J3.4 METHANE AND NITROUS OXIDE FLUXES FROM LIQUID SWINE MANURE IN STORAGE DETERMINED WITH A MICROMETEOROLOGICAL MASS BALANCE TECHNIQUE

C. Wagner-Riddle, A.G. Thompson, and K.H. Park
University of Guelph, Guelph, Ontario, Canada

1. INTRODUCTION

Animal production in confinement results in large amounts of liquid or solid waste that frequently need to be stored before field conditions are appropriate for application. The readily available carbon (C) content and anaerobic nature of liquid manure has been found to produce large quantities of methane (CH_4) (Sharpe and Harper, 1999; Sommer et al., 2000). Nitrous oxide (N_2O) has also been suggested to be released from liquid manure storage, with IPCC (1996) estimating that 0.1% of the total nitrogen (N) in the manure is lost as N_2O-N. However, recent research has found no detectable N_2O emissions from the storage of liquid manure (Harper et al., 2000; Sommer et al., 2000) unless a crust was present, forming an aerobic layer.

Environmental factors, such as temperature and precipitation, are believed to affect CH_4 and N_2O emissions, due to their direct or indirect effect on the microbial processes that result in production of these gases. In order to better quantify emissions, studies conducted *in situ*, with simultaneous monitoring of CH_4 and N_2O fluxes for a range of environmental conditions are required. In this study, we used a micrometeorological mass balance method to monitor CH_4 and N_2O fluxes from liquid swine manure in storage. Our objectives were: 1) to test the suitability of using a mass balance method employing four towers (one on each side of the manure storage area), and 2) to quantify the CH_4 and N_2O fluxes from solid manure in storage during the different times of the year.

2. MATERIALS AND METHODS

2.1 Site description

The measurement of N_2O and CH_4 fluxes from liquid swine manure storage was conducted at the Arkell Research Farm, University of Guelph, Arkell, ON (43.53 ºN, 80.17 ºW). Emissions were examined during four distinct climatic periods: June 25 to July 18, 2000; Oct. 24 to Nov. 5, 2000; Jan. 9 to Jan. 14, 2001; and Mar. 22 to May 3, 2001. The farrow to finish operation at this site, with approximately 375 sows fed a corn – soybean diet, was the source of the manure. The minimal deviations in barn management, on a yearly basis, produced manure of relatively consistent characteristics. Between the spring of 1996 and the spring of 2001 the manure had an average dry matter content of 1.24%, NH_4^+-N content of 1521 ppm, and total N, P and K of 0.18%, 0.05% and 0.09%, respectively.

* *Corresponding author:* Claudia Wagner-Riddle, Univ. of Guelph, Dept. Land Resource Science, Guelph, ON, N1G 2W1 Canada
email: criddle@lrs.uoguelph.ca

2.2 Flux Measurements

Half hourly fluxes of both gases were calculated using the IHF method, approximated as follows:

$$F = \frac{1}{L}\sum_{i=1}^{i=4}\left(\overline{u_i c_{(d)i}} - \overline{u_i c_{(u)i}}\right) ?\, z$$

The $\overline{u}_i\ \overline{c_{(d)i}}$ and $\overline{u_i c_{(u)i}}$ terms refer to the mean wind speed, at level i, multiplied by the mean concentration measured at downwind and upwind towers, respectively. The wind speed was assumed to be the same at both the upwind and downwind towers. Periods when the speed from at least one anemometer was below 1 m s^{-1} were discarded. The ?z term refers to the sampling layer, assuming the wind speeds and concentrations monitored at the 25, 100, 200 and 350 cm heights to be representative of the 0 – 50, 50 – 150, 150 – 250, and 250 – 450 cm air layers, respectively. The maximum vertical gaseous emissions to a height of 4.5 m above the top of the concrete walls was assumed to be adequate based on the sampling height to fetch ratio of 10:1 for neutral conditions (Denmead et al., 1999). The fetch (L) was calculated every five minutes using the wind direction data and the geometric configuration of the manure tanks and tower positions. The average fetch over a half hour period was then used to calculate the flux. Data were discarded if the maximum and minimum wind directions of the half hour period varied by more than 45°. The presence of manure silos and building around the manure tanks also required that data from certain wind directions be discarded. The wind direction (5 min) and vertical speed (30 min) profile were recorded on site, using a mast mounted onto the fence surrounding the manure pits. The concentration of N_2O and CH_4 was monitored using two Tunable Diode Laser Trace Gas Analyzers (TDLTGA), one for each gas. Four towers were placed around the tanks, and each tower was equipped with four air sample intakes. Each intake consisted of a filter and a needle valve. The needle valves, set at an intake rate of 0.7 LPM, were connected to tubing (polyethylene, 3.2 mm i.d., 75 m long) which carried the samples to a mobile trailer. A vacuum pump was used to draw the samples from the intakes to the trailer. Before reaching the TDLTGA the samples passed through a valve manifold unit . This unit, capable of handling all 16 intakes, enabled the switching between the different sample intakes and the two analysers. The sample destined for the TDLTGA, at a given time, were passed through a dryer system. The system of both TDLTGA ran at a pressure of 55 mb. The software controlling the TDLTGA utilized a master/slave option, which enabled the N_2O TDLTGA computer, the master, to control the switching between sample sites and analysers through relay drivers in the valve manifold, and collect the data from the CH_4 TDLTGA computer. Each sample was examined in sequence for 12.5 seconds at a sampling frequency of 10 Hz. Of the 125 data points obtained during each switching sequence 40 points were omitted to prevent the contamination of samples between sites. The average concentration for each site was recorded over 30 minute periods.

3. RESULTS AND DISCUSSION

The four periods of emission flux measurements were each climatically distinct, with average temperatures of 17.7, 7.0, -3.7 and 5.0°C for the Summer 2000, Fall 2000, Winter 2001 and Spring 2001, respectively. Due to time constraints and equipment availability, the length of data collection varied from 21, 11, 5 and 43 days for the Summer 2000, Fall 2000, Winter 2001 and Spring 2001 sampling periods, respectively. From these periods 140, 94, 47 and 710 mean half hourly fluxes of N_2O and CH_4 met the criteria of the data filters. Nitrous oxide emissions for all periods were highly variable with most half hourly mean fluxes below the detection limit of the sampling system (~1000 ng m^{-2} s^{-2}; data not shown). This is in agreement with previous research by Harper et al. (2000), using a similar system, and Sommer et al. (2000). Both studies did not find any detectable N_2O emissions from liquid swine manure storage when a cover was not present.

Methane fluxes were highly variable during each sampling period (Figure 1). The variability was found to be primarily related to the treatment of the manure rather than the climatic conditions of the sampling periods. During the summer, fall and spring sampling periods, there were times when manure was removed and applied to surrounding croplands. Corresponding to these times of removal elevated fluxes of CH_4 were recorded, very noticeably during the Fall 2000. This is attributed to the mechanical agitation of the manure prior to removal. Visual observations confirmed that bubbles escaping from the bottom of the tanks increased concentrations at downwind towers, and it is believed that during agitation numerous bubbles are released at once drastically increasing emissions from the tanks.

The addition of manure to the tanks was another source of variability in the emissions. As the manure was pumped into the tanks CH_4 was released from the mixing action of the entering manure, believed to release CH_4 bubbles trapped in the tanks, and from CH_4 leaving the entering manure. This is most evident during the Winter 2001 sampling period. For the first two days of recording there were only minimal emissions, but when manure was added to the tanks between day 12 and 15 emissions rose. Manure addition during the other sampling periods was not recorded, but is a potential explanation for emission spikes when the manure was not being agitated.

In summary, the IHF method in combination with a TDLTGA system no detectable flux of N_2O was detected from the storage of swine manure as a liquid. Methane emissions were detectable for all sampling periods, being highly variable both during and across the periods. Variations in emission during the periods were found to be linked to the treatment of the wastes, with increased fluxes during periods of manure removal and addition. Temperature of the manure was suggested to explain the differences amongst the sampling periods.

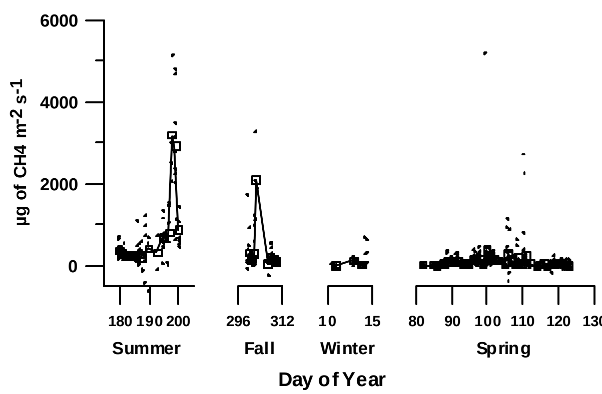

Fig. 1. Flux of CH_4 during the Summer 2000, Fall 2000, Winter 2001 and Spring 2001 sampling periods at the Arkell Research Farm. The dots indicate the mean half hourly fluxes and the open squares indicate the mean daily fluxes.

4. ACKNOWLEDGMENTS

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5. REFERENCES

Denmead, O.T., R Leuning, D.W.T. Griffith, and C.P. Meyer. 1999. Some recent developments in trace gas flux measurement techniques. In Bouwman, A.F. (ed), Approaches to scaling a trace gas fluxes in ecosystems. Elsevier Science, B.V.

Harper, L.A., R.R. Sharpe, and T.B. Parkin. 2000. Gaseous nitrogen emissions from anaerobic swine lagoons: ammonia, nitrous oxide, and dinitrogen gas. *J. Env. Qual.*, **29**, 1356-1365.

Intergovernmental Panel on Climate Change (IPCC). 1996. Technical Summary, In Climate Change 1995: The science of climate change, J.T. Houghton et al. (eds). Cambridge University Press, Great Britain.

Sharpe, R.R., and L.A. Harper. 1999. Methane emissions from an anaerobic swine lagoon. *Atm. Environ.*, **33**, 3627-3633.

Sommer, S.G., S.O. Petersen, and H.T. Søgaard. 2000. Greenhouse gas emission from stored livestock slurry. *J. Env. Qual.*, **29**,744-751.