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INTERMITTENT MEASUREMENTS TO ESTIMATE AMMONIA EMISSIONS FROM MANURE STORAGE SYSTEMS

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ABSTRACT: The production of animals must comply with several environmental requirements. Monitoring ammonia emissions from agricultural buildings and storage systems is one of them. To reduce cost, techniques were developed that use inexpensive measuring equipment and do not require long periods of measurements, a technique based on intermittent measurements of ammonia was developed for mechanically ventilated barns. More specifically, easily-measured variables, such as ventilation rate, temperature, and animal weight are measured continuously, while the ammonia emission rate is measured intermittently at six well-selected days per year. Mathematical modelling techniques are subsequently used to estimate the ammonia emission rate online. The intermittent ammonia measurements are used to regularly calibrate the model. However, for manure stores, this technique has never been applied due to lack of a reliable ventilation rate measurement system. The objective of this paper is to introduce a procedure to determine the ammonia emissions from manure storage systems in the field, based on intermittent measurements of the ammonia emission rate. In this study, an experimental tank was filled with fattening pig slurry. One was covered with a mechanically ventilated cover. Based on the knowledge that ammonia emissions are strongly related to air and manure temperature, a technique was developed to estimate ammonia emissions online. A steady-state regression model was used to calculate the cumulative ammonia emissions over the complete measurement period with 9% accuracy. This paper demonstrates the possibilities of model-based procedures for the development of an inexpensive system for determination of ammonia emissions.

INTRODUCTION: Intensive livestock production is of major importance to the economies of many countries, but is also connected with a number of environmental effects, including airborne emissions. In Europe for example, pig production is concentrated in several regions characterised by large-scale intensive farms. Ammonia emissions from liquid manure inside pig houses are related to the ammonia concentration difference between the manure and the air above the manure, manure pH, manure temperature and air temperature and air velocity over the manure surface (Ye *et al.*, 2008; Zhang *et al.*, 2008; Saha *et al.*, 2010).

Currently, measurements of ammonia emissions from manure storage systems in field conditions are expensive due to the equipment needed (e.g. nitrogen oxide (NO_x) analyser), the manpower and the time-consuming measuring periods (up to 200 days for fattening pigs). Moreover, governments are looking for field measurements in high numbers of livestock buildings and storage systems to implement a policy to reduce ammonia emissions (Vranken *et al.*, 2004; Bluteau, 2009; Hamelin *et al.*, 2010).

The method of “intermittent measurements” was developed for livestock houses and attempts to offer an alternative to the expensive measuring approach by limiting the number of required measuring days (Vranken *et al.*, 2004). With the method of intermittent measurements, the ammonia concentration in a specific animal house is modelled each moment based on an empirical ammonia emission model for an

individual livestock building. This ammonia model calculates the ammonia emission from easily measurable climate variables (indoor temperature, outdoor temperature and ventilation rate) that are continuously available throughout the year from the climate controller in combination with management variables, such as weight and number of animals.

The intermittent method was originally developed in previous studies (Vranken *et al.*, 2002) to reduce the high cost of continuous ammonia emission measurements from animal buildings and not from manure storage systems.

The main objectives of this paper are to present a reference technique to monitor the entire emissions from a manure storage tank, and to apply the intermittent measurements approach to estimate ammonia emission from a manure store.

1. MATERIALS AND METHODS:

1.1. Experiment: The experiment was conducted using an experimental storage tank at the National Pig Experimental Station in Romillé, France. The tank was filled with fattening pig manure and totally covered with a cover that was ventilated by a mechanically ventilated system. The tank had a total 13.5 m³ volume of slurry and the dimensions of the cover are 6 × 3.5 m and ridge height of 2.5 m. The cover was equipped with a fan with a 35 cm diameter, with max ventilation rate of 2600 m³/h and placed in the upper side of the cover. The experiment occurred for three consecutive months.

1.2. Measurements: Ammonia concentration, ventilation rate, outdoor and indoor air temperatures, indoor air relative humidity, near-manure surface air temperature and humidity, and manure temperatures in different depths (5 cm and 30 cm) were continuously measured. Continuous measurements were taken over the entire slurry storage period (three months) from 22 June 2009 until 15 September 2009.

The ammonia concentration was measured with a photo-acoustic multi-gas monitor (INNOVA 1312) with a 6-channel-multi-sampler. Indoor air samples were taken in the exhaust of the ventilation. Ammonia concentration was measured every 1 hour. A calibrated ventilation rate sensor measured ventilation rates with ± 45 m³/h accuracy. Indoor air temperature was measured in the exhaust openings. All variables (ventilation rate, slurry temperature, indoor air temperature, surface air temperature and humidity) were recorded every 15 minutes.

1.3. Intermittent measurements method: In the principles of intermittent measurements method, the expensive field measurements of ammonia emissions are performed for a limited number of measuring days distributed over the whole estimation period. Using the data of these selected days, a simple mathematical model was developed that relates the expensive field measurements of ammonia emission with the continuously measured related variables, such as outside temperature, indoor air temperature, slurry temperature and indoor air relative humidity. This statistical model is used in a following step to estimate the ammonia emission over all other days, using the data of the easily-measured related variables over the whole year. For validation of the procedure, continuous measurements of ammonia emission were used as reference data.

Ammonia emission from the manure storage system can be calculated as a function f of number of easy measurable variables as follows:

$$E=f(\text{near manure surface air temperature, slurry temperature})$$

Where E is the ammonia emission (g/h)

2. RESULTS AND DISCUSSION:

2.1. Model identification: The correlation coefficient matrix (Table 1) was calculated from the whole measurement period, including the ammonia emission and the related variables, specifically: the indoor air temperature, near slurry surface air temperature, slurry surface temperature, below slurry surface temperature, indoor air temperature, indoor relative humidity, and ventilation rate.

Table 1. Correlation coefficient matrix results from covered slurry storage tank including the ammonia emission and the related variables.

Variables	Correlation coefficients						
	E	u ₁	u ₂	u ₃	u ₄	u ₅	u ₆
Ammonia emission (E)	1						
Near surface air temp. (u ₁)	0.88	1					
Surface temp. (u ₂)	0.73	0.82	1				
Indoor air temp. (u ₃)	0.67	0.90	0.59	1			
Below surface temp. (u ₄)	0.41	0.39	0.44	0.18	1		
Indoor humidity (u ₅)	0.45	0.58	0.22	0.53	0.11	1	
Ventilation rate (u ₆)	0.50	0.32	0.29	0.41	0.19	0.58	1

The matrix showed a high correlation between ammonia emission and several of the proposed related variables. Near slurry surface air temperature, slurry surface temperature u_2 had a strong correlation with ammonia emission E. Therefore, it was judged that at least the variables u_1 and u_2 should be included in the model structure. Using only these two variables, a linear steady-state model structure was defined to predict ammonia emission over the whole measuring period.

The following linear steady-state model structure was used:

$$E=au_1+bu_2+e$$

where E is the ammonia emission $g \cdot h^{-1}$, a and b are the estimated model parameters. For the selected days for modelling, the value of the coefficient of determination R^2 was at least 0.84.

Figure 1 shows an example of using the presented model structure to predict the ammonia emission from a covered storage tank over a period of one month. The model parameters (a and b) were estimated in which the data of the first five days was used to estimate the model parameters. The resulting linear steady-state model was

used to predict the ammonia emission over the all other days, using only the data of the related variables over the entire time period. For validation of the procedure, continuous measurements of ammonia emission were used as reference data (Figure 1).

The resulting model well-described the ammonia emission from the first five days and had a R^2 of 0.84 (Figure 1.A). Ammonia emission data from the selected day was used later to validate and retune the model parameters (Figure 1.B). The validation results showed that the model parameters did not change significantly ($a=0.2386$ and $b=-0.0227$). The model was used to simulate the ammonia emission from the whole period. The measured ammonia emission from the storage tank for one month was about 3.4 kg and the predicted ammonia emission was about 3.1 kg. The error of the predicted ammonia emission (with 95% certainty under the normal distribution) was greater than 9 %.

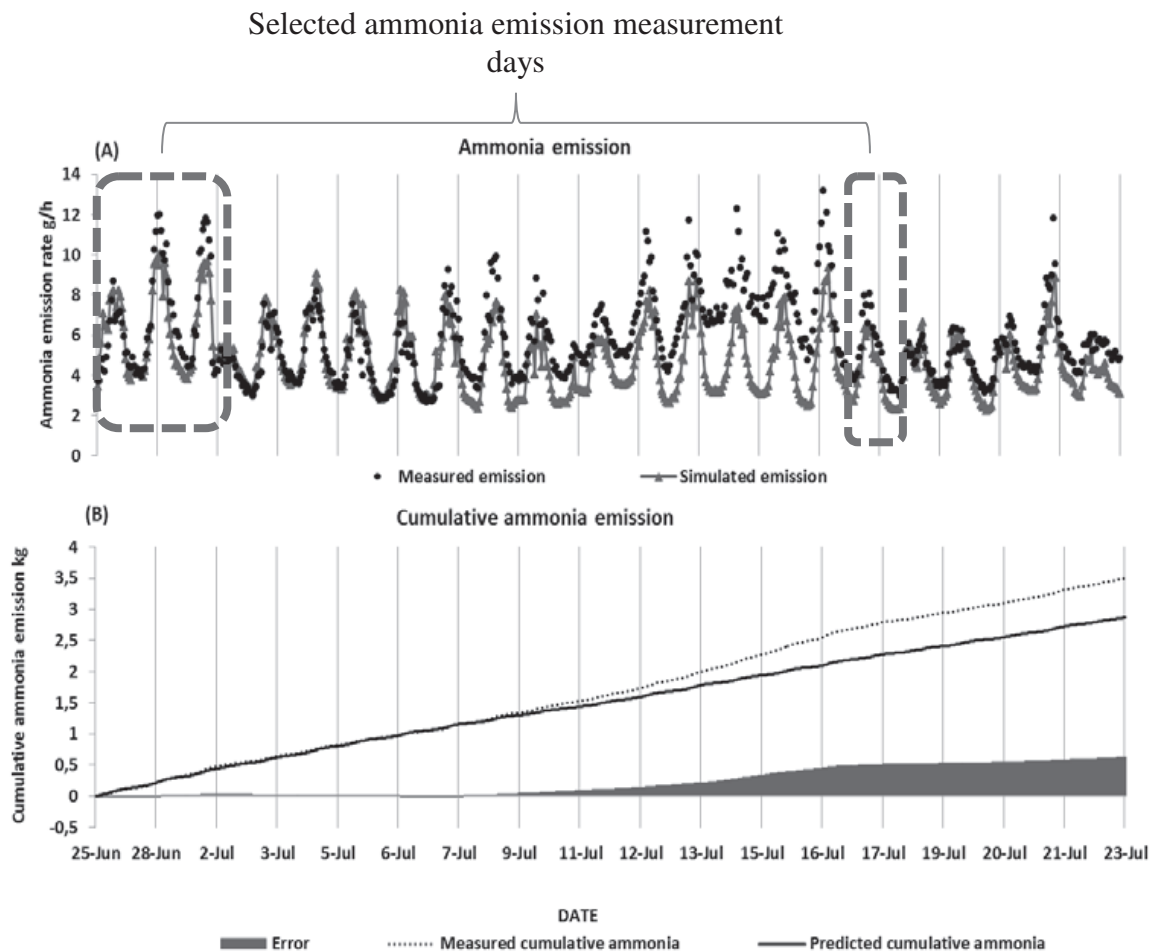


Figure 1. Comparison of measured and simulated ammonia emissions

CONCLUSION: Near surface air temperature and manure surface temperature within the ranges of 12-45°C and 15-32°C, respectively, are sufficient and suitable to model ammonia emission and to estimate the cumulative ammonia emission. The resulting linear steady-state model well-described the ammonia emission from the storage tank for the modelling days with a R^2 of 0.84. The model was suitable to calculate the cumulative ammonia emission (max Error=9%). Ammonia emission data from one day with sampling frequency of 1 sample per hour was sufficient to validate the model

parameters. During these three months of ammonia emission monitoring, the model parameters did not change significantly; however, it is suggested to calibrate/retune the model parameters during the different seasons in the year.

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