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Measurement of Ammonia Emissions in Naturally Ventilated Cattle Housings with an Exercise Yard: Selection of Relevant Accompanying Parameters

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Abstract

Measurements are carried out on six farms to quantify ammonia emissions from naturally ventilated dairy cattle loose housing with an exercise yard. Along with the experimental concept, sampling and analysis of the target figures, the selection and recording of relevant accompanying parameters are decisive to meaningful results and their interpretation. Accompanying parameters describe each measurement situation. They are also influencing variables relevant to ammonia emission. With accompanying parameters, emission data can be tested for plausibility and compared within one farm over the course of time as well as between individual farms. The collection of accompanying parameters must also be coordinated with the recording of target parameters.

Live weight, feed and milk data are needed to describe nitrogen conversion. The potential for ammonia formation in the cattle shed may be characterised by the nitrogen fractions in the urine, the nitrogen content of the excrements on the exercise areas and by the type, degree and proportions of exercise area soiling. In addition to the starting substrate and its pH value, temperature and air speed play a major role in the formation and release of ammonia, along with dung removal. The described accompanying parameters should therefore be integrated into emission measurements.

Introduction

To improve the data basis for ammonia (NH_3) emission inventories, measurements are currently carried out on six commercial farms with cubicles, natural ventilation, solid-floored exercise areas and a peripheral exercise yard. A tracer ratio method with two tracer gases (SF_6, SF_5CF_3) is employed to quantify emissions from housing and exercise yard (Schrade et al. 2007, Zeyer et al. 2007). Along with the dosing, sampling and analysis of tracer gases and ammonia, the selection and recording of relevant accompanying parameters are decisive to sound results and their interpretation. The literature frequently records only isolated points or a few influencing variables relating to accompanying parameters. This makes it more difficult to carry out a direct comparison between emission data from different studies.

Importance of Accompanying Parameters

Accompanying parameters primarily describe each measurement situation, providing information e.g. on animals, feed, husbandry, management and climate. Relevant influencing variables must be demonstrated and quantified, particularly with regard to emission-reducing measures. Climatic parameters also serve to standardise analytical values. With the aid of accompanying parameters, emission data can be tested for plausibility and compared within one farm over the course of time. Details of areas, stock levels, climate, feed level and performance level are essential for a comparison of emission values between individual farms, housing systems, country-specific characteristics and different studies. Parameters such as area, number of animals, livestock units or time are needed as reference variables to ammonia emissions. The fullest possible feed and excretion data should be available for calculation of the nitrogen flow (N). The data basis can thus be improved for previously unvalidated N flow models.

Variables Influencing Ammonia Formation and Release

Relevant accompanying parameters based on literature, completed with further aspects, were selected and compiled in order to cover the variety of the variables influencing the formation and release of ammonia in the housing area and to describe the emission process (Fig. 1) as comprehensively as possible.

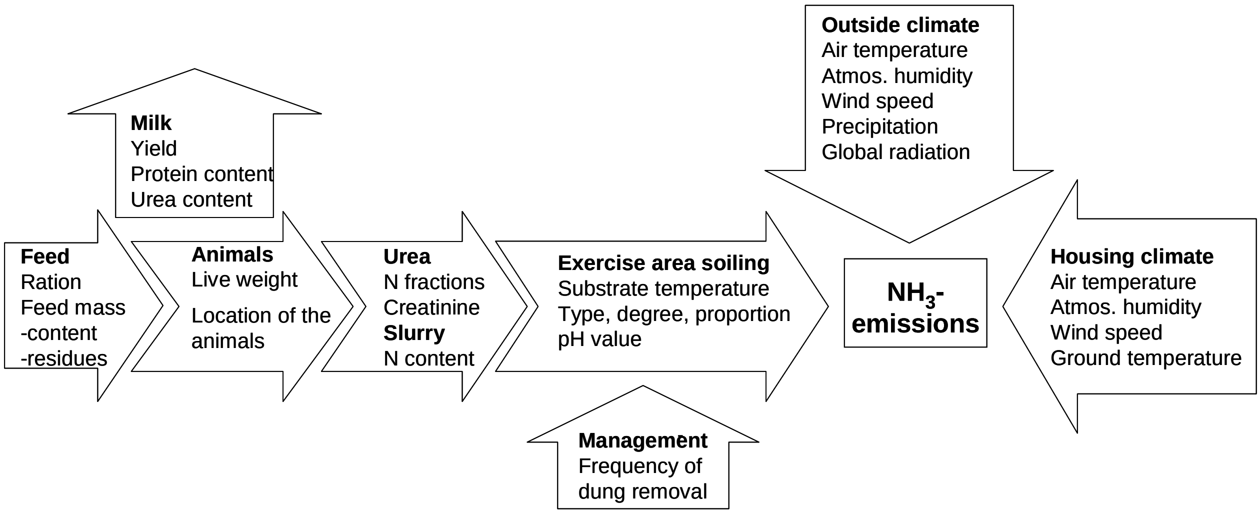

Figure 1: Relevant accompanying parameters for the NH_3 emission process.

N Utilisation

Ammonia emissions are one part of the N output from cattle farming. In order to calculate the N flow, the N input and N output have to be fully recorded along with other indications of N utilisation by the animal. According to Tamminga (1992), an average Dutch dairy cow stores only 2 % of the nitrogen supplied as reserves in the body, around 19 % passes into the milk, about 29 % is excreted in the faeces and approximately 50 % in the urine.

Data on feed components, masses, dry matter content, ingredients and feed residues are gathered as the basis from which to derive the N input. This allows differences between farms, seasons and rations due to feed to be described. As well as feed data, the live weight of the animals, milk yield, milk protein and urea values are used to characterise the N utilisation. The urea content of the tank milk is easy to be determined and a reliable indicator of N utilisation and the N level for the whole herd as a comparison of seasons, farms and countries. Van Duinkerken et al. (2005) established a positive correlation between the urea content of the tank milk and the level of ammonia emissions.

Hydrolysis

Ammonia is produced by hydrolysis of urea in the urine. The catalyst for this process is the enzyme urease, which is produced by faecal microorganisms. Under practical conditions, urease activity and thus urea conversion are very high and thus the urea concentration may therefore be considered a limiting factor for hydrolysis (Monteny 2000). Studies and models show a clear link between feed characteristics and the urinary urea concentration (De Boer et al. 2002) as well as between urinary urea and ammonia emissions (Monteny et al. 2002). Analysis of the N fractions in the urine provides information about the ammonia formation potential on the soiled areas. The order of magnitude of the urea volume can be derived from the urinary creatinine content (Silva et al. 2001).

Soiling of Exercise Yards

The occurrence of faeces and urine depends essentially on the time spent by the animals in the individual housing areas. The intensity of use of an exercise area is determined on the one hand by allocation to individual functional areas and on the other by the structural and climatic design and spatial layout. In particular, exercise yard use can vary considerably between farms and seasons due to the spatial layout (peripheral to the housing or integrated as a traffic area between different functional areas), the presence of attractiveness-enhancing elements (cattle brushes, drinking troughs, etc.) and the orientation (sun – shade). Conclusions may be drawn from the quantification of animal dwell times concerning differences in quantities of faeces and urea occurring and, thus, the emission potential of the different areas. The size of the active emission area, i.e. the soiled area per animal, also is of importance. Thus the recording of exercise yards in terms of type, degree and proportions of soiling provides detailed indications with a view to the emission potential. The N content of the excrement gives further indications as to the ammonia formation potential and the N output. Samples of the faeces/urine mixture occurring on solid-floored exercise areas are relatively easy to be collected for quantitative nutrient analysis. Quantification of the excreted mass would also be useful. The supply of N for ammonia formation depends also on the thickness of the excrement layer. This depends not only on the mass of excrement occurring but also on the frequency of dung removal and the cleaning quality (floor-scraper interaction). In addition, the ammonia formation potential of different exercise areas varies according to differences in the constructural design. Coarse structured floor surfaces are harder to clean and therefore have a higher level of residual soiling and a larger active emission area. Slopes, on the other hand, promote urine drainage.

There is a dissociation equilibrium between ammonium and dissolved ammonia in the liquid phase. This is influenced by the substrate temperature and by the pH value of the faeces/urine mixture (Monteny and Erisman 1998). If the latter is lower than 7, the equilibrium shifts in favour of ammonium (Groot Koerkamp et al. 1998).

Climate

Outdoor climate parameters such as air temperature, wind data, global radiation and precipitation describe the climatic context of emission measurements. Indoor climate parameters are important influencing factors on emissions. Indoor climate parameters can also be used to characterise the effects of the building shell on the air exchange rate and temperature, in particular. There are big differences between farms depending on the location, aspect, layout and design. Temperature has a considerable effect on ammonia formation and release. A comparison of emission data from various authors shows a positive correlation between the indoor temperature and the level of ammonia emissions on a farm (Keck et al. 2006). In order to describe the effects of temperature on ammonia emissions, the floor or substrate temperature and/or the air temperature has to be recorded in the immediate vicinity of the soiled areas. With temperature emissions can be compared and variations on a farm according to seasons, from day to day and in the course of a day can be shown up. Solar radiation increases the floor or substrate temperature and thus, initially, the ammonia formation. Depending on its intensity and duration, solar radiation can help to dry soiled exercise areas and thus check further ammonia formation and release. Ammonia release depends both on temperature and the air speed over the soiled surface (Hartung 1995, Monteny and Erisman 1998). Moreover, the wind speed and wind direction can provide information about transfers of emissions and tracer gases between the cattle shed and the exercise yard.

Further Functions of Accompanying Parameters

Accompanying parameters used to plausibilise, standardise and adjust measurements are shown in Table 1. The wind speed in the immediate vicinity of the sampling location is closely connected with dilution of the ammonia and tracer gas concentration and can be used to plausibilise measurements and the tracer ratio method. According to the measuring and analytical method, parameters such as temperature, relative atmospheric humidity and air pressure are necessary in order to standardise analysis values. To adjust the measured ammonia concentration, the background concentration at locations unaffected by the cattle shed has to be determined.

All the reference variables must be recorded completely (Table 1). This allows different studies to be compared.

Table 1: Accompanying parameters for plausibilisation, standardisation and adjustment of measurements and as reference variables

Plausibilisation - of the tracer ratio method - of ammonia and tracer gas concentrations	 - Wind speed, wind direction - Wind speed at sampling locations
Standardisation of ammonia concentrations	Temperature, relative atmospheric humidity, air pressure
Adjustment of ammonia concentrations	Background ammonia concentration
Reference variables for emission data	Area, number of animals, livestock units, time

Aspects of Accompanying Parameters for Experimental Design and Data Analysis

The aim of the study is to determine ammonia emissions in respect of a dairy cattle housing system. Important influencing variables have to be quantified in order to work out emission-reducing measures. Emissions can be explained according to the experimental approach and by the interaction of different influencing variables (Table 2).

Table 2: Interaction of individual accompanying parameters on the emission level and variations

Absolute emission level	**Inter-farm emission variations**	**Intra-farm emission variation**	
		Seasonal	**In the course of a day**
Constructural design and layout Feed Animal use (time) Soiled exercise areas		Constructural design Feed ration changes Temperature Wind speed	Temperature Wind speed Feeding, dung removal and milking times Animal use (time)

Due to the big climatic variation in the course of a year with outdoor climate housing, measuring periods have to be spread representatively over the year. A large number of farms would also be desirable. However, time and costs of emission measurement are limiting factors. To cover both the farm-to-farm variation in emissions and the seasonal effects, emission measurements are carried out on six farms in two to three different seasons in each case (summer, winter, in-between season). The variation in the course of a day is affected both by climate parameters and also by management aspects such as feeding, dung removal and milking times. These set times also affect animal use of various functional areas.

In order to describe a particular measurement situation, the collection of the accompanying parameters within the whole measurement concept must be matched to the target figures. This applies especially to the number of measurement sites and positioning of the measuring equipment. For example, the choice of location for the weather station should reflect the climatic conditions at the location but should not be influenced by the cattle shed. If emissions from the housing and from the exercise yard are considered separately, accompanying parameters must also be allocable to the respective areas. There must be specific differentiation between individual animal level and herd level. Whereas, for instance, feed data on working farms can only be recorded in respect of the whole herd, urine samples must be differentiated at individual animal level according to lactation stage. Suitable sampling times and measuring intervals should be established taking into account the variability in time and the importance of the individual parameters. To ensure comparability of the individual measurement and accompanying parameters, sampling must be coordinated in time. Care should be taken to ensure the least possible disruption to farm operations and animal activity. A corresponding adapting phase is necessary, especially at changes of feed or structural alterations concerning the animals. The additional working time requirement for the collection of accompanying parameters must also be allowed for within the framework of emission measurements. A time and sequence grid can usefully be established for the accompanying parameters to be recorded on a spot-check basis and systematically transferred to all the measurements. The number of samples and analyses should be selected so as to enable significant statements to be made. Mixed samples aggregated in time and space suffice for quantitative analysis of excrement from individual housing areas and these keep the analytical expenses down.

Prospects

The described accompanying parameters are recorded to document the conditions underlying each measurement situation and to demonstrate influencing variables relevant to ammonia emission. The combination of those accompanying parameters is a key factor for meaningful emission results and their interpretation. As one result the relationship between relevant accompanying parameters and emission data will be described, as well as a comparison between seasonal effects. With the aid of suitable statistical methods the significance of influencing variables and also correlations between individual influencing variables will be shown.

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