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MEASUREMENT OF AMMONIA EMISSIONS FROM THREE AMMONIA EMISSION REDUCTION SYSTEMS FOR DAIRY CATTLE USING A DYNAMIC FLUX CHAMBER

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ABSTRACT There is increasing interest among dairy farmers in The Netherlands for animal friendly housing systems that at the same moment reduce the ammonia emission compared to currently available systems. Therefore, there is a need for a relatively cheap and easy measuring method to investigate the potential effect of new emission reduction systems. In 2008 and 2009 Wageningen UR Livestock Research preformed emission measurements on 3 different ammonia emission reduction systems using a dynamic flux chamber. All systems were meant for use in a free stall housing system for dairy cows. Two of the emission reduction systems were concrete floors and one was an emission reduction system covering the slurry in the pits. The experiments were conducted at three different practical dairy farms in the Netherlands, one for each system. Emission of the reduction system was related to emission of a references floor. In all cases a concrete slatted floor with slurry pits was used as a reference. Emission levels ranged from 39% to 71% of the emission of the reference system. The two systems based on reduction of floors emissions seemed to have more perspective than the system based on reduction of pit emissions. A complete closing of the pits is however an important condition. Because of the case-control character of the flux chamber measurements the results can not be translated directly to full scale emission factors for dairy housing neither can they be used for between farms comparison.

Keywords: ammonia emission, flux chamber, cattle housing.

INTRODUCTION

Agriculture is the most important source of ammonia (NH_3) emissions in the Netherlands. In 2008, approximately 90% of the Dutch ammonia emissions originated from agricultural activities (PBL, 2010). In 2008 cattle husbandry in total (including beef cattle, veal calves and suckling cows) was responsible for 49% of the total ammonia emission from agriculture. Dairy cattle emitted 33% of the total agricultural ammonia emission and 67% of the total ammonia emission from cattle husbandry. More than half (52%) of the ammonia emission from dairy cattle comes from housing and slurry storage. Although absolute emissions decreased over the last decades the relative contribution was constant. In the light of the expected increase of dairy cattle production there is an urgent need for housing systems with lower ammonia emissions. For the development and assessment of new open housing types it is of most importance to have an approved measuring method. For mechanically ventilated buildings adequate methods are available (Mosquera *et al.*, 2002a and Mosquera *et al*., 2002b). Emission points are well defined and ventilation rates and gas concentrations can be measured with sufficient accuracy. Ventilation rates from naturally ventilated livestock housings can be measured using the tracer gas technique. This can be an artificial tracergas like SF_6 or an already available gas like CO_2. This technique presumes a good mixing of tracergas and target gas (i.e. ammonia). This is no longer guaranteed in very open buildings. One other possibility is the use of flux chambers that determine emissions at floor level. In 2008 and 2009 Wageningen UR Livestock Research preformed emission measurements on several ammonia emission reduction systems using the flux chamber technique. All systems were meant for use in a free stall housing system for dairy cows. The open flux chamber used in these measurements is described in Mosquera *et al.* (2009). Question all three measuring projects was how the emission level of the reduction systems relates to a reference. The results of three emission reduction systems will be described here.

MATERIAL AND METHODS

Two of the emission reduction systems, identified as A and B, were concrete floors and one was an emission reduction systems covering the slurry in the pits, identified as C. Reduction principle of both A and B is based on a fast removal of urine and a separate removal of the feces by scrapers. Floor A is a complete solid floor closing the pits, floor B has slots between solid floor element to drain urine and feces to the pits. Both floors have a pattern of grooves to prevent cow slip incidence. The experiments were conducted at three different practical diary farms in the Netherlands, one for each systems. Emission of all reduction systems was related to emission of a references floor. In all cases a concrete slatted floor with slurry pits was used as a reference.

Figure 1. Open flux chamber.

The dimensions of the flux chamber were 2.37 m x 2.32 m x 0.40 m. The flux Q ($g\ m^{-2}\ h^{-1}$) from the emitting surface A (5.50 m^2) was calculated by multiplying the ventilation rate ϕ ($m^3\ h^{-1}$) and the difference in concentration between the incoming (C_{in}) and outgoing (C_{out}) air from the chamber:

$$Q = \frac{\phi \cdot (C_{uit} - C_{in})}{A}$$

The concentration of NH_3 in the in- and outgoing air in the flux chamber was measured by using a photoacoustic monitor (Innova 1312). A fan (Fancom FMS 35) with a diameter of 35 cm and a ventilation capacity of 3000 m^3 h^{-1} was installed in the tube of the outgoing air. The ventilation rate inside the chamber was determined by using a fan-wheel anemometer coupled to the used Fancom fan. The fan-wheel anemometer was calibrated at the start of the measurements, resulting in the following calibration line:

Ventilation rate [m^3 h^{-1}] = 1,89 * [pulses/s] * 60 [s/min] / 4 [pulses/turnover] + 21

During measurements the fan was adjusted at 30% of its maximum ventilation capacity. Besides, the temperature (^oC) and relative humidity (%) were measured for all measurements close to the place where the chamber was placed by using a Rotronic Hygromer®. This sensor had an accuracy of respectively ± 1,0 °C and ± 2 % for temperature and relative humidity. The signal of the Rotronic and fan-wheel anemometer were registered every 5 minutes by a data acquisition system (Koenders CR-10). When relevant a section of the underlying pits was divided from the rest of the pits by sheets of plywood. In that cases measured emissions are a combination of emission from floor surface and pits.

RESULTS AND DISCUSSION

System A was measured on the 25th of September and the 2nd and 9th of October 2009. System B was measured on the 16th of October and 3rd of November 2009. System C was measured from the 3rd to the 6th of November 2008. Table 1 shows the average climatic conditions and the average ventilation rates through the flux chamber.

Table 1.Average climatic conditions (Temperature and Relative Humidity), number of replications and flux chamber ventilation rates of different reduction systems. Significant differences ($p<0.05$) between measurements within a system are represented by different superscripts. s.e.d.: standard error of differences.

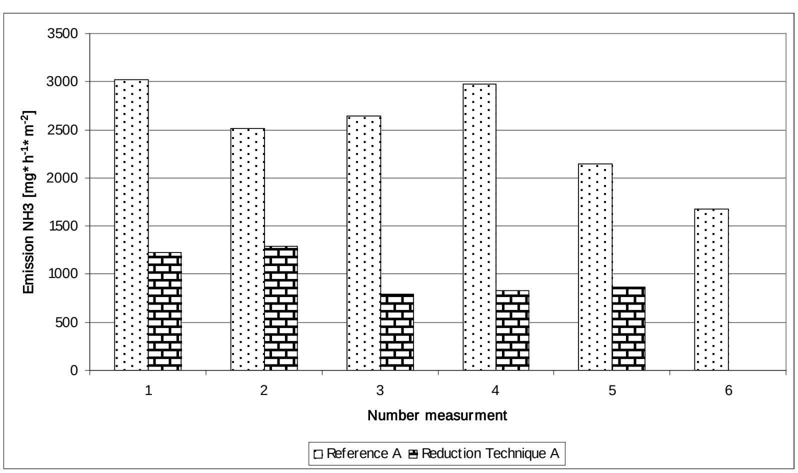
Measure	Replications	T [^oC]	RH [%]	Ventilation [m^3 h^{-1}]
References A	6	14.5±2.1^a	69.9±4.9^a	888±1.4^a
System A	5	17.0±2.1^a	61.3±4.9^a	888±1.4^a
Reference B	4	10.8±0.9^a	79.8±7.5^a	889±0.5^a
System B	4	11.5±0.9^a	76.6±7.5^a	889±0.5^a
System B+	1	10.1	90.7	884
Reference C	7	12.5±1.2^a	85.3±5.6^a	889±0.5^a
System C	7	11.9±1.2^a	84.8±5.6^a	889±0.5^a

The flux chamber ventilation rate ranged from 29-30% of the maximum ventilation capacity resulting in an air velocity of 0.24-0.26 m s^{-1} above the floor surface. That is a typical air velocity measured at the floor level on cattle houses. Temperature (T) and relative humidity (RH) are in a close range and typical for autumn climatic conditions in The Netherland. Within farms differences of temperature, relative humidity and ventilation rate between reduction system and references for were not significant ($p<0.005$).

Table 2. Ammonia emissions and relative emission compared to reference measurements of different systems. Significant differences ($p<0.05$) between measurement within a system are represented by different superscripts. s.e.d.: standard error of differences.

Measure	NH_3 [mg m^{-2} h^{-1}]	Relative emission [%]
References A	2771^a	100
System A	1081^b	39
s.e.d. A	374.9	
Reference B	1138^a	100
System B	1432^b	126
s.e.d. B	84.4	
System B+	599	53
Reference C	1248^a	100
System C	889^b	71
s.e.d.	82.3	

Table 2 shows the ammonia emission of the different systems together with the emission related to the within farm references. Absolute levels of reduction systems differed significantly ($p<0.05$) from their references. Emission levels of system A and C were 39% and 71% respectively, related to their references. Emission level of reduction system B however was 125% related to the reference. An additional measurement of system B (B+) while the slot was covered showed substantially lower emission (48%). This differences between results of B and B+ probably has to do with the use of open flux chambers on floors with a relatively small air exchange area between pit headspace and the rest of the air in the barn. Due to the small air exchange the concentration of ammonia in de pit head space above the slurry is high during practical circumstances. Applying a small under pressure during flux chamber measurements gives probably an overestimation of the contribution of the slurry pit to the total ammonia emission. Figure 2 shows the emission levels of the different reduction systems and their references per replicated measurement.



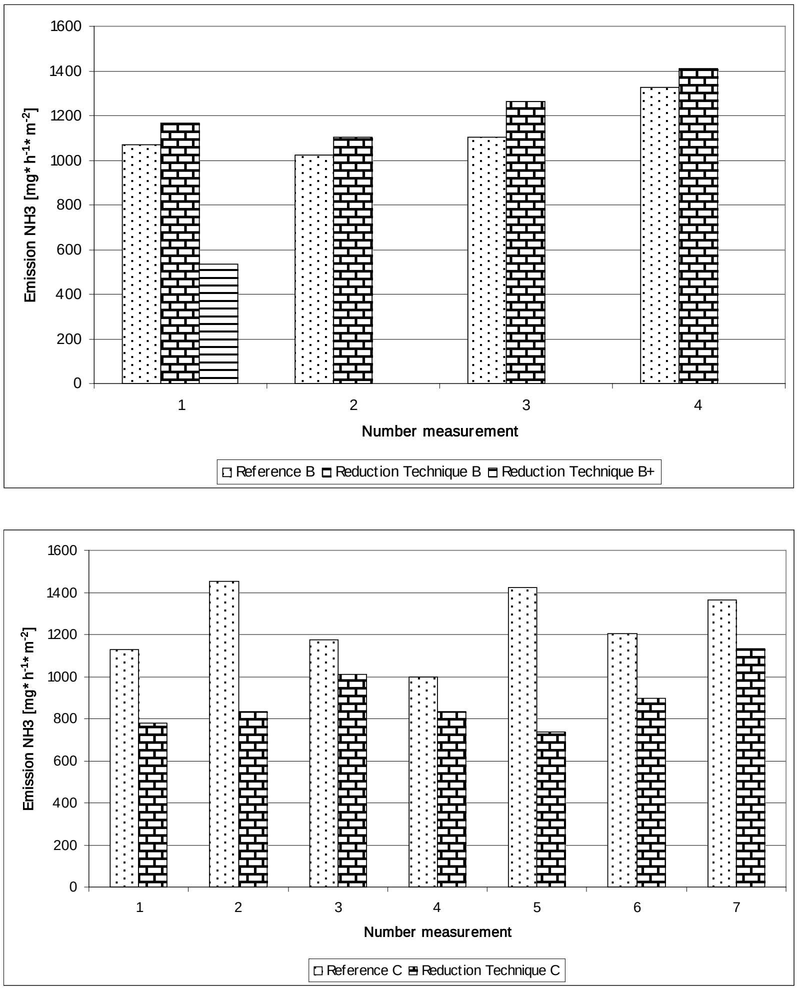


Figure 2. Ammonia emission level of the different reduction systems and paired references per replicated measurement.

CONCLUSIONS

Two systems (A and C) showed a significant reduction of the ammonia emissions with emission levels of 39% and 71% of the ammonia emission from the reference system. One system (B) showed a significant increase of the ammonia emissions with emission levels of 125% of the ammonia emission from the reference system. First measurement showed that system B has a promising reduction option by closing the slots between floor elements. Because of the case-control character of the flux chamber measurements the results can not be translated directly to full scale emission factors for dairy housing neither can they be used for between farms comparison.

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