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Accompanying parameters for the measurement of ammonia emissions from dairy cattle housing

In the literature on ammonia emissions (NH_3) accompanying parameters are often documented on a selective basis only. This makes it difficult to classify values and compare different studies. Information on housing system, feed, animals, nitrogen utilisation, excretions, exercise area soiling, dung removal, climate and management must be collected for the characterisation of each measuring situation, for the plausibility check of measured data, as reference values and as important influencing variables. The recording of the many emission-relevant influencing variables should be synchronised with the NH_3 emission as target value. This improves the conclusiveness of emission data and facilitates their comparison and interpretation.

Keywords
Emission, ammonia, accompanying parameter, dairy cattle

Abstract
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From both an agricultural and an environmental policy perspective there is a pressing need for up-to-date emission data on ammonia (NH_3) from dairy housing. Such data is used firstly for the comparative assessment and optimisation of housing systems, and secondly as a contribution to emission inventories. Systematic measurements in widespread housing systems are required in order to improve the data base. Promising mitigation measures must be developed, quantified and compared with a view to reducing NH_3 emissions.

Data from the literature on NH_3 emissions are often difficult to compare: descriptive information on the measurement situation, for example climate parameters, or details relating to housing system, management, livestock and feeding are sometimes incomplete or totally absent. As well as sampling and analysis to determine the NH3 emission target figure, the selection and recording of relevant accompanying parameters are crucial for the conclusiveness of results and their interpretation. The measurement concept described below for the selection and collection of accompanying parameters relevant to NH_3 emission measurements in naturally ventilated dairy housing was formulated on the basis of the literature as a prerequisite for practical measurements.

Functions of accompanying parameters

Accompanying parameters primarily describe a particular measurement situation, providing information on housing system, animals, feeding, dung removal, management and climate (**table 1**). In each case full particulars of areas, stocking rate, breed, climatic conditions, feed and yield levels are essential when comparing emission values of individual farms, housing systems, country-specific characteristics and different studies. With the aid of accompanying parameters emission data can be checked for plausibility and compared both within one farm over the course of time and between individual farms. The air speed in the immediate vicinity of sampling locations is closely associated with the dilution of NH_3 concentration and can be used to check the plausibility of measured values. Depending on measurement and analysis methods, parameters such as temperature, relative humidity and air pressure are needed for the standardisation of analytical values. The background concentration in the area surrounding the emission source must be determined in order to correct the NH_3 concentration measured. Parameters such as areas, animal numbers and livestock units or time designations must be recorded as comprehensively as possible as reference values. They enable a comparison between different studies. Relevant emission-influencing variables must be determined and quantified with a view to modelling emissions and deriving mitigation measures.

Selection of accompanying parameters

The accompanying parameters shown in **figure 1** were selected in order to cover the variety of the variables influencing the

formation and release of NH_3 from dairy loose housing, and to describe the emissions as comprehensively as possible.

Nitrogen utilisation

A complete record of nitrogen input (feed) and nitrogen output (milk, excrements) together with additional indications for nitrogen utilisation in livestock (live weight, yield level) is needed to estimate nitrogen utilisation. Under practical conditions urease activity and hence urea splitting is very high, so urea concentration is considered to be a limiting factor for hydrolysis [1]. Studies and models show a significant link between feed characteristics and urea concentration in the urine [2] as well as between urea concentration in the urine and NH_3 emissions [3; 4]. The urine volume can be derived from the urinary creatinine content [4; 5; 6]. Analysis of the nitrogen fractions in the urine provides information on the NH_3 formation potential of soiled surfaces. Milk urea content, alongside ration calculation and monitoring, is an appropriate indicator for the analysis of herd or lactation group ration composition in order to assess the nitrogen supply of rumen microbes [7]. NH_3 emission depends, among other parameters, on the urea level of the tank milk [7; 8; 9]. Milk urea level is a reliable, easy-to-determine indicator for nitrogen utilisation, thus facilitating classification of the nitrogen level of the whole herd when comparing seasons, farms and countries.

Exercise area soiling

The nitrogen levels of excrements on soiled exercise area surfaces give further indications of NH_3 formation potential and nitrogen output. Samples of the faeces/urine mixture on solid floors are relatively easy to collect for nitrogen fraction analysis. Nitrogen release for NH_3 formation depends basically on

Table 1

Table 1: Different functions and examples of accompanying parameters

Funktion von Begleitparametern/ ***Function of accompanying parameters***	**Beispiele von Begleitparametern/** ***Examples of accompanying parameters***
Einordnung der Messsituation/ *Characterisation of the measuring situation*	Fläche, Tierbesatz, Tieraufenthalt, Klima, Management, Laufflächenverschmutzung, N-Gehalte in Harn und Gülle, Fütterungs- und Leistungsniveau/ *Area, stocking rate, animal location, climate, management, exercise area soiling, N content in urea and slurry, feed and yield level*
Plausibilisierung von NH_3-Konzentrationen/ *Plausibility of NH_3 concentrations*	Luftgeschwindigkeit an Probenahmeorten/ *Air speed at sampling locations*
Normierung von Messwerten/ *Standardisation of measuring values*	Temperatur, relative Luftfeuchtigkeit, Luftdruck/ *Temperature, relative atmospheric humidity, air pressure*
Korrektur von NH_3-Konzentrationen/ *Adjustment of NH_3 concentrations*	Hintergrundkonzentration von NH_3/ *Background NH_3 concentrations*
Bezugsgrößen für Emissionsdaten/ *Reference variables for emission data*	Fläche, Tierzahl, Anzahl Großvieheinheiten, Zeit/ *Area, number of animals, livestock units, time*
Einflussgrößen auf die NH_3-Emission/ *Influencing variables of NH_3 emission*	Temperatur, Luftgeschwindigkeit, Management, Laufflächenverschmutzung, N-Gehalte in Harn und Gülle, Fütterungs- und Leistungsniveau/ *Temperature, air speed, management, exercise area soiling, N content in urea and slurry, feed and yield level*

Fig. 1

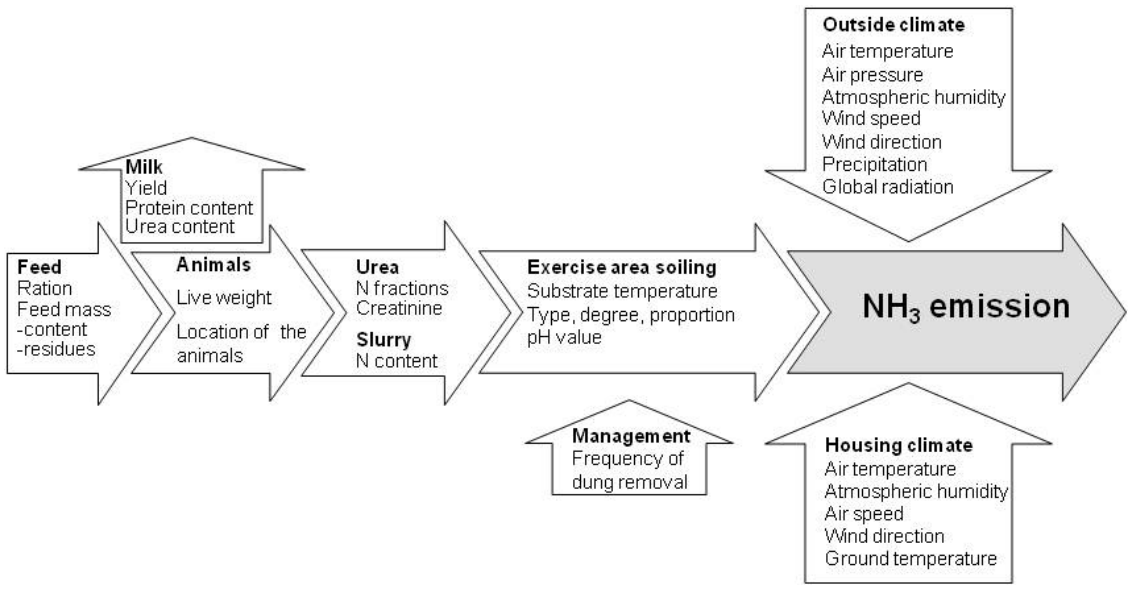

Fig. 1: Relevant accompanying parameters for the NH_3 emission process

the layer thickness, composition and age of floor soiling. A role is played here not only by the weight of excrement, but also by cleaning frequency and quality (floor-scraper interaction). The scoring of floors by type, degree and proportion of soiling provides pointers for emission potential [7]. The size of the emission-active surface, i.e. the soiled area per animal or livestock unit, also affects the release of ammonia. The assumption is that the time spent by the animals in individual housing areas correlates with the amount of faeces and urine [10]. Quantifying animal location makes it possible to draw conclusions on differences in faeces and urine incidence and hence also on the emission potential of particular housing areas [7].

Climatic parameters

NH_3 release depends on temperature and the air speed over the soiled surface [7; 11; 12]. Soil and substrate temperatures and/or the air temperature and air speed in the immediate vicinity of emitting areas are valuable in describing the influence of climatic parameters on NH_3 emissions. The information of temperature patterns makes it possible to classify emissions and show farm variations by season, from day to day and during the course of a day. Housing climate parameters can also be used to characterise the effect of the building shell, particularly on air exchange and temperature. In addition, outside climate parameters such as air temperature, wind data, global radiation and precipitation describe the climatic conditions underlying emission measurements.

Aspects of accompanying parameters for the measurement concept

Depending on the issue and experimental approach, emissions can be explained and compared by the interaction of the selected influencing variables (**table 2**). This should considered when defining the measurement concept.

In order to describe a particular measurement situation, the recording of the target figure and the accompanying parameters must be coordinated within the framework of the overall measurement concept. This applies particularly to the number of measurement points and the positioning of measuring equipment as well as the measuring interval and sampling times.

The siting of the weather station, for example, should reflect the climatic conditions on site but should not be influenced by the cowshed building. If emissions from various areas of the stable are regarded 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 example, feeding data on commercial farms can only be recorded for the whole herd, urine samples must be differentiated on an individual animal level according to lactation stage. The variation in the course of a day is affected both by climate parameters and also by organisational aspects such as the times of feeding, dung removal and milking. These timers also affect animal use of different areas of activity. Sampling times and measuring intervals should be arranged according to the variability in time and the importance of the individual parameters. To allow a comparison of target parameters and individual accompanying parameters coordinated timing is necessary for recording. Disturbances to farm procedures and animal activity should be avoided. An appropriate adapting phase is necessary, especially if there are changes in feed or structural alterations in the livestock area. 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 be usefully 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 defined so that sound conclusions are possible, furthermore taking account of seasonal and time-of-day variability.

Conclusions

Accompanying parameters such as information on housing system, feed, livestock, nitrogen utilisation, exercise area soiling, dung removal, climate and management have to be be inte-

Table 2

Table 2: Interaction of individual accompanying parameters on inter-farm and intra-farm emission level and variations

Absolutes Emissionsniveau/ ***Absolute emission level***	**Variation zwischen Betrieben/** ***Inter-farm emission variation***	**Variation innerhalb eines Betriebes/ Intra-farm emission variation**	
		Zwischen Jahreszeiten/ ***Seasonal***	**Im Tagesverlauf/** ***In the course of a day***
Bauliche Ausführung und Anordnung Fütterungs- und Leistungsniveau Verschmutzte Laufflächen Klima/ *Structural design and layout* *Feed and yield level* *Soiled exercise areas* *Climate*		Bauliche Ausführung Wechsel der Futterration Temperatur Luftgeschwindigkeit Tierbesatz/ *Structural design* *Feed ration changes* *Temperature* *Air speed* *Stocking rate*	Tieraufenthalt/-aktivität Fütterungs-, Entmistungs-, Melkzeiten Temperatur Luftgeschwindigkeit/ *Animal location/activity (time)* *Feeding, dung removal and milking times* *Temperature* *Air speed*

grated in a measurement concept for NH_3 emissions. They describe the conditions underlying each measurement situation and identify the relevant variables influencing NH_3 emission. Accompanying parameters can be used to check the plausibility of measuring values, to standardise and correct them. Accompanying parameters also serve as reference values for emission. The targeted selection of accompanying parameters is the key to reliable emission data and the interpretation thereof, as well as to the comparability of different studies. The recording of accompanying parameters must be chronologically and spatially matched to the target value. On the basis of the relevant influencing variables measures can be located for the required emission reduction.

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