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COMPARISON OF AMMONIA EMISSIONS FROM A NATURALLY VENTILATED DAIRY LOOSE HOUSING WITH SOLID FLOOR SURFACES OVER TWO SEASONS

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ABSTRACT To date, ammonia (NH_3) emissions have not been determined for loose housing systems with outdoor exercise areas, which are common in Switzerland. The measurements presented below were carried out in a naturally ventilated loose housing with cubicles (46 cows), solid floor surfaces and a combined cubicle access area/outdoor exercise area alongside the cowshed. The feeding aisle and the combined cubicle access area/outdoor exercise area were mucked out four times daily with stationary scrapers. To account for seasonal effects, measurements were performed over a three day period in both summer and winter. A tracer ratio method with two tracer gases was developed to quantify emissions from two sources with different emission levels. In order to characterise the measuring situation the following parameters were also recorded: descriptive farm data, climate, use of the different areas by the animals, aisle/exercise area soiling, as well as nitrogen input, output and utilisation. In both seasons, animal uses as well as soiling levels were higher in the feeding aisle than in the combined cubicle access area/outdoor exercise area. The proportion of dry soiling was considerably greater in summer than in winter. Temperatures were between 7 and 37 °C during summer, and between -8 and 12 °C in winter. The average daily values for NH_3 emissions ranged from 46.2 to 67.4 g/LU·d in summer and from 12.4 to 12.9 g/LU·d in winter. Diurnal patterns were only recognisable during the warm season. Events such as mucking out operations are partly reflected in the NH_3 emissions.

Keywords: ammonia emission, tracer ratio method, dairy cattle, loose housing, outdoor exercise area, natural ventilation, climate

INTRODUCTION 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 to evaluate NH_3 reduction measures. Currently available literature data on ammonia emissions from dairy cattle are not meaningful for loose housing systems with naturally ventilated outdoor exercise areas that are common in Switzerland. Furthermore, the published emission values show a wide spread and do not provide systematic seasonal coverage. The lack of emission data for natural ventilation and from area sources is mainly due to difficulties in determining the air-exchange rate.

MATERIALS AND METHODS In order to improve the data basis for NH_3 emissions from dairy farming, systematic measurements were performed in six naturally ventilated cubicle loose housing facilities with solid floor exercise areas and an outdoor exercise area (Schrade, 2009). 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 documented and discussed below. One side wall is partly equipped with curtains and the outdoor exercise area at oposite 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 is 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. To account for the two areas with potentially different source strength (housing and outdoor area), the already established tracer gas SF_6 was only applied to the feeding aisle, and a second tracer gas, SF_5CF_3, was used for the combined cubicle access area/outdoor exercise area (Zeyer et al., 2007). The diluted tracer gases were continuously supplied directly above the emitting traffic areas via tube systems with 46 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 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 as well as nitrogen input, output and utilisation (Schrade et al., 2008). The measurement period was three days in each season.

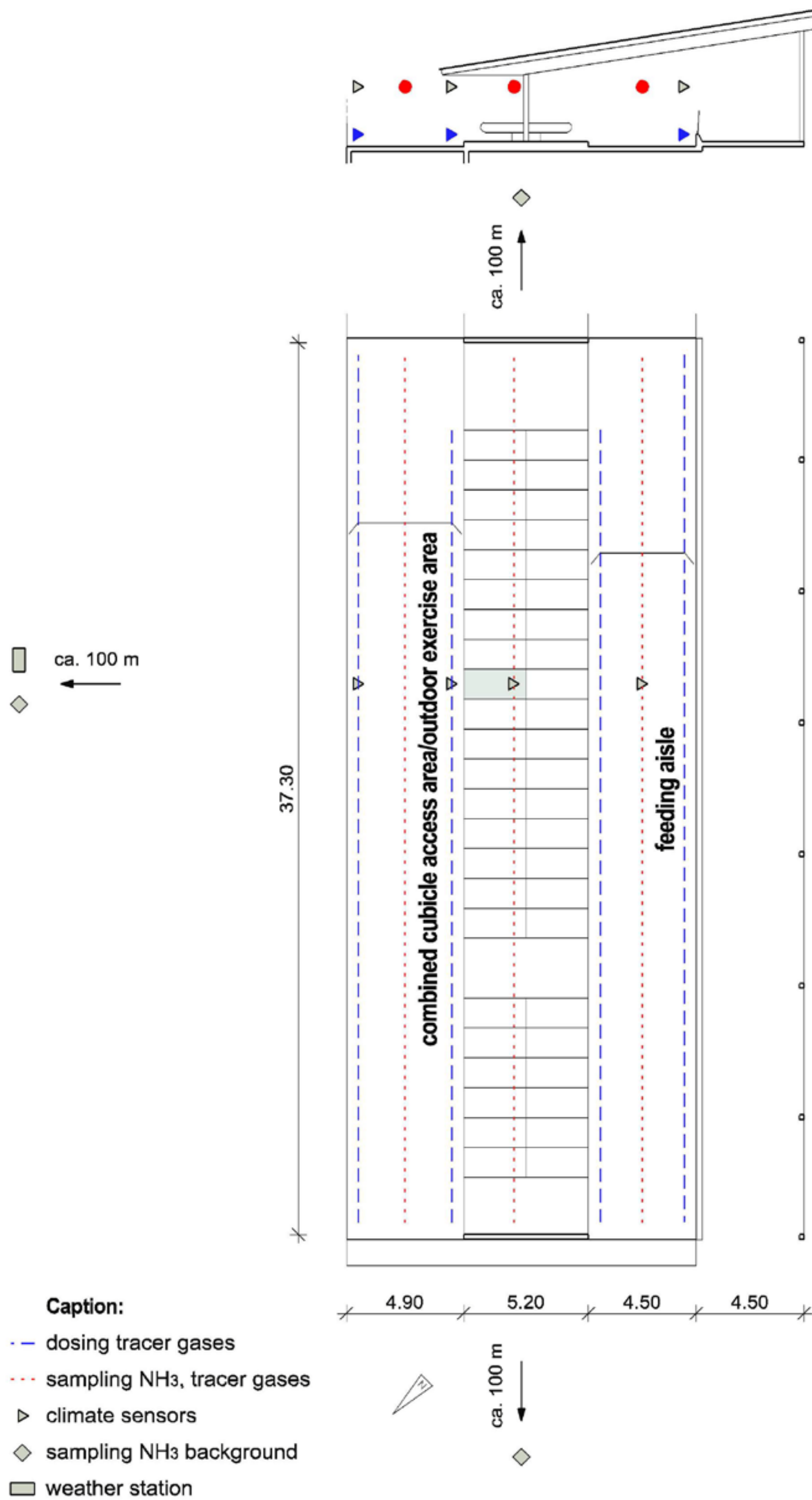

Figure 1: Floor plan and section of double-row cubicle loose housing with combined cubicle access area/outdoor exercise area for dairy cattle, with dosing, sampling and climate sensors.

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, the use of the different areas by the animals and the 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 can be considered an indication of the emission that has already taken place.

Table 1. Data on feeding, animal parameters, use of the combined cubicle access area/outdoor exercise area by the animals, areas, exercise-area soiling and climate data of winter and summer measurements.

Measurement period / parameter	**Winter** 08–10 Feb., 2008	**Summer** 05–08 July, 2008
Feed, animal parameters (mean value across herd)		
N input feed [g/LU·d]	220	210
Live weight [kg]	849	824
Milk yield [kg/cow·d]	28,1	30,6
Tank milk urea level [mg/dl] (protein content [%])	24 (3.3); 31 (3.4)	27 (3.2); 23 (3.2)
Use of the combined cubicle access area/outdoor exercise area by the animals [%] (Mean value across measurement period)	28.4	34.4
Area [m^2/cow]		
Total	11.6	11.4
of which aisle/exercise area	8.2	8.1
of which combined cubicle access area/outdoor exercise area	3.7	3.6
Exercise area soiling (mean value across measurement period)		
Level immediately prior to mucking out feeding aisle [mm]	2.6	2.8
Level immediately prior to mucking out combined cubicle access area/outdoor exercise area [mm]	1.4	1.7
Proportions of damp / dry / clean feeding aisle [%]	82 / 0 / 17	77 / 19 / 4
Proportions of damp / dry / clean combined cubicle access area/outdoor exercise area [%]	66 / 0 / 33	54 / 28 / 19
Climate (arithm. mean; minimum to maximum)		
Outside temperature [°C]	1; –8 to +12	19; +7 to +37
Wind speed in housing at 3 m height [m/s]	0.3; 0.1 to 1.2	0.5; 0.1 to 2.8

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 winter and from 7 to 37 °C during summer measurements. 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 emissions between 12.4 and 12.9 g/LU·d. In comparison, Seipelt et al. (1999) published a considerably higher value of 40.3 g/LU·d for winter NH_3 emissions from a cubicle loose housing with solid floor exercise areas but no outdoor exercise area. In the summer, we determined daily mean values of NH_3 emissions between 46.2 and 67.4 g/LU·d. In the literature (Rom et al., 2004; Zhang et al., 2005), NH_3 emissions at summer temperatures were often lower, with values between 9 and 57 g/LU·d. We also determined the rate of N-NH_3 output to N-feed input which was distinctly higher during summer (18 to 26 %) than during winter (5 %).

Diurnal patterns in NH_3 emissions were apparent only in the summer measurement (Figure 3). Emissions rose in parallel to the temperature increase. By contrast, NH_3 emission in the winter remained at nearly the same level despite an increase in temperature (Figure 2). This leads to the conclusion that emissions are only temperature dependent above a certain temperature. Some isolated emission events can be explained by increased animal activity associated with the main feeding times (around 6 am and 6 pm) and by mucking out operations at night (approx. 10 pm).

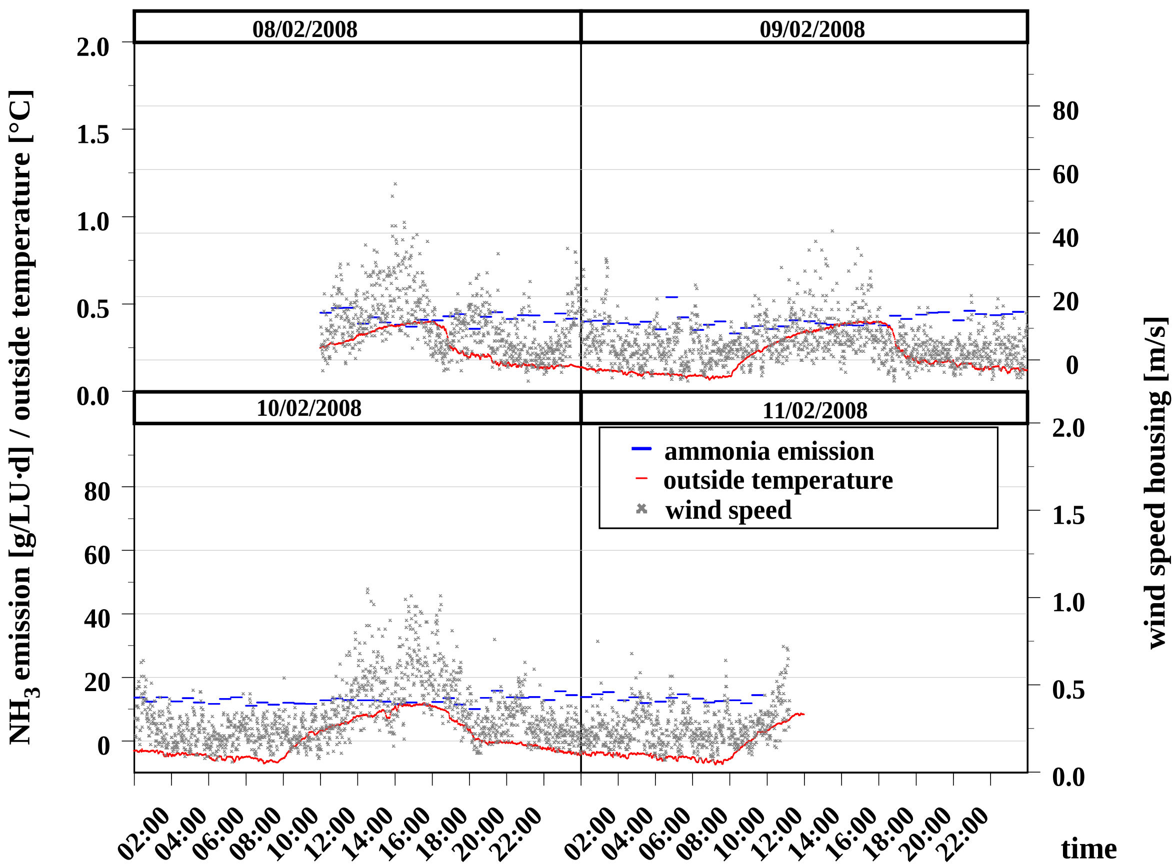

Figure 2: Diurnal NH_3 emission patterns [g/LU·d], wind speed in housing 3 m high [m/s] and outside temperature of the winter measurement.

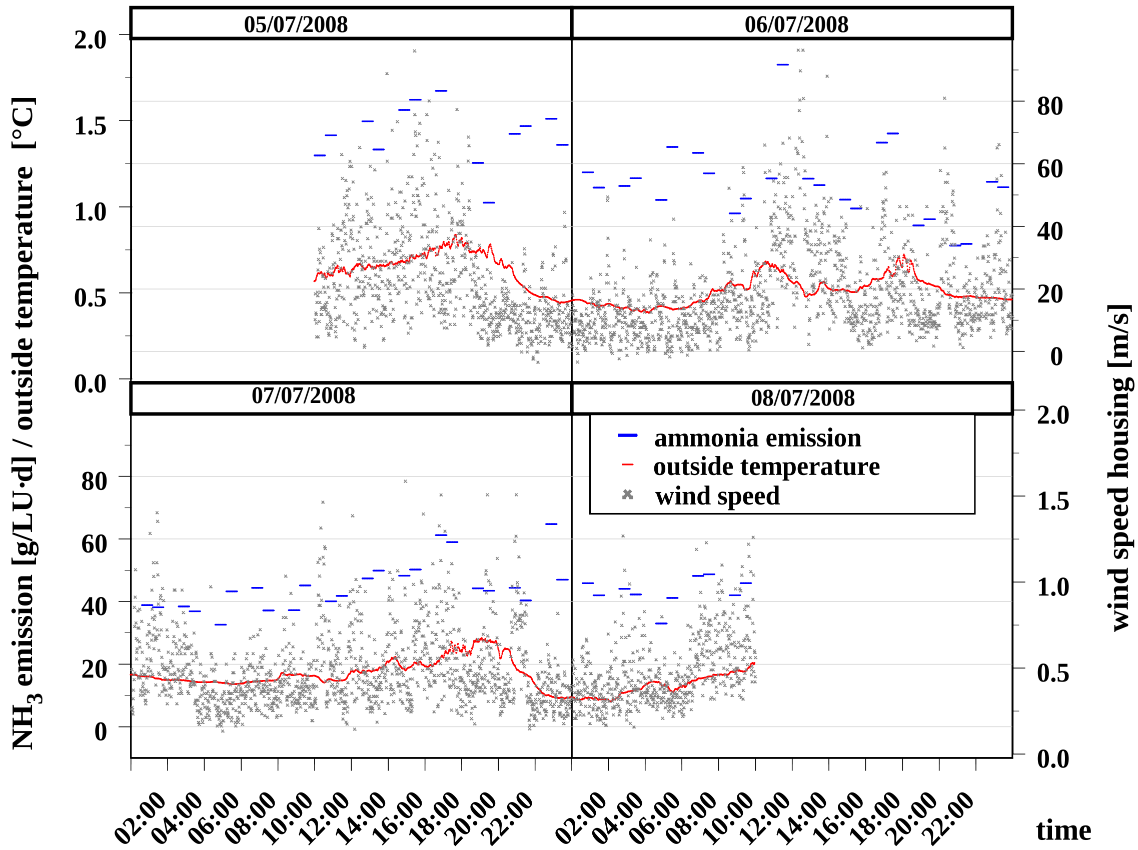

Figure 3: Diurnal NH_3 emission patterns [g/LU·d], wind speed in housing 3 m high [m/s] and outside temperature of the summer measurement.

CONCLUSIONS NH_3 emissions showed a strong seasonal dependence. The daily mean emission values were 12.4 - 12.9 g/LU·d in winter and 46.2 - 67.4 g/LU·d in summer. Accordingly, the rate of N-NH_3 output to N-feed input was significantly higher in the summer (18 - 26 %) than in the winter (5 %). Diurnal patterns of NH_3 emissions were only noticeable 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.

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