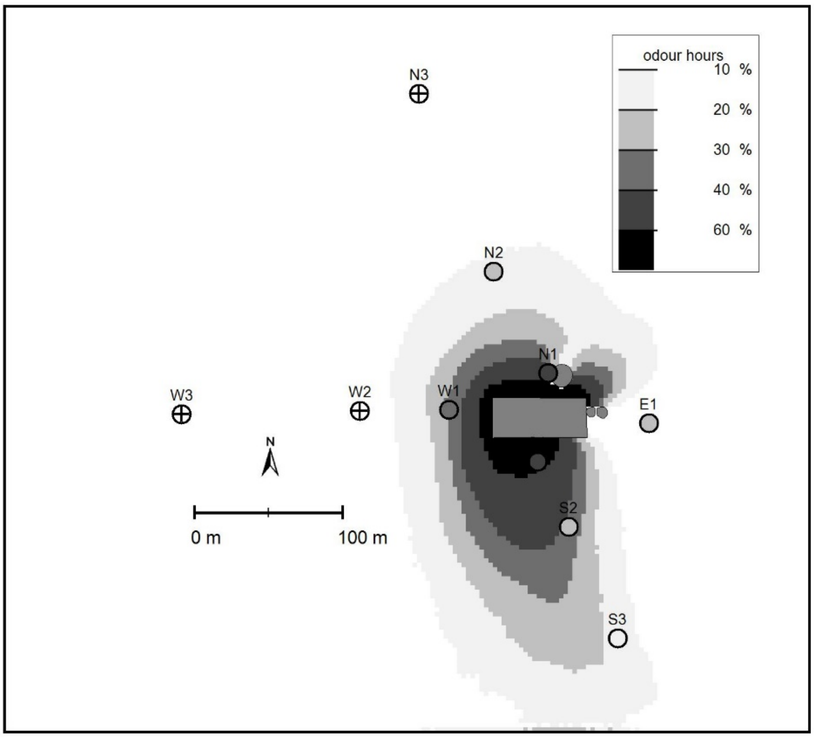

Figure 6. Simulated odour–hour frequencies with the Lagrangian particle model GRAL using an emission rate of 3.5 MOU_E h^{-1}. Observed odour-hour frequencies are depicted by the circles. Sites N3, W2, and W3 were not included in the field campaign.

4.2. Ammonia

Observed ammonia concentrations at the locations as illustrated in Figure 2 for the period from January to November 2021 were used for deriving corresponding emission factors. Highest concentrations were between 25 and 30 µg m^{-3} at the sites S1 and N1 (Figure 7), which are located less than 20 m away from the fattening piggery. At the sampling points W1 and E1, which are also very close to the livestock building, measured ammonia concentrations were below 10 µg m^{-3}. This can be reasoned by the predominant northerly and southerly wind directions. Less than 5 µg m^{-3} were observed at the sampling points W2 and W3. These two sites seem to represent already the prevailing background concentration over the observational period in this area.

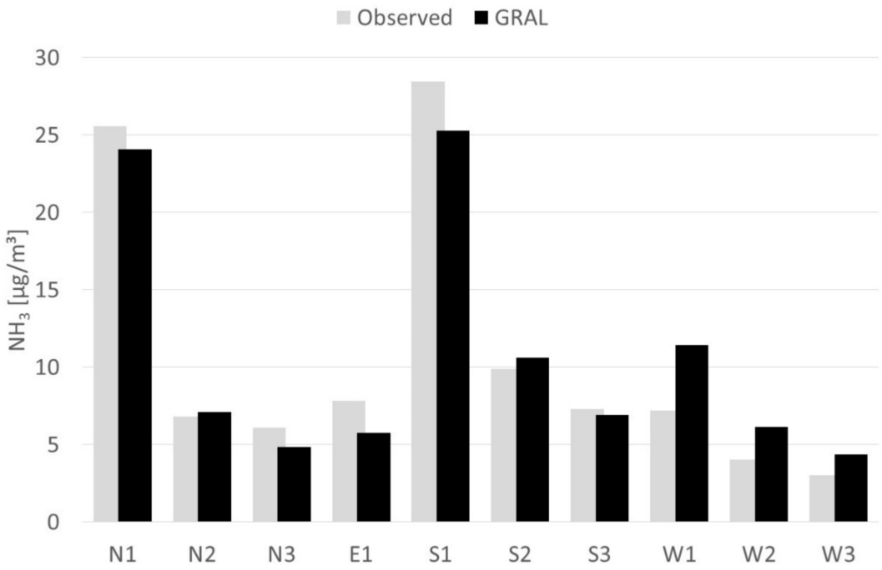

Figure 7. Comparison of observed and modelled ammonia concentrations for each sampling point averaged over the period from January to November 2021.

The meteorological conditions in this period did not differ significantly from the ones during the field inspections for odour. Dispersion modelling has been carried out in a similar way as for odour, while Equation (1) has been slightly amended to take the background ammonia concentrations B_{NH3} into account:

$$MAB = \frac{1}{n} \sum_{n} |O_n - (M_n + B_{NH3})| \tag{2}$$

Equation (2) has been applied using monthly mean ammonia concentrations. Furthermore, the background ammonia concentration was assumed to be horizontally homogenous for each month. This is likely a simplification of real conditions as other sources for ammonia emissions such as fattening piggeries in the surroundings or manure spreading may cause horizontally non-homogenous concentrations patterns. Nevertheless, very good agreement between observed and modelled ammonia concentrations (Figures 7 and 8) were found for an average emission factor of 0.07 kg h^{-1} and a background concentration for ammonia of 4.0 µg m^{-3} over the entire period. The latter is in very good accordance with observed background concentrations in the region. In the period from April 2021 to April 2022 a mean background concentration of 3.9 µg m^{-3} was measured at six sampling sites, which were placed remote from any livestock buildings near the villages of St. Anna and Heimschuh, Styria (Austria). Both are within a distance of about 25 km of the study site and share the same characteristics regarding meteorology and agricultural activities.

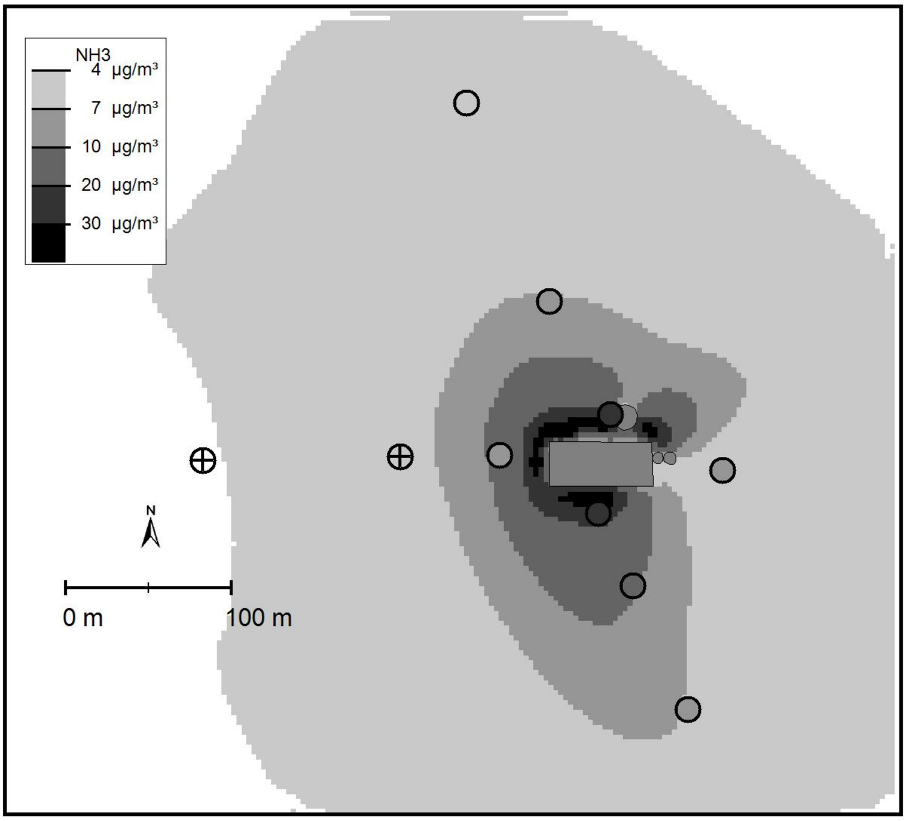

Figure 8. Simulated average ammonia concentrations with the Lagrangian particle model GRAL using an emission rate of 0.07 kg h^{-1}. Observed concentrations are depicted by the circles.

The calculated monthly mean background concentrations for ammonia by applying Equation (2) are shown in Figure 9. A clear seasonal variability with a maximum in spring and autumn is visible, which can be attributed most likely to enhanced manure spreading during these months.

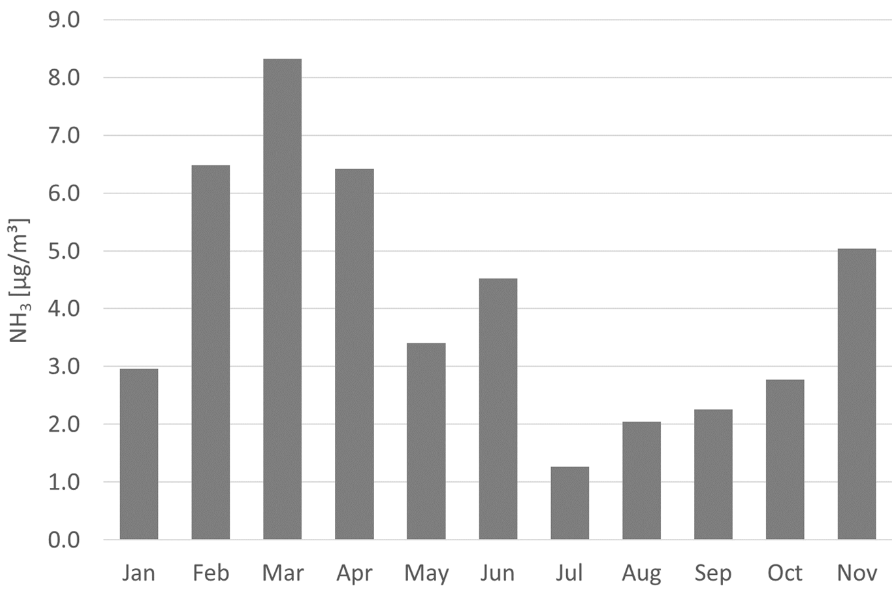

Figure 9. Derived background concentrations for ammonia on a monthly mean basis for the entire observational period from January to November 2021.

5. Discussion

The main drawbacks of the observational campaigns are that they were limited to a single fattening piggery and that the experimental layout did not allow for testing each mitigation technique separately. Therefore, it might be useful to compare the emission rates derived in this study with previously observed emission rates in fattening piggeries, where either none or only single mitigation techniques were implemented. This can give some more insight into the reduction potential of each mitigation technique.

Considering the average number and weight of the pigs over the investigation period (850 animals; average weight 75 kg) would give an odour-emission rate (OER) of 0.015 OU_E kg^{-1} s^{-1} per animal place. This OER is about 95% lower compared to previously measured odour emissions in Styria in conventional fattening piggeries without the reduction measures outlined in chapter 2 [11,28]. Table 3 lists some OER observed in other countries. To allow a comparison of reported OER in the various studies an average weight of 75 kg (as in this study) for the fattening pigs was used to convert OER given in OU_E $animal^{-1}$ s^{-1} into OU_E kg^{-1} s^{-1}. Without any mitigation measures OER are mostly larger than 0.250 OU_E kg^{-1} s^{-1}, except for the standard OER suggested by the VDI 3894-1 [5] of 0.100 OU_E kg^{-1} s^{-1}, which does not compare well with OER from other countries as has already been discussed in [18]. Nevertheless, the reduction potential for protein-adjusted feeding is estimated to be 20% by the VDI 3894-1 [5]. Sun et al. [29] reported about 30% reduction in OER between fully and partly slatted floors in Canada. A quite low OER of 5.9 OU_E animal s^{-1} was found in the Netherlands for a combination of a partly slatted floor and a V-shaped manure belt [30].

Table 3. Comparison of published emission factors for fattening piggeries in the literature.

Study	Emission Factor [OU_E kg^{-1} s^{-1}]	Remarks	Country
This work	0.015	Separation liquid/solid excrements Protein-adjusted feeding Reduced excretion area Excretion area outside	Austria
Oettl et al. [11]	0.277	No reduction measures.	Austria
Mösenbacher et al. [28]	0.282	No reduction measures.	Austria
Sun et al. [29]	0.299	No reduction measures.	Canada
	0.212	Partly slatted floor.	
VDI 3894-1 [5]	0.100	No reduction measures.	Germany
Hayes et al. [31]	0.246	No reduction measures.	Ireland
Rzeźnik and Mielcarek-Bocheńska [32]	0.419	No reduction measures.	Poland
Calafat and Gallego-Salguero [33]	0.196	No reduction measures.	Spain
Ogink and Koerkamp [34]	0.299	No reduction measures.	Netherlands
	0.128	Restricted emitting surface.	
	0.144	Cooled surface of stored slurry.	
	0.145	Flushing system (twice daily)	
Santonja et al. [30]	0.079	V-shaped manure belts Partly slatted floor	Netherlands

It is worthwhile mentioning that the fattening piggery of this study had to undergo the obliged licencing procedure as any other livestock building in Styria. As the exact OER was not available at that time, the following OER was assumed in the odour assessment carried out for the authorities:

OER = 0.180 OU_E kg^{-1} s^{-1} × 0.8 (protein-reduced feeding) × 0.8 (open shed) × 0.9 (cool pads) × 0.25 (separation of excrements and urine) = 0.026 OU_E kg^{-1} s^{-1}

The reference OER of 0.180 OU_E kg^{-1} s^{-1} as well as the reduction factors were taken from the Styrian guideline for estimating OER from animal husbandry as presented in [18]. As can be seen, the assumed reference OER and the reduction factors for each mitigation technique have already been in fair agreement with the OER derived in this work.

An average emission factor for ammonia of 0.73 kg^{-1} a^{-1} per animal place can be derived from this study. The EMEP/EEA (2019) emission inventory guidebook as well as the German guideline VDI 3894-1 [5] suggest an emission factor for fattening piggeries with slurry of 3.64 kg^{-1} a^{-1}. In comparison, the emission factor derived in this study is about 80% lower highlighting the effectiveness of the implemented reduction measures. Further emission rates of other studies are listed in Table 4. As for odour, strong reduction potentials were found for partly slatted floors and V-shaped manure belts [29,30].

Table 4. Comparison of published emission factors for fattening piggeries in the literature (AP = animal place).

Study	Emission Factor [kg AP^{-1} a^{-1}]	Remarks	Country
This work	0.73	Separation liquid/solid excrements Protein-adjusted feeding Reduced excretion area Excretion area outside	Austria
Mösenbacher et al. [28]	*3.26*	No reduction measures.	Austria
Sun et al. [29]	5.68	No reduction measures.	Canada
	3.79	Partly slatted floor.	
VDI 3894-1 [5]	3.64	No reduction measures.	Germany
Hayes et al. [31]	*3.66*	No reduction measures.	Ireland
Santonja et al. [30]	1.05	V-shaped manure belts Partly slatted floor	Netherlands

6. Conclusions

The study reveals that the placement of a V-shaped scraper in combination with a pit for efficiently separating the liquid excrements from the solid ones, a protein-reduced feeding adjusted for the actual growing rate of the pigs, and a reduced area for dunging successfully minimizes the emissions of ammonia and odour from fattening piggeries. The climate conditions prevailing in Austria characterised by very low ambient-air temperatures in wintertime (e.g., the mean winter temperature in the southeast lowlands of Styria over the period of 1981–2010 is approximately 0 °C) help also in reducing emissions when the dunging area is placed outside of the livestock building. Consequently, using the emission factors of this work in different climate conditions requires careful examination about possible influences of ambient air temperatures and possibly wind speeds as well, due to the impact on evaporation fluxes.

Taking the emission factor from the EMEP/EEA [35] for fattening pigs with slurry as reference, a reduction potential of 80% was found for ammonia. Unfortunately, the methodology does not allow for estimating the reduction potentials for each mitigation technique separately. In the future, additional studies at other fattening piggeries will certainly be necessary for confirming the obtained results and for discriminating the reduction potential for each abatement technique. For instance, [29] found about 35% lower ammonia emissions for partly slatted floors compared to fully slatted floors in a fattening piggery in Canada.

It is worthwhile mentioning that an odour-emission factor of 0.02 OU_E kg^{-1} s^{-1}, derived in a study carried out in the region of Upper Austria at a similar fattening piggery [36] using dynamic field inspections and dispersion modelling, is in good agreement with the corresponding emission factor found in this work.

Though odour emissions were found to be on a comparably low level, care must be taken in odour assessment studies for regulatory purposes as emissions are emitted close to the surface. In this study, the maximum setback distance in main wind direction (towards south) would be 170 m based on the corresponding limit value of 20% odour-hours, which is prescribed for rural villages in many regions in Austria [18].

Ultimately, there does not seem to be a trade-off between techniques supporting animal welfare and methods for reducing ammonia and odour emissions in fattening piggeries.

Author Contributions: Conceptualization, D.O.; Methodology, D.O.; Investigation, R.M., A.Z., H.O. and M.K.; Project Administration, E.Z.; Simulations, D.O.; Writing—Original Draft Preparation, D.O.; Writing—Review and Editing, H.O., M.K.; Funding Acquisition, E.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This project received funding from the European Agricultural Fund for Rural Development (EAFRD) under grant Nr. LE 14–20, and the Austrian Federal Ministry for Agriculture, Regions and Tourism.

Institutional Review Board Statement: Ethical review and approval were waived for this study, due to the fact that there exists a national Austrian law strictly regulating animal husbandry (1. Tierschutzverordnung, BGBl. II Nr. 485/2004).

Informed Consent Statement: Not applicable.

Data Availability Statement: Data reported in this study is available on request from the authors.

Acknowledgments: We would like to express our gratefulness to the owners of the fattening piggery Josef and Christine Neuhold for their support (e.g., catering with home-made products) while carrying out the study.

Conflicts of Interest: The authors declare no conflict of interest.

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