Ammonia emission from naturally ventilated building for dairy cows.

Emissions d’ammoniac issues de bâtiments bovins à ventilation naturelle.

Jean-Baptiste DOLLE.
Institut de l’Elevage. 56, Avenue Roger Salengro.
62051 Saint-Laurent-Blangy Cedex. France.
E-mail : arras.inst-elevage@wanadoo.fr

Abstract

The current work concerns ammonia volatilisation in French naturally ventilated housing systems for dairy cows. Measurements of ammonia emissions require the determination of ventilation rate and concentration of air pollutant leaving the building. For measuring the ventilation rate, we have used a technique based on tracer gas, helium and developed a new model to predict ventilation with meteorological and animal parameters. The ammonia measurements were continuously made by a bubbling method and an infrared photoacoustic spectrometer. At the same time, we have tested an electrochemical sensor and made selectively measures with indicator tubes. The experiments realised on different buildings have shown the difficulties to appreciate the ventilation rate ranging between 600 and 2500 m³/cow/h in naturally ventilated buildings. The average ammonia concentration is included in 0.5 to 8 ppm and the emissions are contained between 3 to 8 kg/cow/seven months housing.

Résumé

Le présent travail concerne la mesure des émissions d’ammoniac issues de bâtiments bovins naturellement ventilées en France. Les mesures sur les émissions d’ammoniac exigent la détermination du flux d’air et de la concentration en polluant atmosphérique quittant le bâtiment. Pour la mesure des flux d’air, nous avons utilisé une technique basée sur le gaz traceur hélium et nous avons développé un modèle qui prédit la ventilation en fonction de paramètres météorologiques et liés aux animaux. Les essais réalisés sur différents bâtiments ont montré la difficulté d’apprécier les taux de ventilation qui varient entre 600 et 2500 m^3/vache/heure dans les bâtiments naturellement ventilés. La concentration moyenne en ammoniac est comprise entre 0,5 et 8 ppm et les émissions correspondantes s’établissent entre 3 et 8 kg/vache pour les 7 mois de stabulation.

1. Introduction

A large part of ammonia emissions is due to livestock farming activities : housing, storage, spreading and grazing are the four sources of ammonia which represented respectively about 35 %, 20 %, 40 % and 5 % of the emissions.

The losses result of the fast conversion of the urea by a faecal enzyme : urease. The process takes place when urine is in contact with manure on polluted floors. The contribution of emission depends on several factors : types of housing, manure management, ventilation system, storage type, spreading equipment...

This study concerns the first part of the manure handling : buildings with natural ventilation system for dairy cows. The aims are to measure ammonia level, to quantify the volatilisation and to show the influence of different parameters in housing systems without modifying breeding conditions.

Our investigations leaded in different buildings with many big equipments (spectrometer, ...) and heavy method (tracer gas) have an another focus : comparing several methods, judging their performance and accuracy for at least developing a straightforward model to estimate ventilation rate, measure ammonia concentration and so, ammonia emissions.

2. Material and methods

2. 1. Housing

Measures were carried out in four housing systems with dairy cows :

- loose cubicle housing with concrete floor,
- loose cubicle housing with slatted floor,
- loose straw bedded housing with a concrete feeding area,
- loose straw bedded housing with a slatted floor feeding area.

These building are equipped with an open ridge and space boarding on sides for natural ventilation. The open areas and the soil surface respect the recommendations per cow.

2. 2. Equipment and variables measured

The measure of ammonia emission needs to determine the ammonia concentration and the ventilation rate. If it is easier to measure the gas concentration, the estimation of the ventilation for this type of building is very difficult. The air inflow and outflow are mixed and the air flow rate is the result of the chimney effect and wind effect.

☐ <u>Ventilation rate measurements</u>
Two techniques have been developed to estimate ventilation rate :

↳ tracer gas method with helium,
↳ prediction model now of being developed by J. CAPDEVILLE (Institut de l'Elevage).

Tracer gas method consist to follow concentration of a gas during a laps of time to estimate the airflow in the building. The gas tracer helium is broken up in the building with a jetflow (ventury system). Taking air are realised through eight flexible tubings disposed in the building. A sample of average air is analysed in a spectrometer to detect instantaneously the evolution of helium concentration and estimate ventilation rate.

The prediction model, unlike some theoretical models proposed in order to predict the air flow rate in naturally ventilated buildings, we chose to consider that some of the mains parameters involved in the calculations can't be known with a sufficient accuracy. It seems easy to measure the areas of the inlets and the outlets and to put them into the model, but the actual active surface is impossible to determine ; in fact, only a part of the areas is active and this part depends on the shape of the openings themselves, but also on the speed and the direction of the wind. Similarly, the total heating you must take in account in the calculations isn't only produced by the cows but also by the straw bedded lying areas and by the sun shine on specific conditions. So, in order to be able to apply the model to measurements in farm situation, we considered that we only could try to explain how the ambient conditions measured inside the building were obtained according to the conditions outside, and the knowledge we had of the principles of the natural ventilation.

The best indicator of the flow rate is the difference of water content of the air between outside and inside. This difference can easily be calculated with the measurement of the temperature and the relative humidity. If the model gives a value of the water vapour produced by all the activities in the building with a sufficient accuracy, you can evaluate the flow rate which permitted to reach the values you measured for temperature and humidity inside the building.

The principle is to proceed with an iterative calculation (increasing progressively the area of the openings and the additional sources of heating) till the difference between predicted and measured values becomes very small (neglectible). Then we extract from intermediate parameters some interesting informations like the flow rate or the ratio between stack effect and wind effect and so on ...

So this model needs to have sensors inside and outside the building. Inside we record continuously temperature and humidity and outside a meteorological station save data on temperature, humidity, wind speed and wind direction.

The prediction model in process gives results with an accuracy around 10 to 20 % compared with the ventilation rate measured. This model easy to use, with simple parameters, must be improved to increase accuracy.

☐ Ammonia measurements
Four techniques have been used to measure ammonia concentration :
- bubbling method,
- infrared photoacoustic spectrometer,
- electrochemical sensor,
- indicator tubes.

The bubbling material and the infrared photoacoustic spectrometer are connected to the flexible tubings used to measure helium.

The electrochemical sensor is linked to a data logger for a continuously measurement of ammonia concentration. One measure a day is made with indicator diffusion tubes (GASTEC and DRAGER) to compare with electrochemical value and correct if necessary.

Bubbling is consider the reference method. In comparison with this reference, spectrometer and electrochemical measurements give results with an accuracy around 10 %.

3. Results

The experiments have been made in 1997 and 1998 during the winter over one to four days. The measures realised on the seven buildings are not enough numerous to compare housing systems with or without straw, with or without slatted floor... Tendencies discovered here have to be confirmed with further measurements.

3. 1. Ammonia and temperature

The ammonia concentration represented on figure 1, varies the whole day. On a three days period in winter, the ammonia level is comprised between 1 and 8 ppm. Meteorological conditions during this experiment, with large daily temperature variation and no wind, permit to judge the influence of inside temperature level on ammonia concentration.

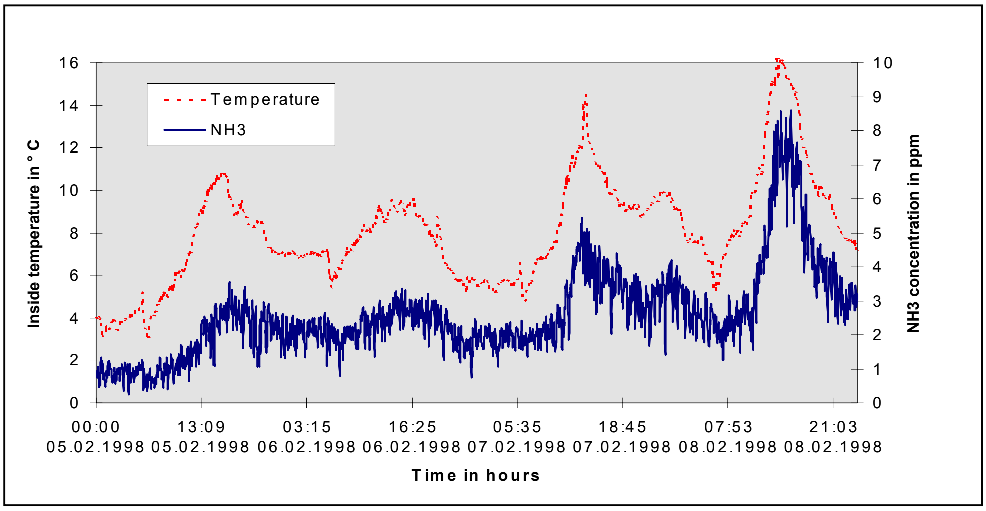

Figure 1
Temperature influence on ammonia concentration in condition without wind

A similar building in another period is represented on figure 2. The daily temperature variation between 8 to 16°C for the two days period has apparently a smaller effect on ammonia concentration comprise between 0.40 and 1.20 ppm. This observation is due to meteorological conditions, the wind of 5 m/s creates a big air renewal which hides temperature effect.

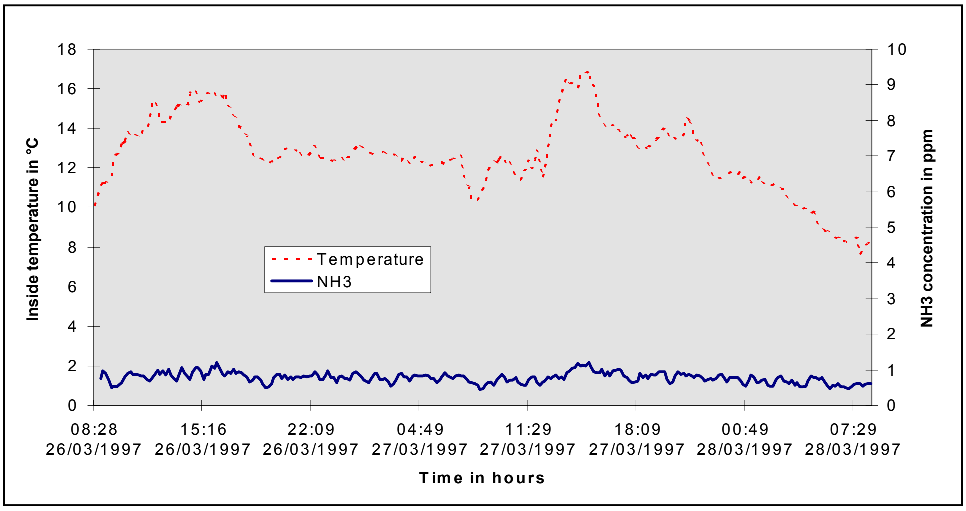

Figure 2
Temperature influence on ammonia concentration in condition with a wind of 5 m/s.

3. 2. Ammonia and mixing

An observation over three days in a building with slatted floor is represented on figure 3. Like in the previous experimentations, we see the temperature incidence on ammonia levels. After one month without mixing the farmer begins mixing with a tractor the 18th March 98 at 11.00 a.m. during six hours and the 19th March at 10.30 a.m. during seven hours for a spreading the 20th. In comparison with the 17 March, day without mixing, we can see the mixing incidence on the ammonia concentration, in approximately the same meteorological conditions.

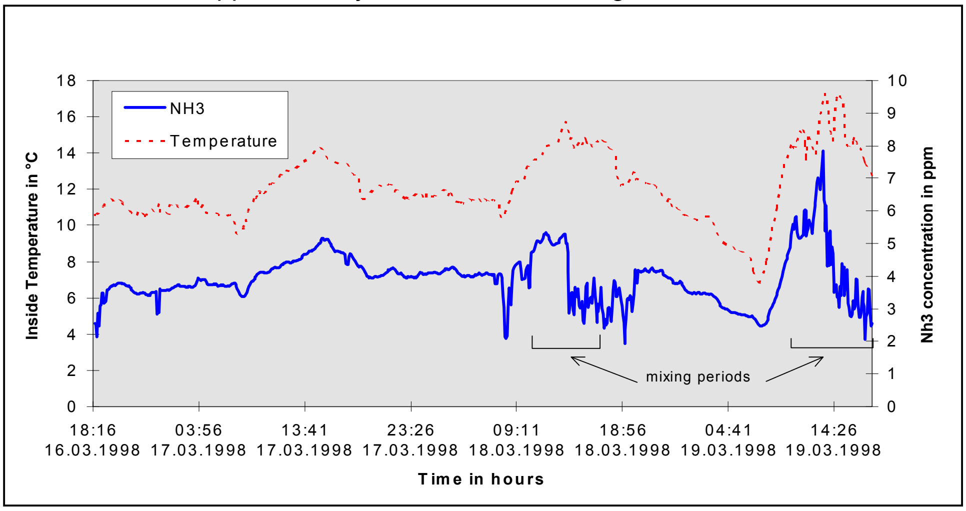

Figure 3
Incidence of mixing on ammonia concentration

First we observe an ammonia concentration increase after the beginning of mixing. Second, about three hours later, the ammonia level decreases rapidly and becomes stabilised till the end of mixing and a laps of time after. Later the ammonia concentration gets back into a normal level.

This phenomena provokes questions. The mixing seems to contribute rapidly to the ammonia volatilisation of the ammoniacal nitrogen while stocks last. Then mineralization restocks ammoniacal pool and volatilisation becomes stabilised.

3. 3. Ventilation rate

The tracer gas method, used in different buildings with different weather conditions, permitted to determine ventilation rate in the range of 600 - 2500 m³/cow/h. This ventilation range depends on building width and building structure, in situation without wind. In another meteorological conditions, it depends on building orientation too.

With the high ventilation rate (table 1), ammonia concentrations are smaller. This reduction of ammonia level can be explained by the rising dilution of ambient air with clean air. Inversely for low ventilation rate, ammonia levels are not always the highest. In this case, effect of housing system and inside temperature on volatilisation are more significants.

	Ventilation rate m³/cow/h	NH_3 concentration ppm	NH_3 emissions kg/cow/7 months housing
High ventilation rate	1000 - 2500	0.50 - 1.20	6 - 8
Low ventilation rate	600 - 1000	1.00 - 4.00	3 - 6

Table 1
First results on ammonia emission measurements except mixing period.

3. 4. Emissions

The ventilation has an effect on ammonia level in housing. So to estimate the emissions we must use the values obtained in the same building at the same time. With these elements, ammonia emissions are in the range of 3 - 8 kg/cow/ seven months housing (table 1). With this seven experiments, we can't make a correlation between these emissions and the housing system, because the weather conditions are very different. But a comparison with data published in bibliography shows that emission rates calculated in this study are in the same range.

4. Conclusion

4.1. In naturally ventilated buildings for cattle, we can't control meteorological conditions, but it's important to know factors which influence ammonia volatilisation. Our investigations allowed us to determine the influence of environmental factors on ammonia emissions.

4.2. In our conditions, ambient temperature has a big effect on ammonia concentration. Inversely, wind and high ventilation rate contribute to decrease ammonia concentration but generate the biggest emission into atmosphere.

4.3. Farmer activities have an incidence on ammonia volatilisation too. The effect of mixing is very important on ammonia concentration in ambient air.

4.4. These observations made on 7 buildings have to be confirmed and need further investigations on this subject.