Accuracy of SMDAE to Determine Ammonia Concentration in Animal Facilities in Hot Climates

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Abstract

Considering the importance of developing reliable methodologies and low cost methods to determine ammonia concentration in animal buildings the main objective of this study was to evaluate the accuracy of SMDAE (Saraz Method for Determination of Ammonia Emissions) to quantify the ammonia concentration inside of animal facilities located in Minas Gerais, Brazil. Results obtained with SMDAE were compared to those obtained by electrochemical sensors located inside of a controlled chamber with known concentrations of 5, 10, 15, 20 and 25 ppm of ammonia. It can be concluded that the SMDAE is satisfactory accurate within the analyzed ranges. However, this accuracy is reduced for higher values of ammonia concentration. With this results an equation was adjusted for SMDAE to determine the concentration of ammonia in the environment.

Keywords: animal housing environmental, air quality, ammonia emission.

1. Introduction

Ammonia is the most common pollutant found in high concentrations inside of animal production facilities (OWADA et al., 2007). Besides the economic issues related to ammonia gas in animal husbandry environments due to damaging the health of animals and workers, it is noteworthy that ammonia is a greenhouse gas, generating undesirable environmental consequences when emitted in high concentrations (FELIX & CARDOSO, 2012). It may also contaminate water, air and soil, affecting the planet's future and animal production sustainability (CAROLLA et al., 2009). Thus, it is necessary to implement technological strategies to minimize the environmental impact caused by the emission of greenhouse gases (VARGAS-NIETO et al., 2011).

For regions with tropical and subtropical climates, such as Brazil, determining the concentration and emission of ammoniais much more complex since virtually all livestock shelters are kept open, constituting open or partially open (hybrid) systems, which have interference of uncontrollable external wind currents. (TINOCO & OSORIO, 2008).

Among the methods available to naturally ventilate facilities, that ispredominantly in open facilities, predominate the passive flow methods. Among these methods the SMDAE method proposed by Saraz et al. (2014), is noted for its simplicity, efficiency, and applicability to being able to determine ammonia emissions in livestock production in open facilities.

The Saraz method was evaluated in field conditions (SARAZ et al., 2014), and was considered to be efficient in measuring ammonia emissions from broiler litter coming in very low concentrations, such as 0.5 ppm and 1.0 ppm in ventilation conditions for natural air velocity above 0.1 m s^{-1}. However, according to Saraz et al. (2014), the method needs to be improved and more research should be conducted into different concentrations and environmental conditions, with the aim of gaining a better understanding of the efficiency and applicability in inventories of greenhouse gases such as ammonia gas.

Despite the great diversity of available methods to quantify the concentration of ammonia in the atmosphere , the majority of these are expensive and involve undertaking a series of steps in the laboratory that may contaminate the sample. Therefore, comparison studies are still required, as well as the adaptation and application of methods to quantify ammonia (FELIX & CARDOSO, 2012).

Thus, there is a need to assess the efficiency of the proposed SMDAE method in different environmental conditions, with variations in ambient air velocities, and with different ammonia concentrations studied by Saraz et al. (2014), in the conditions in the field shelters for livestock. In order to do this, it is important to find a reliable method of calibration, which allows for the actual and possible values of ammonia levels to be quantified. The pickup device employed in the SMDAE method is capable of measuring in environments with climate variability and, therefore, it captures the rate of ammonia emissions in a controlled situation by generating an equation for the SMDAE method environmental setting.

2. Materials and Methods

This work was conducted in the Department of Agricultural Engineering at Federal University of Viçosa in climatic chambers, at Ambiagro – the Center for Research in Agro-industrial ambience – , and also at the Engineering Systems and laboratories in the area of Rural Buildings and Ambience and Energy in Agriculture.

2.1 The beacon equipment development

To enable the improvement of the Saraz method, fully sealed beacon equipment was developed, consisting of a box of translucent glass and polycarbonate with the following dimensions: 30.0 x 38.0 x 28.0 cm (length, width, height). This was inserted into climatic chamber in order to obtain controlled environmental conditions, enabling the analysis in an environment in which the temperature and humidity were controlled and known.

The box, called a normalizing box, was divided into two compartments, an entry sector, and a gas outlet with the same dimensions 30.0 x 18.0 x 28.0 cm (length, width, height). The sector gas inlet was composed of a housing provided with openings for gases to enter (ammonia and pure air) through silicone tubing connected to the external gas cylinders for the purpose of this study. This compartment was provided with two circular openings of 4.0 cm radius, sealed by absorbent porous material positioned above the hoods, which when in use, forced the removal of the outside air to the box. The sector gas outlet, was, in turn, subdivided into two equal sized compartments to allow two samples of air through the porous absorbent material via the exhaust and, hence, two replicates for each variable were analyzed (Figures 1 and 2)

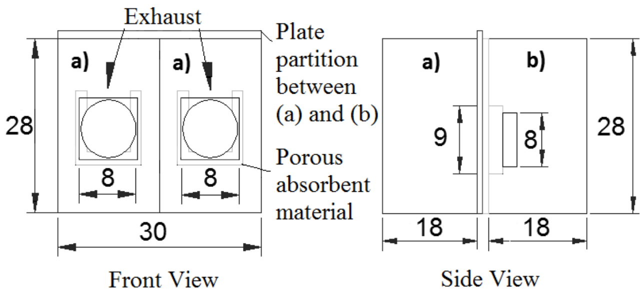

Figure 1. Schematic of normalizing box. Front and side view of the box showing the extraction fans and the compartments: a) gas inlet, b) gas outlet (measured in cm).
Source: The authors.

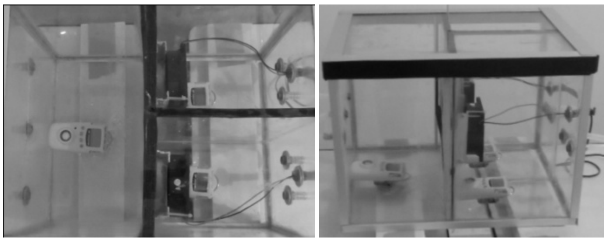

Figure 2. Box top view (left) and (right) lateral view.
Source: The authors.

2.2 Absorbent porous material

The absorbent porous material used was composed of polyurethane sponges with density 0.0162 g cm^{-3} and dimensions of 8.0 cm in length, 9.0 cm in height, and 2.0 cm in thickness. For each repetition, the sponges were impregnated with 25 ml of sulfuric acid (H_2SO_4) 1.0 mol L^{-1}, and glycerin ($C_3H_5(OH)_3$) 3% v/v before sealing the holes of each of the box's input compartments, according to the method proposed by Saraz et al. (2014).

2.3 Exhaust fans

The exit velocity of the gas at a known concentration through the porous absorbent material was different for each treatment (0.1, 1.2, and 2.4 m s^{-1}). This was achieved using hoods installed inside the box that forced the gas through the passage foams, drawing air from inlet compartment to the outlet compartment. The exhaust fans were made by fans or cooler "sleeve bearings" with dimensions of 80 x 80 mm, had a DC voltage of 12 V, a current of 0.15 A, and a speed of 1800 rpm. The speed of the exhaust was controlled by a universal energy source model FT-1462P with a power of 18 W, a maximum load of 1000 mA, a 110/220 Vac input, and seven outputs. Initially, an exhaust calibration curve was taken to determine the rate of entry of gas into the foam; one hot wire term anemometer (TESTO model 425) was used, measuring with a range from 0 to 20 m s^{-1} and with an accuracy of ± 0.03 m s^{-1} and a resolution of 0.01 m s^{-1}.

2.4 Electrochemical Sensors

Electrochemical detectors were used as the instruments to make reference measurements of the various adopted ammonia concentrations (5, 10, 15, 20, and 25 ppm). The BW "Gas Alert Extreme Ammonia Detectors", which are compact and affordable, present a variation in measuring accuracy from 0 to 100 ppm 2%, and operate at a relative humidity from 15 to 90% and a temperature of -20 to +50° C were used.

2.5 Concentration of ammonia

The ammonia concentration was determined from the amount of ammonia that the sponges captured, impregnated first with sulfuric acid and glycerin; that were responsible for fixing the diffused ammonia.

After the capture period, the exhaust fans were turned off and the absorbent porous material was removed, stored and refrigerated in plastic wrap to be taken to the laboratory for the ammonia to be extracted according to the Kjeldahl method, in accordance with the methodology adopted by Saraz et al. (2014).

The ammonia concentration captured by the sponges, that is, the concentration obtained by the SMDAE method, was compared to the concentration of ammonia present in the actual normalizing box in terms of the amount of ammonia contained in the foam and calculated in the box, considering the volume of the foam and the normalizing box. Thus, for the amount of ammonia present in the box, the volume of gas input was considered to be equal to 15,120 cm^3, taking into account the dimensions of 30.0 cm length, 18.0 cm width, and 28.0 cm in chamber height. For the sponge, the amount was 144 cm^3, considering the dimensions of 2.0 cm thickness, 8.0 cm width, and 9.0 cm height. An equation to adjust the concentration obtained from the absorbing porous material due to the expected concentration to be collected by the sponge was generated.

By calculating the quantity values of the NH_3 and NH_3 concentrations observed with the expected values in the environment, the efficiency was analyzed by the Saraz method according to the time of exposure to the different concentrations of the ammonia situations and different speeds of the exhaust air.

2.6 Experimental Design

The experiment was carried out according to a completely randomized design in a 5 × 3 factorial arrangement consisting of five ammonia concentrations and three air velocities.. Thus, the treatments consisted of the combination of five different concentrations of ammonia (5, 10, 15, 20, and 25 ppm) and three different speeds of the exhaust air (0.1, 1.2, and 2.4 m s^{-1}) to analyze the amount of ammonia recovered by the foam of the differents conditions. There were used four replications for each treatment, totaling 60 samples (n = 60).

The data about theamount of ammonia obtained by foam were subjected to analysis of variance (ANOVA). When the F test of ANOVA showed difference, the means were compared by Tukey's test. For all statistical analysis, the value of 5% for the probability of type I error was adopted. We would then carry out a linear regression analysis to determine the coefficients of the model using the Sigma Plot version 12.0 program.

3. Results and Discussion

Table 1 presents data for mean recovery of ammonia using SMDAE method for the different concentrations tested. It is observed that, for lower concentrations, the SMDAE method displayed the highest ammonia recovery efficiencies of around 81% for the 5 ppm concentration and 51% for the 10 ppm concentration. These results are in agreement with work done by Saraz et al. (2014), which was undertaken in field conditions with a recovery of volatilized ammonia poultry manure in the 68–82% range.

Table 1. Average recovery of NH_3 using the SMDAE method in different concentrations analyzed and their standard deviations

NH_3 Concentration (ppm)	Average recovery (%) ± Standard deviation
5	81.10±8.22^a
10	51.54±5.80^b
15	41.00±3.10^c
20	36.90±6.90^d
25	34.31±3.20^e

Means followed by different letters in the emissions of ammonia rates column differ (P <0.05) from Tukey's test.
Source: The authors.

The Saraz method proves to be more efficient, compared to studies by Hernandes & Cazetta (2001), Da Ros (2005), Araújo et al. (2009) e Alves et al. (2011), which use a collection chamber to determine volatilized ammonia from poultry manure and soil that would normally have maximum values of 70% recovery of ammonia.

This higher recovery efficiency of ammonia through the collector box sponge, compared to what happens in practice, can be explained by the fact that, in this experiment, ammonia present in the ambient air was volatilized. This is unlike what happens in other studies in which the ammonia was still in the process of volatilization in the middle bed or the ground and was then captured by the collector. It was thus dependent on the environment's conditions of volatilization , which can interfere with the recovery efficiency. Similar results were found in Lara Cabezas & Trivelin (1990) and

Araújo et al. (2009)'s studies, which showed that the efficiency of the collection chamber for open semi-static NH_3 varies with the amount of volatilized ammonia, both under greenhouse and in field conditions.

Therefore, it can be inferred, that the method used in this study has a good recovery efficiency of ammonia, without an adjustment curve for environments, with concentrations of up to 10 ppm.

Figure 3 shows the linear regression curve for the amount of ammonia obtained by the sponge and the amount of ammonia present in different concentrations. It can be observed in Figure 3 that, independent of the velocity of the exhaust air, one can adjust an equation for any concentration within the values that are being analyzed (up to 25 ppm), since there is a high correlation between the values obtained by foam ammonia and the ammonia values calculated in the environment (R^2 = 0.997). This correlation is linear, showing that the method is valid and can be used for the conditions that are analyzed.

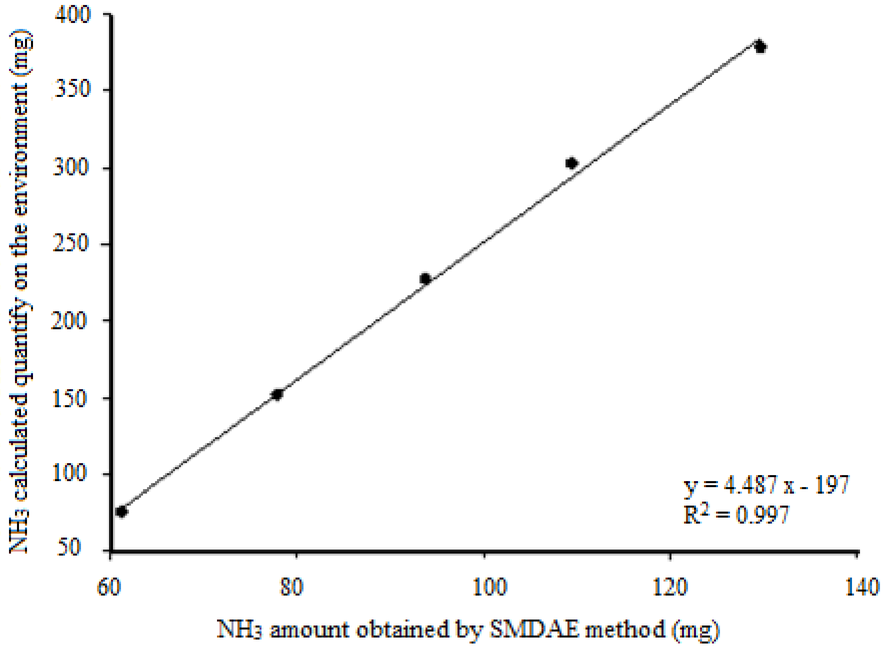

Figure 3. The linear regression curve for the different concentrations of ammonia obtained by the absorbent porous material (SMDAE) and the amount of ammonia present in the environment.
Source: The authors.

Using the regression equation shown in Figure 3, the calibration equation for the Saraz method, Equation 1, was obtained to determine the actual amount of ammonia captured in situations in which the environment contained less than 25 ppm of ammonia.

$$NH_3(mg) = 4.487 \times NH_3 obtained(mg) - 197 \qquad (1)$$

Figure 4 shows the relationship between the concentration of ammonia present in the environment and the ammonia concentration obtained by the absorbent porous material using the SMDAE method, at different speeds of exhaust air. No statistically significant difference (P> 0.05) was found using analysis of variance among the three adopted speeds (0.1, 1.2 and 2.4 m s^{-1}). This indicates that the use of the SMDAE method enables the efficient recovery of ammonia without being affected by the air velocity, and, as was expected, the amount of ammonia recovered decreases with increasing air velocity.

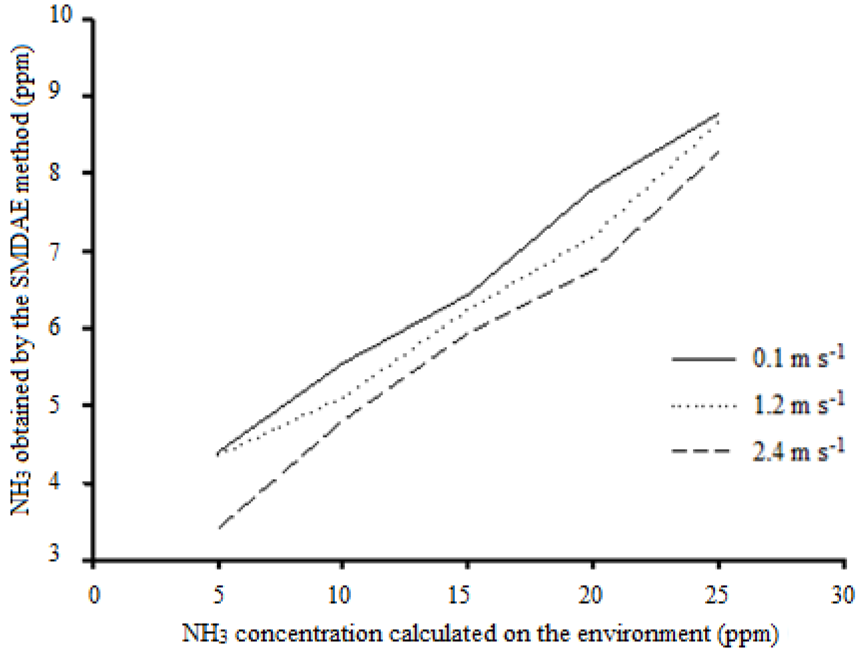

Figure 4. Representative curves of the speeds of the exhaust air with the ammonia concentration obtained by the absorbent porous material in different ambient concentrations.
Source: The authors.

Similarly, to Figure 4, the Figure 5 shows that, independent of the velocity of the exhaust air, the behavior of the curves is the same for all the velocities studied. The amount of ammonia captured by the collector was directly proportional to the concentration of ammonia in the environment, i.e., the higher the amount of ammonia present in the environment, greater was the amount collected by the SMDAE method. In contrast, there is an inversely proportional relation when analyzing the exhaust air speed and the amount of ammonia captured by the collector; the higher the speed of the exhaust air, the smaller the amount of ammonia captured by the SMDAE method.

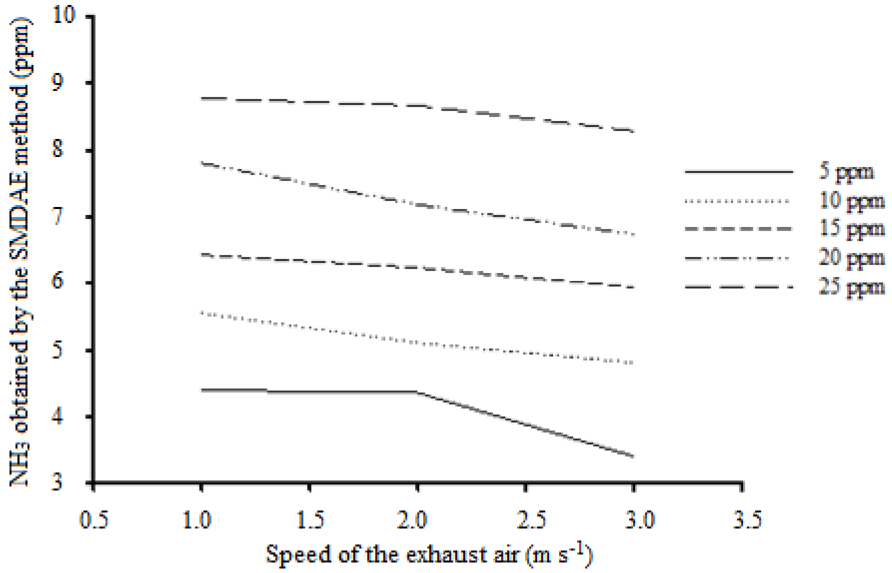

Figure 5. Representative ammonia curves according to the amount absorbed by the porous material and different speeds of the analyzed exhaust air environment.
Source: The authors.

4. Conclusions

View of the results found, the SMDAE method can be considered an efficient method. To determine concentrations up to 10 ppm it does not need adjustment and presents a good recovery efficiency. For concentrations higher than 10 ppm, the method can be used with confidence through the use of generated equations to adjust the concentration of ammonia (Equation 1), regardless of air velocity.

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