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DEVELOPMENT OF A FAST MEASUREMENT METHOD FOR THE DETERMINATION OF AMMONIA EMISSION REDUCTION FROM FLOOR RELATED MEASURES

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ABSTRACT New ammonia reduction measures based on new designs for floors or for the manure pit are in development for the cattle industry in the Netherlands. The effect of these systems could be investigated by measuring emission effects at floor level rather than from the whole barn, i.e. by comparing new floors and reference floors with flux chamber measurements. By doing this, the environmental potential can be determined faster and cheaper than by measuring whole barn emissions. In order to design an accurate comparison method, information is required on essential characteristics of the flux chamber measurement and spatial and temporal variation of floor emission. This paper describes experiments performed with a dynamic flux chamber in cattle houses to provide this information. Measurements were performed at three different (floor) places in the barn and at four air flow levels. Ammonia concentrations in the dynamic flux chamber reached equilibrium after approximately five minutes. The relation between ammonia emission and air flow was not linear: the emission rate slowed down for increasing air flow values. There was a significant difference in emission between measurements at different (floor) places in the barn (spatial variability). Measurements also showed a significant difference in ammonia emission between measurement days (variability in time), but not within a measurement day. For a good estimation of the ammonia emissions at the floor level it is therefore advised to measure at different (floor) places in the barn during a number of days, if possible under different weather conditions.

Keywords: Ammonia emission, flux chamber, cattle housing

INTRODUCTION

Agriculture is the most important source of ammonia (NH_3) emissions in the Netherlands. In 2003, approximately 91% of the Dutch NH_3 emissions originated from agricultural activities (MNP, 2005). Livestock buildings, and application of manure/slurry into the field, are the most important sources of NH_3 emissions from agriculture. Together they were responsible for about 80% of the total NH_3 emissions. In order to reduce NH_3 emissions the EU has set a policy towards emission ceilings (maximum amount of a substance expressed in kton, which may be emitted from a member state in a calendar year) for all member states. This ceiling is for the Netherlands 128 kton NH_3 per year in

2010 (EU, 2001), which is a reduction of approximately 40% relative to the emission in 1980 (234 kton; Sliggers, 2001), being the reference year for the Dutch government. Besides, the Dutch government aims to a much further reduction (100 kton NH_3 per year) in order to protect vulnerable ecosystems (VROM, 2001). The contribution of agriculture should be than reduced to bout 86 kton (Sliggers, 2001).

In the Netherlands, only low emission housing systems that are included in the Regulation ammonia and animal husbandry (Rav; Infomil, 2008) may be applied. New, potentially ammonia emission housing systems, must be measured according to the official measurement protocol in order to be eligible for inclusion in the Rav. This means, among other things, that measurements should be performed at four different locations with the same housing system for a period of one year.

A number of ammonia reduction measures, based on new designs for floors or for the manure pit, has been implemented in the cattle sector. The effect of these systems could be investigated by measuring at the floor level rather than from the whole barn. By doing this, the environmental potential of these measures could be determined faster and cheaper than by measuring the emissions from the whole barn. However, for this method to be applied it is necessary to also include measurements on a reference floor. The reason is that measurements at the floor level cannot be compared directly with barn emissions, and therefore with the existing emission factors.

This paper reports the results of measurements performed to establish the reproducibility of measurements performed with the flux chamber method to determine ammonia emissions from cattle houses. This included, among others, the effect of temporal and spatial variability on the measured emissions.

MATERIAL AND METHODS

This research was performed at the Experimental Research Center Waiboerhoeve in Lelystad (The Netherlands). A flux chamber (Figure 1; 2.37 m x 2.32 m x 0.40 m) was used to measure ammonia emissions from different sections of the slatted floor (including the manure pit under the floor) in the cattle house.

Figure 1 Dynamic flux chamber.

The flux Q (g m^{-2} h^{-1}) from the emitting surface A [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:

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

The concentration of NH_3 in the in- and outgoing air 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 flux chamber to allow for a good mixing of the air inside the chamber. 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

Besides, the temperature (^{o}C) and relative humidity (%) were measured for all measurement periods close to the place where the chamber was placed by using a Rotronic Hygromer®. This sensor was 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).

The following questions were addressed during this research:

- The effect of the air velocity inside the flux chamber on the ammonia emission. This was investigated by measuring the ammonia emission at different ventilation rate levels.
- The spatial variability of ammonia emissions at the floor level. To study this effect, the flux chamber was placed at three different floor places in the barn.

- Temporal variability of ammonia emissions within a day (e.g. due to variations in temperature, air velocity and flow at the floor level, animal behaviour) and between days. This was investigated by measuring during six different days, both in the morning and in the afternoon, at the three different floor places. This resulted in a total of 36 measurements.

All measurements were performed in a completely randomized block design. The overall effect of the treatments (spatial and temporal variability) was studied by using the REsidual Maximum Likelihood (REML) directive of the statistical package Genstat.

RESULTS

Figure 2 shows the concentration pattern measured after placing the dynamic flux chamber. Ammonia concentration inside the chamber reached an equilibrium after approximately five minutes.

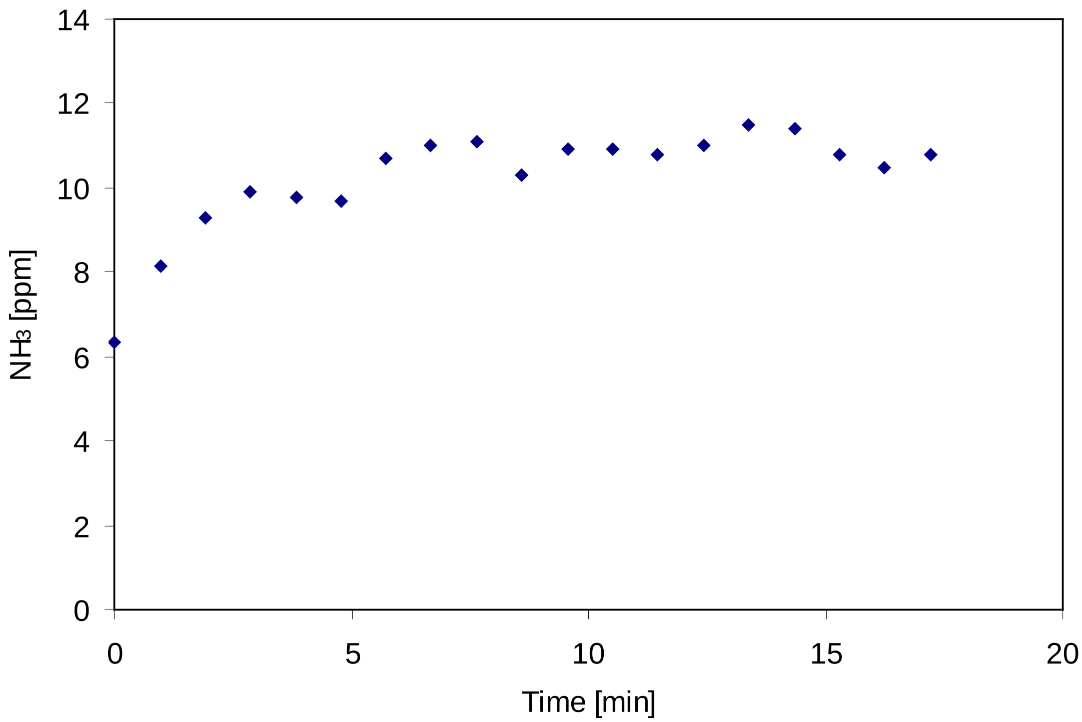

Figure 2 Ammonia concentration pattern inside the dynamic flux chamber. Applied

ventilation rate: 860 m^3 uur^{-1}.

To investigate the effect of the air velocity inside the flux chamber on the ammonia emission, four different ventilation rate levels were applied: 15, 30, 40 and 50% of the maximum capacity of the ventilator. One measurement was performed per measurement point (floor place) and ventilation rate level, resulting in a total of 12 measurements. Figure 3 shows that the relation between the ammonia emission and the ventilation rate was not linear.

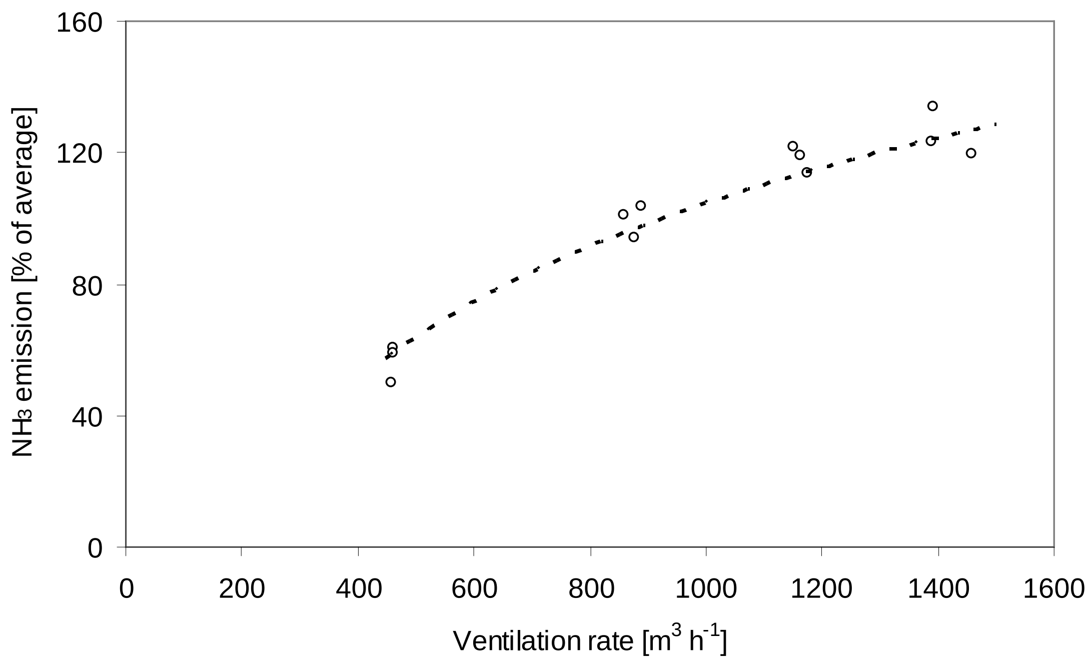

Figure 3 Relation between the ammonia emission and the ventilation rate level of the ventilator in the chamber

To investigate the effect of spatial and temporal variability on NH_3 emissions, a constant ventilation rate was used in the flux chamber. The applied ventilation rate level (15% or 450 m^3 h^{-1}), resulting on an air velocity of 0.13 m s^{-1} above the floor surface, is a typical air velocity measured at the floor level on cattle houses (Smits, personal communication). All 36 measurements (6 measurement days, and per day measurements in the morning and in the afternoon at the three different floor places) were performed within two weeks (14-23 October). This was aimed to minimize variations in the climatic conditions in the barn during the measurements. Despite this, variations in temperature and relative humidity were significantly different between measurement days (Table 1). These differences could not be explained by variations between different floor places in the barn or by the time of the day (morning or afternoon) where the measurements were performed (Table 2). Ammonia emissions were also significantly different between measurement days (Table 1). The time of the day did not have a significant effect on the NH_3 emissions (Table 2).

Table 1. Average climatic conditions and ammonia emissions for all measurement days. Significant differences ($P<0.05$) between measurement days are represented by different superscripts. RH: relative humidity. s.e.d.: standard error of differences.

Date	T [^oC]	RH [%]	NH_3 [$mg\ m^{-2}\ h^{-1}$]
14/10/2008	$17{,}7^{c}$	$64{,}8^{a}$	$450^{a,b}$
16/10/2008	$13{,}9^{a,b}$	$73{,}8^{b}$	$377^{a,b,c}$
17/10/2008	$15{,}7^{b}$	$65{,}2^{a}$	498^{a}
21/10/2008	$13{,}2^{a}$	$78{,}1^{b}$	$322^{b,c}$
22/10/2008	$13{,}4^{a}$	$66{,}3^{a}$	$439^{a,b,c}$
23/10/2008	$13{,}8^{a,b}$	$74{,}1^{b}$	310^{c}
s.e.d	0,9	4,1	67

Table 2. Differences in ammonia emission and climatic conditions (temperature (T) and relative humidity (RH)) per floor place and time of the day. Significant differences ($P<0.05$) between measurement days are represented by different superscripts. s.e.d.: standard error of differences.

			Average ± s.e.d		
		n	T [^oC]	RH [%]	NH_3 [$mg\ m^{-2}\ h^{-1}$]
Floor place	1	12	$14{,}8 \pm 0{,}9^{a}$	$71{,}0 \pm 3{,}1^{a}$	290 ± 44^{a}
	2	12	$14{,}4 \pm 0{,}9^{a}$	$69{,}6 \pm 3{,}1^{a}$	435 ± 44^{b}
	3	12	$14{,}4 \pm 0{,}9^{a}$	$70{,}5 \pm 3{,}1^{a}$	396 ± 44^{b}
Time of the day	Morning	18	$13{,}9 \pm 0{,}7^{a}$	$74{,}4 \pm 2{,}6^{a}$	376 ± 36^{a}
	Afternoon	18	$15{,}1 \pm 0{,}7^{a}$	$66{,}4 \pm 2{,}6^{b}$	371 ± 44^{a}

CONCLUSION

The main conclusions of this research are:

- Ammonia emissions were significantly different at different floor places in the barn. This can be explained by the spatial variability of ammonia emissions at the floor level.
- Ammonia emissions were also significantly different between measurement days.
- Ammonia emissions within a day (morning vs. afternoon) were not significantly different.

To improve the accuracy of ammonia emissions using the flux chamber, we recommend to perform measurements at different floor places in the barn, to minimize spatial variability. Replicate measurements should be performed at different days, and if possible by different climatic conditions in the barn.

Measurements at the floor level with flux chambers cannot be used directly to estimate emissions at the house level. To do this, simultaneous measurements of both ammonia emissions at the floor and the house level at a large number of measurement locations are required.

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