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Measurement of Ammonia Emission in Practical Dairy Farm Environment

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Abstract

Ammonia emission measurement in practical farm environment needs to meet several contradictory requirements. The instrumentation has to be accurate enough yet economical and easy to use. Most of new dairy production buildings are loose-housing type which sets special requirements to positioning of the sensors in 3D. Measurement locations have to be carefully selected so that they represent the flow patterns inside and out of the building. Sensors have to have suitable dynamic behavior and sampling needs to be dense if rapid changes in concentrations due to e.g. the effect of changing daily routines are to be detected.

A practical instrumentation for Ammonia emission measurement was designed and tested in one-week sessions in six different Finnish dairy barns during all four seasons. The positioning of sensors in 3D was tested. The sampling rate was set high to detect the dynamics of emission.

Results show how the instrumentation affects the obtained results. It was concluded that the instrumentation was feasible. It was economical yet accurate enough for the calculation of farm-level Ammonia emission. Further studies are, however, needed to refine the measurement procedure.

Keywords: Ammonia, Emission, Measurement, Dairy, Practice

1. Introduction

Ammonia emissions from dairy barns depend on several variable factors, most importantly on indoor temperature, ventilation, manure composition (type, nitrogen content and pH), manure handling method used, and the quality and quantity of litter (Groot Koerkamp et al. 2001, Gustafsson et al. 2005, Starmans et al. 2007, Maasikmets et al. 2015). National Finnish emission model, however, has been developed on the basis of international guidelines that have been developed for more or less different climatic and technological environments as compared to Finnish conditions. To compensate the difference, correcting coefficients have been used (Grönroos et al. 2009). In order to check and improve the reliability of these calculations, a sufficient number of domestic emission measurements is needed (Hellstedt et al. 2018).

Accurate assessment of national gaseous emissions needs measurements from different practical situations. The measurements need to be done in a proper way so that the results would represent the actual situations accurately enough. On top of this, the environment inside barns sets strict requirements for the measurement electronics, especially as regards to tolerance against low temperature and high relative humidity (Haapala 2003).

In order to be able to detect changes in emission level, the measurements need to be continuously recording. The resolution and detection rate need to be adjusted to detect the emission accurately enough both in level and time. The sensors need to be positioned so that their results represent the flows inside the building. Finally, the instrumentation needs to be easy to use and economical so that it can be widely used on farm level. (Hellstedt & Haapala 2018)

2. Materials and Methods

Measurements of Ammonia emissions were conducted in Finland in insulated and uninsulated stationary and loose-housing barns with different manure management and littering systems. The instrumentation was done with an economical setup enabling accurate measurements in both space and time. Usability of the results and instrumentation were assessed. (Hellstedt et al. 2018)

The measurements were done in 24 one-week sessions, i.e. six barns were measured during all the four seasons. Continuously measuring Dräger PAC 7000 Ammonia sensors with a range of 0 to 300 ppm and a resolution of 1 ppm were used. The Dräger sensors are originally designed to act as personal protection devices in hazardous environments. They were chosen for barn environment because of their ruggedness, adequate accuracy and relatively low price. (Hellstedt & Haapala 2018, Fig. 1.)

The positioning of sensors is critical since airflow patterns depend on barn layout (Teye 2008, Ngwabie et al. 2009). In this study, sensors were installed in three elevations (0.1, 1.0 and 2.5 meters) according to the method used by Teye (2008). There were 9 to 12 Ammonia sensors altogether in the barns, depending on the size of the barn. Airflow was measured with a hot-wire anemometer to position the sensors in representative locations. (Hellstedt & Haapala 2018, Fig. 2.)

Fig. 1. The Ammonia sensors together with CO_2, temperature and RH gauges (left) were placed inside the barns in three elevations (0.1, 1.0 and 2.5 meters) (center) and three to four locations, depending on the size of the barn. If accessible to the cows, the instruments were protected by rugged steel casings (right). (Hellstedt & Haapala 2018)

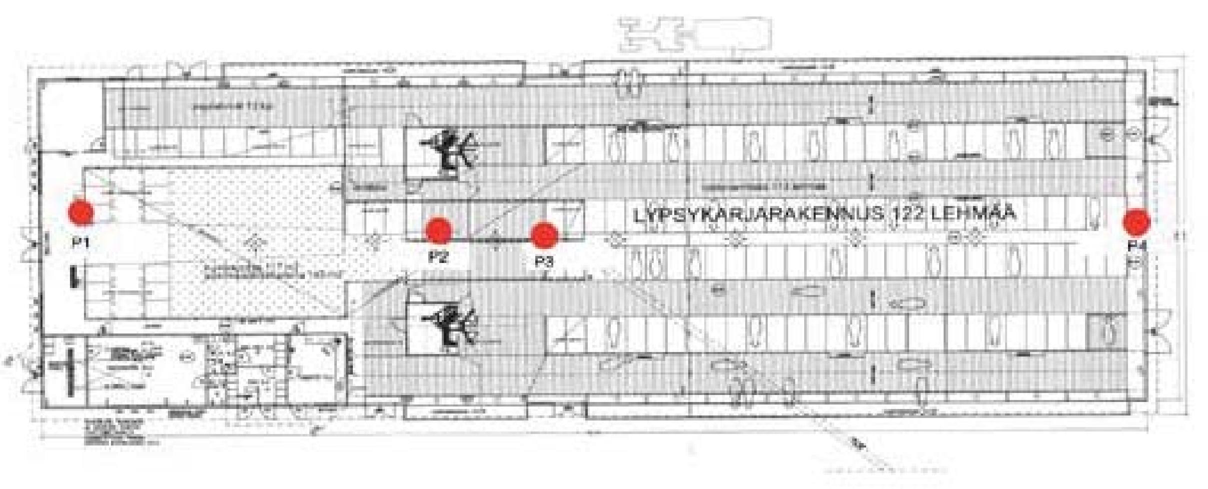

Fig. 2. An example of the positioning of sensors in a loose-housing barn with two milking robots and 122 cows. In each position there are three Ammonia, CO_2, temperature and RH sensors in three elevations (Hellstedt & Haapala 2018).

The detection rate was set high, every 2 minutes, in order to be able to detect the dynamics of the emission. The ventilation rate in the barns was derived out of the measured CO_2 balance. The Ammonia emission was then calculated based on the Ammonia concentrations and the ventilation rate (Teye & Hautala 2007, Eq. 1 and 2)

Production of gas x depends on concentration difference and ventilation:

$$P_x = q_{V_x}\left(C_{g_x} - C_{out_x}\right)$$

where q_{V_x} *is ventilation* (m^3/h)

C_{g_x} *is concentration of the gas inside the building (ppm)*

C_{out_x} *is concentration of the gas in inlet air (ppm)*

Eq. 1.

Emission in g/h/m² is calculated by ventilation and concentration difference:

$$j_{CO_2} = \frac{q_{V_{CO_2}} \rho_{NH_3} \left(C_{g_{NH_3}} - C_{out_{NH_3}}\right) \times 10^{-6}}{A}$$

where

ρ_{NH_3} is density of Ammonia (g/m^3)

A is area of manure-covered areas (m^2)

Eq. 2.

3. Results and Discussion

According to the emission measurement results the barns had significant differences in Ammonia emissions both during the seasons and between the farms as well. In loose-housing barns the level was mostly under 5 g/cow/day whereas in stationary barns it was less, under 3.5 g/cow/day. The emission level for loose-housing barns was considerably lower than the figures that had been previously measured and used in national calculations (Teye 2008, Grönroos et al. 2009). For stationary barns the situation was opposite so that somewhat higher levels of Ammonia emission were found. Loose-housing, however, is the dominant housing system in future in Finland, and stationary barns are not built anymore.

There were several peaks in Ammonia emission during the day. When closer analyzed and compared to the log file kept by the farmer, the peaks occur when the manure is handled or the animals are active. The daily routines cause animal movement and agitation of manure-covered surfaces which enable higher concentrations of Ammonia inside the barn. (Hellstedt et al. 2017, Fig. 3.)

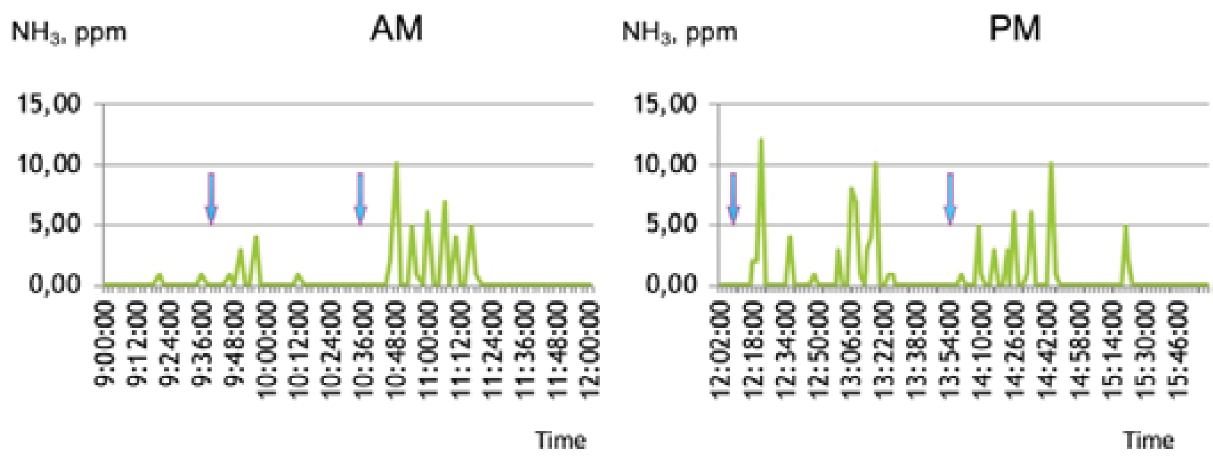

Fig. 3. Ammonia emission during morning and afternoon. The dense detection rate (every 2 minutes) reveals fluctuations in emission. The fluctuations happen as people enter the barn to make the daily management routines (marked with arrows) that cause increased animal movement or agitation of manure-covered surfaces. (Hellstedt et al. 2017)

As there were several sensor locations in the barns, local disturbances causing increased Ammonia level could be detected. In one of the loose-housing barns, the manure removal system was accidentally left on for a longer period. The sensors detected the rise of Ammonia level near the source and how the turbulent airflow mixed the caused higher concentration inside the barn. If there had not been several measurement locations, the reason for elevated Ammonia concentration had not been detected. (Hellstedt et al. 2017, Fig. 4)

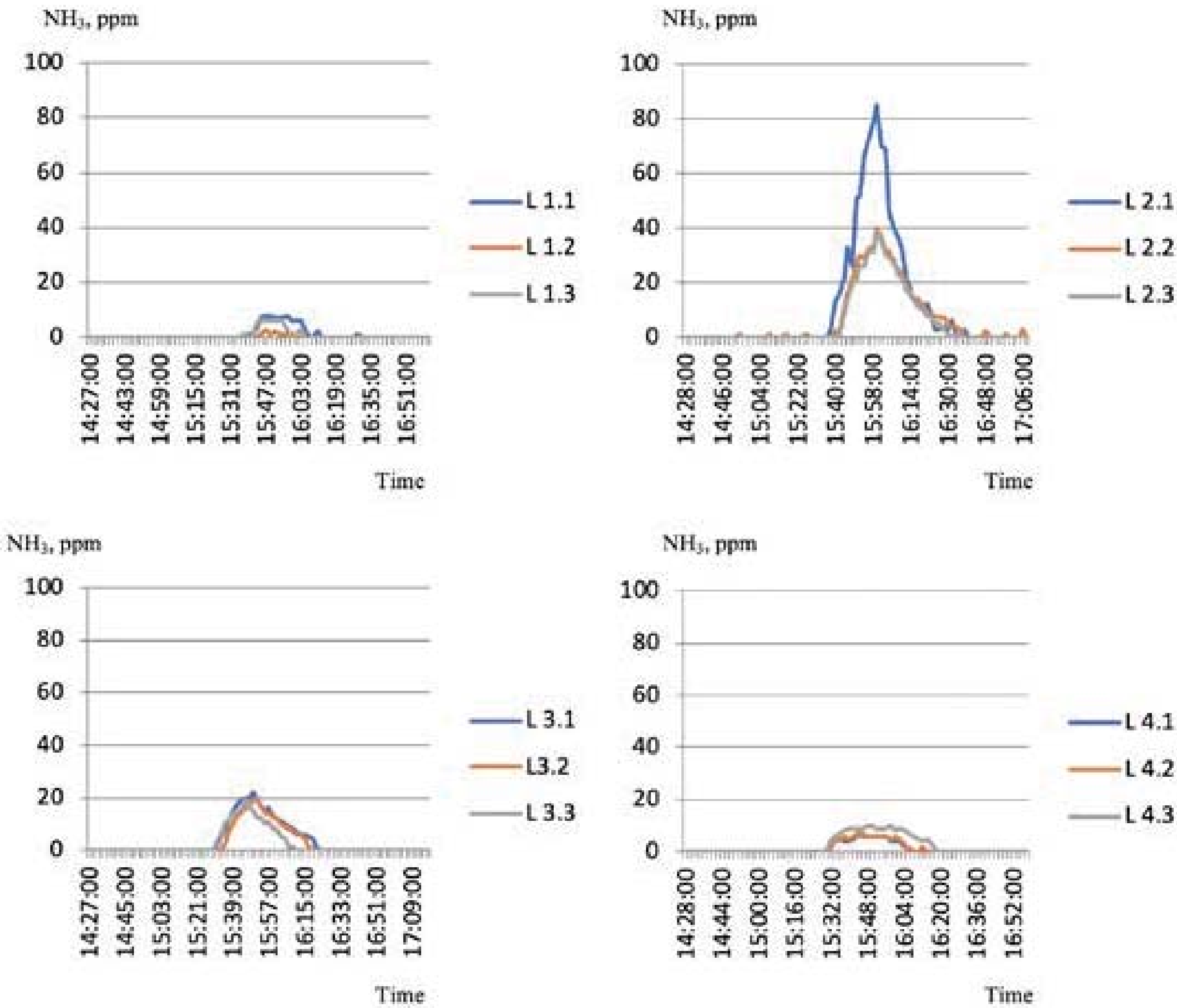

Fig 4. Effect of manure agitation. Manure removal system was accidentally left on for a prolonged period near the point nr 2. The nearby sensors (L2.1 to L2.3.) measured a highly increased Ammonia level specially at ground level (0.1 m). Sensors at positions 1, 3 and 4, further from the source, detected lower levels that had been equalized by the turbulet airflow. (Hellstedt et al. 2017)

4. Conclusions

The measured data suggest that Ammonia emission level in current Finnish barns is significantly lower than projected in the previous modelling. In future, loose housing is dominant and better technologies are utilized so that Ammonia emission per cow will be further diminishing.

Besides the type of barn (layout, milking, feeding, and manure removal systems) the Ammonia emission seems to be greatly affected by management operations. Same type of barn can be managed in different ways, causing considerably different levels of emission. The daily management causes changes in ventilation, temperature and relative humidity, but also in cow activity which has an effect on manure agitation and resulting emission.

The results concerning the implementation point out the importance of understanding the local circumstances and the ability to make the measurement design accordingly. The measurement principle utilized enables a more precise analysis of the differences of barns.

Instrument positioning needs to be adjusted to the barn layout both in 2D and 3D. The continuous measurement principle with dense detection rate and relevant instrument locations allow the researchers to find daily and momentous fluctuations in emission rate caused by the individual management practices on the farms and disturbances in them. These might explain the large variation in emission measurements that have been done before with inadequate instrumentation, i.e. using random sensor locations or unsuitable detection rates.

The price-quality ratio of instrumentation limits the practical usability of measurement methods. Research and inspection have different requirements from those of farm level usage. If emissions need to be measured continuously for practical purposes such as farm management, it is important to create optimized methods for farm level usage.

Further studies are needed to further improve the validity of measurements, to assess the effect of management practices and to assess the effect of manure storage.

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