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Ammonia emissions from loose housing with outdoor exercise area during summer and winter

Emissions of ammonia (NH_3) in naturally ventilated cubicle loose housing for dairy cattle with solid floor exercise surfaces and a peripheral combined cubicle access area/outdoor exercise area were quantified using a tracer ratio method with two tracer gases (SF_6, SF_5CF_3). To account for seasonal effects, measurements were performed over a three day period in both winter and summer. Winter temperatures varied between –8 and 12 °C, and those measured in summer between 7 and 37 °C. The average daily values for NH_3-emissions ranged from 12.4 to 12.9 g/LU • d in winter and from 46.2 to 67.4 g/LU • d in summer. Diurnal patterns were only recognisable during the warm season.

Keywords
Ammonia emission, tracer ratio method, dairy cattle, loose housing, natural ventilation, outdoor exercise area

Abstract
Landtechnik 65 (2010), no. 2, pp. 120-123, 3 figures, 1 table, 4 references

Up-to-date emission data for ammonia are needed for the comparative evaluation and optimisation of housing systems for dairy cattle, as a contribution to emission inventories, and with a view to reduction measures. Literature data on ammonia emissions from dairy cattle are not meaningful for the loose housing systems with outdoor exercise areas common in Switzerland. Existing emission data show a wide spread and do not provide systematic seasonal coverage. In addition, naturally ventilated housing systems with outdoor exercise areas have not been investigated. The lack of emission data for natural ventilation and from area sources can essentially be put down to difficulties in determining the air-exchange rate.

Material and methods

In order to improve the data basis for NH_3 emissions from dairy farming, systematic measurements were taken in six naturally ventilated cubicle loose housing facilities with solid floor exercise areas and an outdoor exercise area [1]. As an example, the NH_3 emissions together with selected accompanying parameters of a winter and summer measurement from a housing with 46 dairy cattle are compared below. One side wall is partly provided with curtains and the outdoor exercise area at other side is bordered with wooden boards. One gable end is open and the other gable end with a gateway has space boards. The unroofed exercise area was arranged alongside the building and not separated from the cubicle access area (**figure 1**). During the measurements the feeding aisle and combined cubicle access area/outdoor exercise area were mucked out four times daily with stationary combi-scrapers. In both seasons the cows were given a total mixed ration.

ART and Empa developed a tracer ratio method with two tracer gases to determine the emissions with natural ventilation and from diffuse sources. In order to show emissions from the two area sources of housing area and outdoor exercise area, the already established tracer gas SF_6 was used in the feeding aisle and a second tracer gas, SF_5CF_3, in the combined cubicle access area/outdoor exercise area. The diluted tracer gases were continuously supplied directly to the emitting surfaces via tube systems with 46 so-called critical capillaries (**figure 1**), thereby imaging the source of the NH_3 emissions. An air-collection system at a height of 3 m comprising Teflon hose and 39 glass critical capillaries 3 m apart allowed representative sampling of the tracer gases and of NH_3. Analysis of the two tracer gases was carried out simultaneously by means of gas chromatography (GC-ECD). NH_3 was quantified by a photoacoustic sensor (PAS). In addition to descriptive farm data, the following parameters were recorded for the characterisation of each measurement situation, for the validation of measured data, as reference variables, and for the derivation of important influencing variables on the emissions:

- outdoor climate
- climate in housing and outdoor exercise area
- use of the different areas by the animals
- aisle/exercise area soiling
- nitrogen input and output
- nitrogen utilisation.

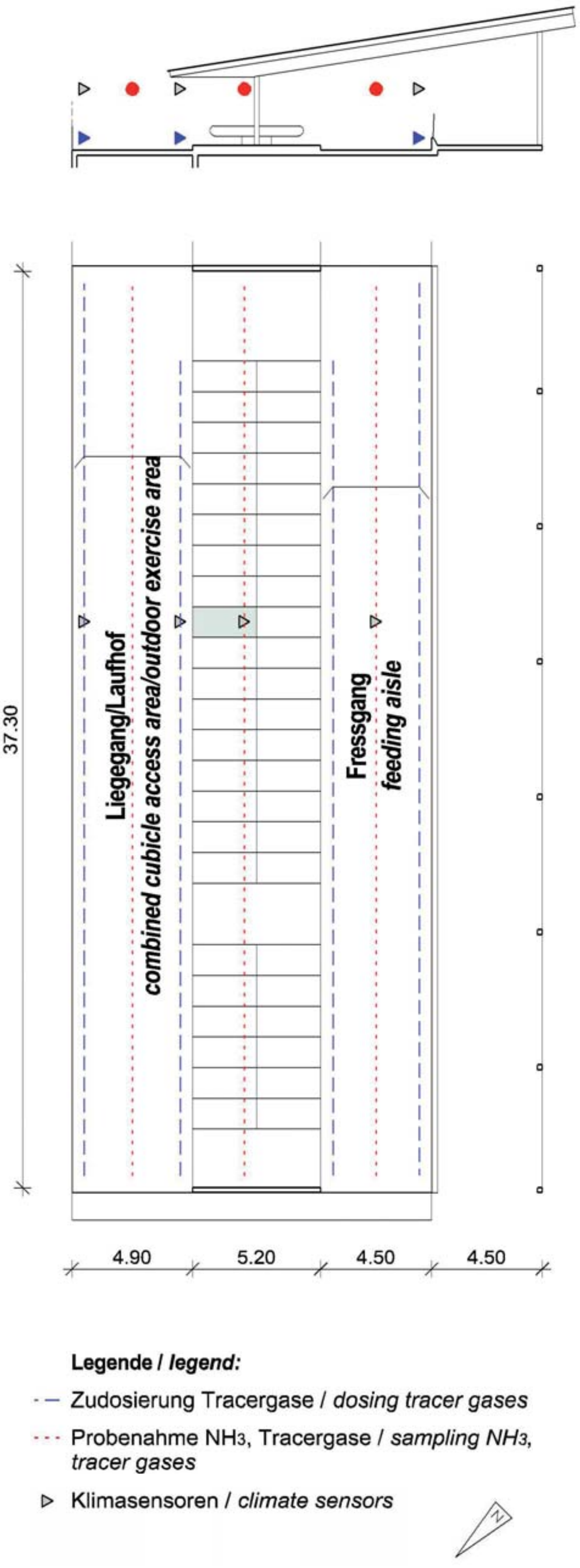
The measurement period was three days in each season.

Results and discussion

Table 1 gives descriptive data on feed, animals, use of the combined cubicle access area/outdoor exercise area by the animals, aisle/exercise area soiling and climate. There were only slight differences between the summer and winter measurement for milk yield and live weight as well as for N-input with feed and the tank milk urea level. Both use of the different areas by the animals and soiling level were higher in the feeding aisle than in the combined cubicle access area/outdoor exercise area in both seasons. The proportion of dry soiling in summer was higher than that measured in winter. The dried soiling is an indication of the emission already taken place.

Figures 2 and **3** show diurnal NH_3 emission patterns, outside temperature and wind speed in the housing at a height of 3 m for the winter and summer measurement. During the day the temperature rose and the wind speed increased at times of increased temperature. Occasionally periods of higher wind speed occurred in the colder nocturnal hours. The outside temperature varied from −8 to 12 °C during the winter measurement and from 7 to 37 °C in the summer measurement. A clear gradient was also noticeable between the seasons in the case of NH_3 emissions. In winter the NH_3 emissions were in a very narrow range, with daily mean values between 12.4 and 12.9 g/LU • d. Literature data on winter NH_3 emissions from cubicle loose housing with solid floor exercise areas but no outdoor exercise area were considerably higher at 40.3 g/LU • d [2]. In the summer measurement the daily mean values of NH_3 emissions varied from 46.2 to 67.4 g/LU •d. In the literature [3; 4] the NH_3 emissions at summer temperatures were rather lower

Fig. 1



Floor plan and section of double-row cubicle loose housing with combined cubicle access area/outdoor exercise area for dairy cattle, with dosing, sampling and climate sensors.

Table 1

Data on feeding, animal parameters, animal use of the combined cubicle access area/outdoor exercise area, areas, exercise-area soiling and climate data of winter and summer measurements

Messzeitraum/Parameter ***Measurement period/parameter***	**Winter/*Winter*** **08.–10. Feb. 2008**	**Sommer/*Summer*** **05.–08. Juli 2008**
Fütterung, Tierparameter (Mittelwert über Herde) ***Feed, animal parameters (mean value across herd)***		
N-Input Fütterung [g/GV • d] *N input feed [g/LU • d]*	220	210
Lebendmasse [kg] *Live weight [kg]*	849	824
Milchleistung [kg/Kuh • d] *Milk yield [kg/cow • d]*	28.1	30.6
Harnstoffgehalt Tankmilch [mg/dl] (Proteingehalt [%]) *Tank milk urea level [mg/dl] (protein content [%])*	24 (3.3); 31 (3.4)	27 (3.2); 23 (3.2)
Tieraufenthalt im Liegegang/Laufhof [%] ***Use of the combined cubicle access area/outdoor exercise area by the animals [%]***		
(Mittelwert über Messperiode) *(Mean value across measurement period)*	28.4	34.4
Fläche [m^2/Tier] ***Area [m^2/animal]***		
Gesamt *Total*	11.6	11.4
davon Lauffläche *of which aisle/exercise area*	8.2	8.1
davon Liegegang/Laufhof *of which combined cubicle access area/outdoor exercise area*	3.7	3.6
Laufflächenverschmutzung (Mittelwert über Messperiode) ***Exercise area soiling (mean value across measurement period)***		
Höhe unmittelbar vor der Entmistung Fressgang [mm] *Level immediately prior to mucking out feeding aisle [mm]*	2.6	2.8
Höhe unmittelbar vor der Entmistung Liegegang/Laufhof [mm] *Level immediately prior to mucking out combined cubicle access area/outdoor exercise area [mm]*	1.4	1.7
Anteile feucht/trocken/sauber Fressgang [%] *Proportions of damp/dry/clean feeding aisle [%]*	82 / 0 / 17	77 / 19 / 4
Anteile feucht/trocken/sauber Liegegang/Laufhof [%] *Proportions of damp/dry/clean combined cubicle access area/outdoor exercise area [%]*	66 / 0 / 33	54 / 28 / 19
Klima (Arithm. Mittel; Minimum bis Maximum) ***Climate (arithm. mean; minimum to maximum)***		
Außentemperatur [°C] *Outside temperature [°C]*	1; –8 to +12	19; +7 to +37
Windgeschwindigkeit im Stall in 3 m Höhe [m/s] *Wind speed in housing at 3 m height [m/s]*	0.3; 0.1–1.2	0.5; 0.1–2.8

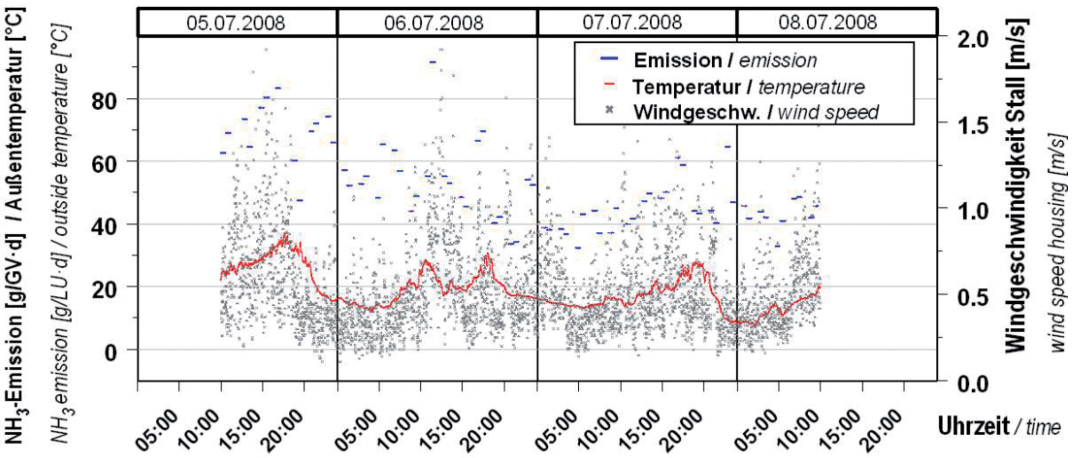
in some cases, with values between 9 and 57 g/LU • d. Between 18 to 26 % in summer the rate of NH_3-N emissions to the N-input across the whole measurement period was considerably higher than in winter, at around 5 %.

Differences during the course of the day in NH_3 emissions were apparent only in the summer measurement (**figure 2**). Emissions rose in parallel to the temperature increase. By contrast, NH_3 emission in the winter measurement remained at almost the same level despite an increase in temperature (**figure 3**). This leads to the conclusion that at a low temperature level a rise in temperature need not bring about an increase in emission. On the other hand, a rise in temperature – starting from a higher temperature level – results in a considerable increase in NH_3 emission. Some isolated high emission values can be explained by major animal activity associated with the main feeding times (from 6 am and 6 pm) and by mucking out operations at night (approx. 10 pm).

Conclusions

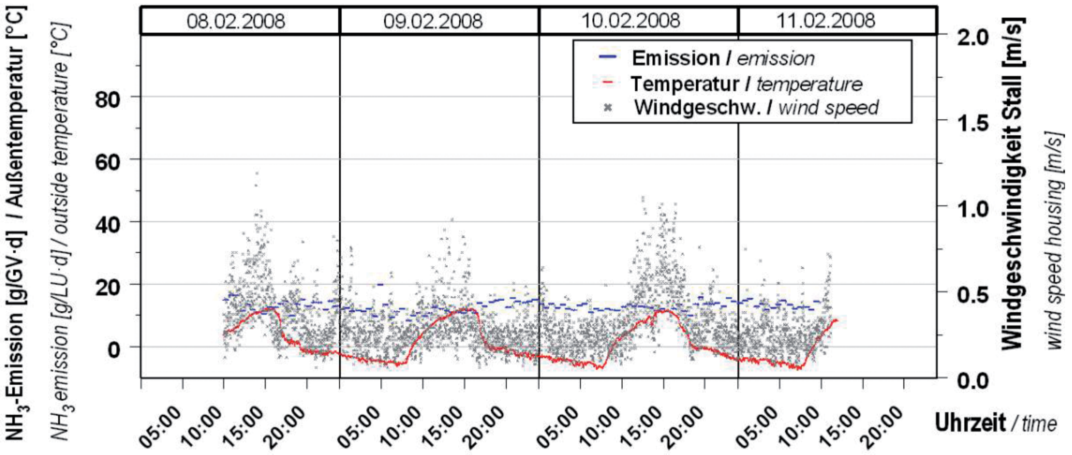
NH_3 emissions showed distinct seasonal effects. The daily mean values of the emissions varied in winter from 12.4 to 12.9 g/LU • d and in summer from 46.2 to 67.4 g/LU • d. At between 18 and 26 % the rate of NH_3-N emissions to the N-input was considerably higher in the summer measurement

Fig. 2



Diurnal NH_3 emission patterns [g/LU • d], wind speed in housing 3 m high [m/s] and outside temperature of the summer measurement

Fig. 3



Diurnal NH_3 emission patterns [g/LU • d], wind speed in housing 3 m high [m/s] and outside temperature of the winter measurement

than in the winter. Diurnal patterns in the level of NH_3 emissions were noticeable only in the warm season. To some extent events such as feeding times and mucking out were reflected in the emissions.

Structural engineering and organisational measures for the reduction of NH_3 emissions should be developed and implemented, particularly for the warm season.

Literature

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