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Innovative Technique for the Measurement of Field Ammonia Emissions in Small Plots after Application of Swine Manure

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Abstract. Once swine manure is applied to agricultural land as a fertilizer, significant nitrogen losses can occur through ammonia (NH_3) volatilisation. Different techniques can be used to reduce NH_3 volatilisation, such as rapidly incorporating manure in soil, in order improve fertilisation efficiency of applied manure as well as limit environmental and health impacts. However, appropriate measurement methods are required to assess the efficiency of these techniques. Many technologies have been developed to measure field emissions and they can be classified in two general groups: micrometeorological methods and chamber methods. However, these conventional methods could not be used to measure NH_3 emissions from the small plots used for a project studying the effect of manure incorporation on nitrogen losses in zero-tillage farming. An innovative technique was therefore developed to overcome certain challenges and measure reproducible NH_3 emissions from small plots.

The technique developed in this project is similar to dynamic flux chambers, but with a much lower ventilation rate, therefore allowing the unit to be placed anywhere on a plot. The NH_3 entering and exiting the chamber is sampled using sulfuric acid bubblers which are periodically sent to the laboratory for analysis. The NH_3 emissions are then calculated using a mass balance and the different air flow rates. Preliminary results from the first growing season show that the total NH_3 emissions varied from 1350 to 4900 mgN/m² depending on the treatment. These emissions represented nitrogen losses between 4 and 14 % of the applied total nitrogen and between 6 and 24 % of the applied ammonium nitrogen (N-NH_4^+).

Keywords. Field ammonia emissions, swine manure.

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Introduction

Analysis of field ammonia (NH₃) emissions represents an interesting challenge for anyone studying the impact of farming practices on the environment. In fact, once swine manure is applied to agricultural land as a fertilizer, significant nitrogen losses can occur through NH₃ volatilisation. Studies show that up to 16 % of ammonium-nitrogen can be lost after 24h of manure surface application. After 10 days, losses can be as high as 43 % (Rochette et al., 2008a and b). Different techniques can be used to reduce NH₃ volatilisation, such as rapidly incorporating manure in soil, in order to improve fertilisation efficiency of applied manure as well as limit environmental and health impacts. However, appropriate measurement methods are required to assess the efficiency of these techniques.

Many technologies have been developed to measure NH₃ field emissions and they can be classified in two general groups, micrometeorological methods and chamber methods, each with its advantages and disadvantages (Moal, 1995). Chamber methods enclose a given surface of soil to measure NH₃ emissions and can further be separated in forced ventilation as in dynamic flux chambers and no ventilation with static chambers. For static chambers, the concentration of NH₃ is allowed to increase in the chamber and air samples are extracted periodically to measure the NH₃ flux. The main advantages of this method are that it is inexpensive and very simple. However, the main drawback is that it creates an artificial environment in and around the chamber. Installing a static chamber on the ground stops all air movement inside the chamber and changes air flow patterns outside the chamber, thereby creating an artificial environment. Since NH₃ emissions are influenced by the air exchange rate and therefore the wind speed, static chambers can produce inaccurate emission data.

In the case of chambers using forced ventilation, wind tunnels are generally used to create an air flow representative of wind conditions. The air is sampled before and after the wind tunnel to measure the increase in the concentration of NH₃. The main advantage of this technique is that the conditions under which NH₃ emissions are measured are closer to the actual field conditions. Dynamic flux chambers are generally reliable and repeatable, but can only be used on the edge of a field since they require a readily available source of fresh air. Furthermore, this type of equipment is often very expensive and requires considerable mechanization, such as a large fan to recreate high wind speeds. For both chamber methods, the NH₃ content in the sampled air is either trapped in an acid solution or sent directly to an analyzer.

The second group of techniques is that of micrometeorological methods. These methods combine NH₃ concentration and wind speed data to calculate the NH₃ flux. A post is placed on the plot where emissions are to be measured in order to measure NH₃ concentrations and wind speeds at different heights. Different models, based on the fact that the transportation of gas molecules is achieved by the air movement, are then used to estimate NH₃ emissions. This technique requires two major elements: large uniform fields and a uniform environment. These elements are essential to minimize wind turbulence and obtain reliable estimates of the NH₃ emissions. However, contrary to chambers, micrometeorological methods do not disturb the area where emissions are measured and produce more realistic data.

Context and Objectives

A research project was recently started at the Research and Development Institute for the Agri-Environment (IRDA) to study the effect of manure incorporation on nitrogen losses in zero-tillage farming compared with conventional farming.

This project is being carried out in Saint-Lambert-de-Lauzon, near Québec, and involves 12 small plots (20m x 30m). These plots are sufficiently large (700 m²) to simulate the conditions found in large crops and are fully equipped to measure the water flow, the concentration of sediments and nutrients in surface and drainage waters.

Four different treatments are evaluated in triplicate and in random blocks. These treatments are:

- No till cultivation with rapid shallow incorporation of pig manure (I)
- No till cultivation without incorporation of pig manure (NI)
- Mouldboard plough tillage with complete incorporation of pig manure after 24 h (MBPT)
- Grassland without incorporation of pig manure (Grassland).

The project will take place over four years and will involve a succession of grains such as corn, soya, winter wheat and corn and grassland composed of timothy and clover. This succession of plants was chosen in order to allow frequent pig manure application throughout the duration of the test.

This project also involves the measurement of ammonia after each manure application during a period of at least 10 days or until emissions end. This involves a measuring device which is placed on the soil of each plot after manure application.

Design of the Innovative Measurement Technique

The type of equipment to be developed in the project had to take into account the context of the project. The existing plots are quite small and close together, not allowing the use of a measuring device like the wind tunnel. In fact, there is no possibility to place the measuring equipment so that the air entering the tunnel is clean air. Also, the field in which the experiment is conducted has a topography that is highly variable, with the presence of ditches, streams and trees, creating wind turbulence and thus excluding the possibility of using the micrometeorological method.

The technique used in the project has therefore to be innovative and developed to overcome those challenges. It was decided to use a chamber to be able to measure the emissions directly in the center of the plot. However, the research team felt that it would be more desirable that the chamber should be ventilated. With a constant and identical air flow in each chamber, a repeatable air exchange rate is assured and it allows each treatment to be compared over several growing seasons.

The traditional chamber has thus been modified. The new concept of measuring chamber is made of aluminum in order to limit the impact of the material on the measurements and its dimensions on the ground are 750-mm long by 300-mm wide. The width is consistent with the width of the field operations, equivalent to one row of corn, two rows of grain or equivalent to 2 manure spreader bands.

The chamber is connected to a system that pumps the air through the chamber at a constant flow rate (12 l/min), which corresponds to an air exchange rate of two minutes. The incoming air is pumped from a chimney, so the ammonia concentration in it is diluted. Then, the air is sent to the chamber using Teflon tubing followed by manifold to distribute the air in the chamber. A schematic of the chamber is shown in Figure 1 while a photo of the system installed in a no-till plot is presented in Figure 2.

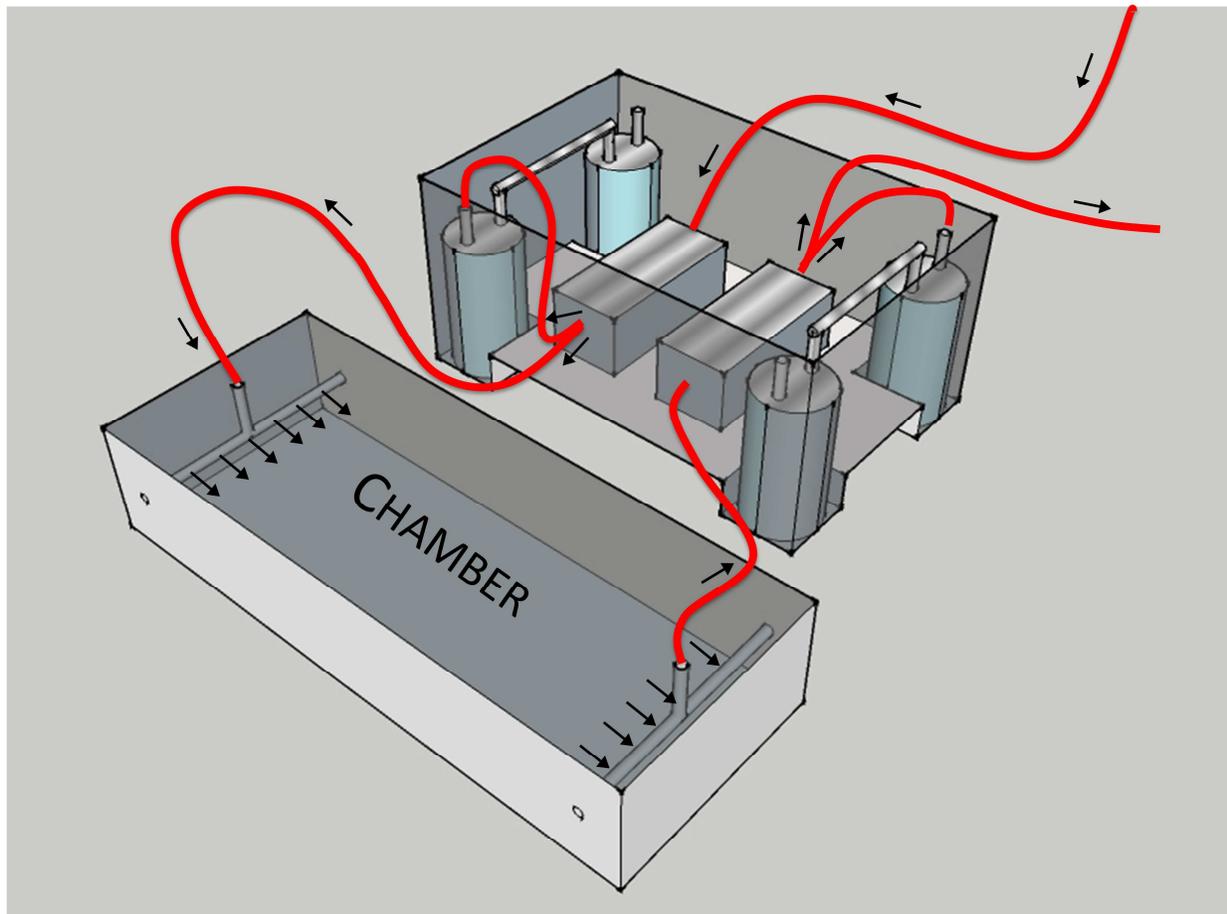


Figure 1. Schematic of the innovative measurement technique

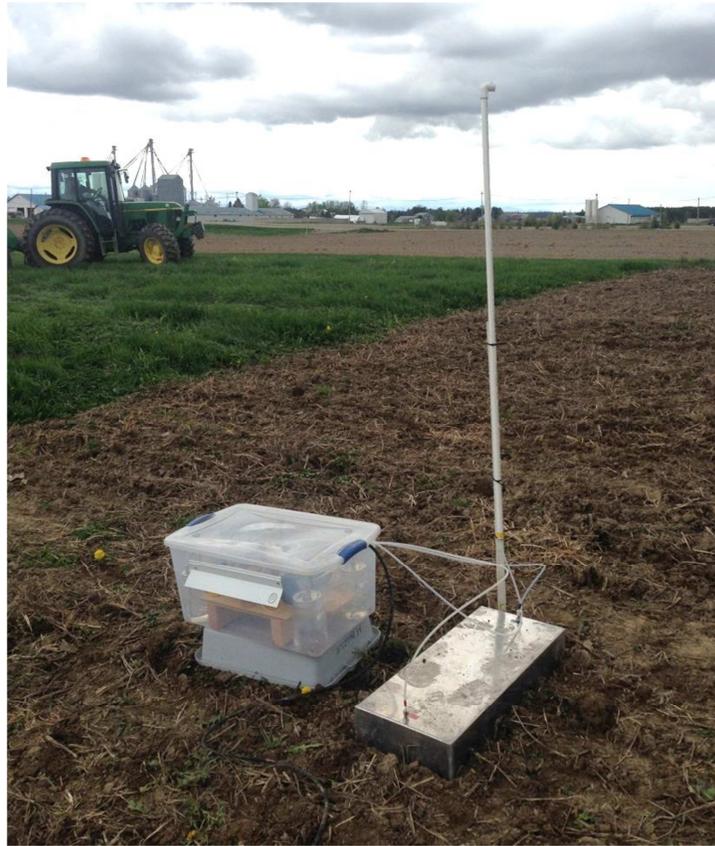


Figure 2. Photo of the chamber and sampling box in a no-till plot

The sampling system is based on the acid bubbling principle. A portion of the incoming and exhaust air is bubbled in a solution of 0.1 N sulfuric acid. Since ammonia is highly soluble in an acid solution, the sampling system traps the ammonia, transforms it in its soluble form which is then sent to the laboratory for analysis. The sampling periods cover the first 4 h, 4 to 24 h, 24 to 96 h and 96 to 192 h. The concentration values measured correspond to an averaged value over each period. It is then possible to calculate the average emissions of NH_3 using the average air flow inside the chamber over the same period.

Results and Discussion

Since the trials for the project began in 2013, results for NH_3 emissions are only available for one growing season. Results shown in Figures 3 and 4 provide emission data for each sample period individually (Figure 3) as well as the cumulative emissions (Figure 4).

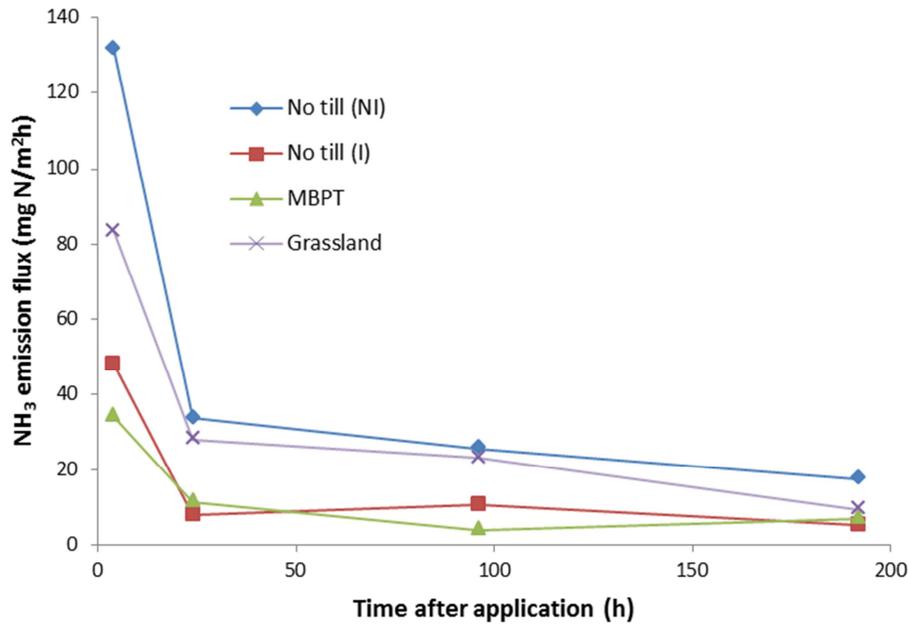


Figure 3. NH₃ emissions for each sample period for each treatment
 NI = non-incorporated, I = incorporated and MBPT = mouldboard plough tillage

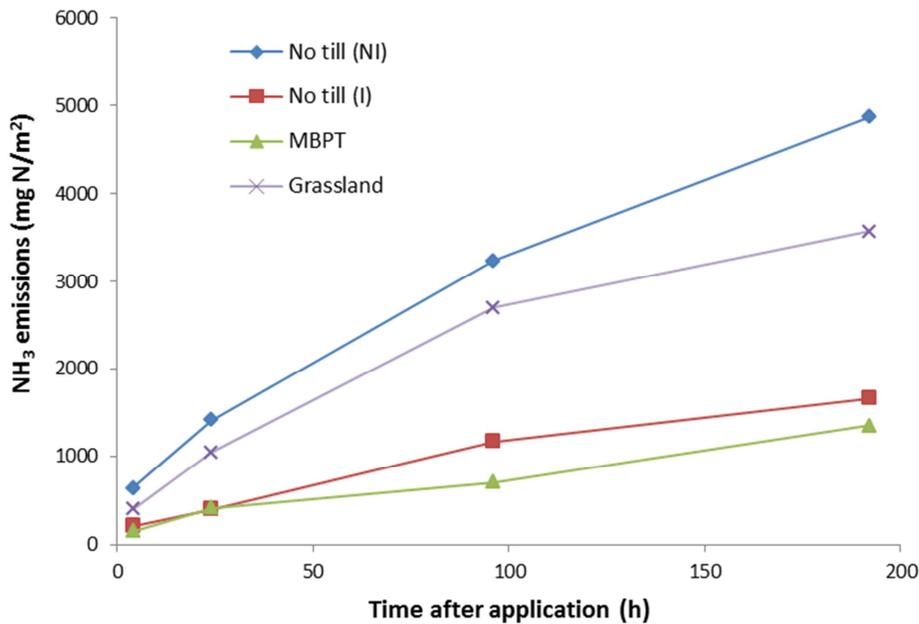


Figure 4. Cumulative NH₃ emissions for each treatment
 NI = non-incorporated, I = incorporated and MBPT = mouldboard plough tillage

Results for each sample period individually in Figure 3 show that emissions varied from as high as 132 mgN/m²/h for no-till without incorporation within the first 4 hours to as low as 4 mgN/m²/h for the mouldboard plough tillage with complete manure incorporation from 24 to 96 hours. For all the treatments, the NH₃ emissions dropped drastically between the first two sampling periods (0 - 4 h and 4 - 24 h) and then continued to decrease at a much lower rate until the end of test. When looking at the cumulative NH₃ emissions in Figure 4, it is much easier to observe the differences between the different treatments. Total emissions varied from 1350 to 4900 mgN/m² which represented losses between 4 and 14 % of the applied total nitrogen and between 6 and 24 % of the applied ammonium nitrogen (N-NH₄⁺).

From these preliminary results from one growing season, it would seem that the no-till without incorporation and the grassland treatments emit the most NH₃. However, for certain periods, the standard deviation within the replicates of a specific treatment was quite high, up to 50 %. Therefore, additional measurements are required to observe any significant differences; two more growing seasons are planned in the project. Furthermore, the cumulative results seem to show that NH₃ was still being emitted even after the end of the test, especially for the no-till without incorporation and the grassland treatments where the slope between the last two points was far from zero. Studies have shown that the rate of NH₃ emissions can vary with time and with weather conditions. In fact, during the same study, Rochette et al. (2008a) observed between 70 and 83 % of NH₃ losses within the first 12 h following manure application for one year whereas as losses were only 25 to 50 % of the total losses occurred during the same period in another year. Nevertheless, the duration of the test must be extended to measure all the NH₃ emissions following manure application and properly compare the different treatments.

The results obtained with the innovative technique developed in this project are similar to other studies on field NH₃ emissions. For example, Powell et al. (2011) measured NH₃ emissions between 500 and 3800 mgN/m² which represented between 4 and 21 % of applied nitrogen depending on the application method and whether the manure was incorporated. These authors did observe reduced nitrogen losses through manure incorporation, but there was no significant impact on crop yields. As with the results presented here, Pfluke et al. (2011) observed a rapid drop in NH₃ emissions following manure application. They also observed a reduction of 30 to 50 % in nitrogen losses through NH₃ volatilisation by using band spreading of manure instead of broadcast application.

Conclusion or Summary

An innovative technique to measure field NH₃ emissions was developed in this project to overcome certain challenges and measure reproducible NH₃ emissions from small plots. The technique developed in this project is similar to dynamic flux chambers, but with a much lower ventilation rate, therefore allowing the unit to be placed anywhere on a plot. In order to avoid any pressure build-up inside the chamber, the air is both pumped into and sucked out of the chamber. The NH₃ entering and exiting the chamber is sampled using sulfuric acid bubblers which are periodically sent to the laboratory for analysis. The NH₃ emissions are then calculated using a mass balance and the different air flow rates. Preliminary results from the first growing season show that the total NH₃ emissions varied from 1350 to 4900 mgN/m² depending on the treatment. These emissions represented nitrogen losses between 4 and 14 % of the applied total nitrogen and between 6 and 24 % of the applied ammonium nitrogen (N-NH₄⁺).

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