Greenhouse gas emissions from land applied swine manure: development of method based on static flux chambers

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ABSTRACT

Assessment of greenhouse gas (GHG) emissions from land-applied swine manure is needed for improved process-based modeling of nitrogen and carbon cycle in animal – crop production systems. In this research, we developed novel method for measurement and estimation of greenhouse gas (CO_2, CH_4 and N_2O) flux (mass/area/time) of land-applied swine manure. New method is based on gas emissions collection with static flux chambers (surface coverage area of 0.134 meters^2 and a head space volume of 6.98 L) and gas analysis with a GC-FID-ECD. New method is also applicable to measure fluxes of GHGs from area sources involving crops and soils, agricultural waste management, municipal and industrial waste. New method was used at the Ag 450 Farm Iowa State University (41.98N, 93.65W) from October 24, 2012 through December 14, 2012 to assess GHG emission from land-applied swine manure on crop land. Gas samples were collected daily from four static flux chambers. Gas method detection limits were 1.99 ppm, 170 ppb, and 20.7 ppb for CO_2, CH_4 and N_2O, respectively. Measured gas concentrations were used to estimate flux using four different models, i.e., (1) linear regression, (2) non-linear regression, (3) non-equilibrium, and (4) revised Hutchinson & Mosier (HMR). Sixteen days of baseline measurements (before manure application) were followed by manure application with deep injection (at 41.2 m^3/ha), and thirty seven days of measurements after manure application.

INTRODUCTION

According to the Agriculture Department's National Agricultural Statistics Service, there were 69,100 hog operations in 2011 (USDA, 2012). Many crop farmers rely heavily on the manure that is produced by these operations as fertilizer. Although there has been no change in the number of hog operations since 2010, there is still a concern for the gas emissions that are being released from the manure that is being applied to post-harvest soil. This study will be conducted to measure the amount of GHG emission from land-applied swine manure in two studies. One study was conducted in the fall of 2012 (October/November) and the second will begin in the spring of 2013 (April). The National Pork Board (NPB) is funding this study and the final report will be used as a basis for manuscripts for peer-review.

MATERIALS & METHODS

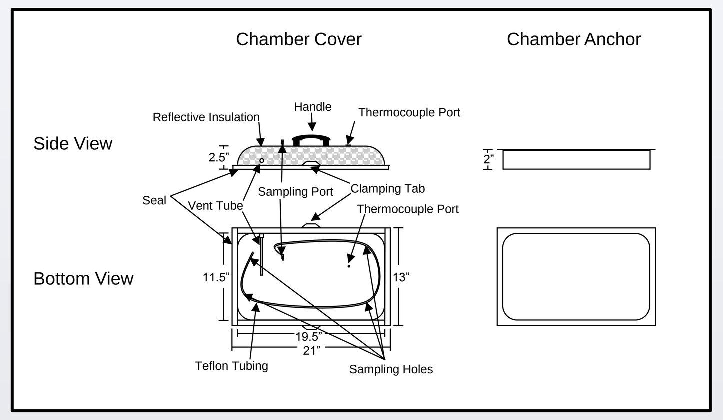

Figure 1: Schematic of static chamber for GHG sampling

Figure 2: Static Chamber, underside cover and chamber anchor

Figure 3: Gas sample collection from static chamber

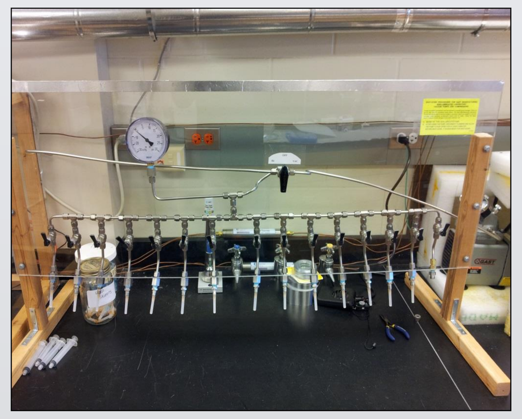

Figure 4: Vial cleaning system, vials purged with helium and evacuated for seven cycles before field sampling

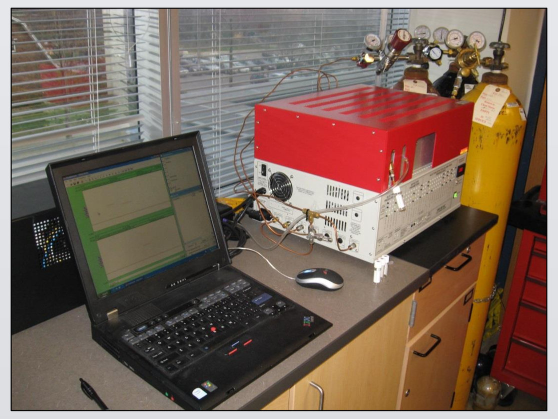

Figure 5: GC-FID-ECD

Flux Estimation Models

Linear Regression Model

Microsoft Excel linear regression was used to determine the flux of each gas by taking the slope of the linear regression line (µL gas L^{-1} h^{-1}) (Eq. 1), multiplying it by the chamber volume (L) and dividing by the chamber surface area (m^2) resulting in flux (µL gas m^{-2} h^{-1}) (Eq. 2).

$$C(t) = St + b \quad Eq.1$$

Where: *C(t)* is concentration (µL gas L^{-1})
t is time (h)
S and b are best fit coefficients with S being the slope

$$J = \frac{SV}{A} \quad Eq.2$$

Where: *J* is Flux (µL gas m^{-2} h^{-1})
S is slope (µL gas L^{-1} h^{-1})
V is chamber volume (L)
A is chamber surface area (m^2)

First Order Linear Regression Model

For the first order linear regression model the same was done as the linear regression model but only on time 0 and 0.25 h data points (Eq. 3).

$$J = \frac{\frac{C_{t\,0.25} - C_{t\,0}}{t_{0.25} - t_0} V}{A} \quad Eq.3$$

Where: *J* is Flux (µL gas m^{-2} h^{-1})
$C_{t0.25}$ is target gas concentration (µL gas L^{-1}) at time 0.25 h
C_{t0} is the target gas concentration (µL gas L^{-1}) at time 0 h
t is time (h)
V is chamber volume (L)
A is chamber surface area (m^2)

HMR Model

The HMR model calculations were done using the HMR package in R statistical software. The HMR model uses non linear regression (Eq. 4) or linear regression (Eq. 1) to best fit the data and outputs the slope of the regression line at t_0 (µL gas L^{-1} h^{-1}), the chamber volume and chamber surface area may also be plugged in to the program to output flux (µL gas m^{-2} h^{-1}), this was not done in this study, the calculation from µL gas L^{-1} h^{-1} to µL gas m^{-2} h^{-1} was done outside of R to minimize unit confusion (Eq. 2).

$$C(t) = a + b(1 - e^{ct}) \quad Eq.4$$

Where: *C(t)* is concentration (µL gas L^{-1})
t is time (h)
a, b and c are best fit coefficients

Hyperbolic Regression Model

The hyperbolic regression calculations were done using Sigma Plot software to best fit data to a hyperbolic function (Eq. 5), data was shifted on the y axis to force the data to start at 0,0 by subtracting concentrations by t_0 concentration (Eq. 6). The resulting derivative at t_0 (Eq. 7) of the best fit hyperbolic function was the slope of the line at t_0 (µL gas L^{-1} h^{-1}), which can be used as HMR calculations to determine µL gas m^{-2} h^{-1} using known volume and surface area of static chambers (Eq. 2).

$$C(t) = \frac{at}{b + t} \quad Eq.5$$

$$C = C_t - C_0 \quad Eq.6$$

$$S = \frac{ab}{b^2} \quad Eq.7$$

Where: *C(t)* is concentration (µL gas L^{-1})
t is time (h)
a and b are best fit coefficients
S is the slope (µL gas L^{-1} h^{-1}) at t_0

RESULTS

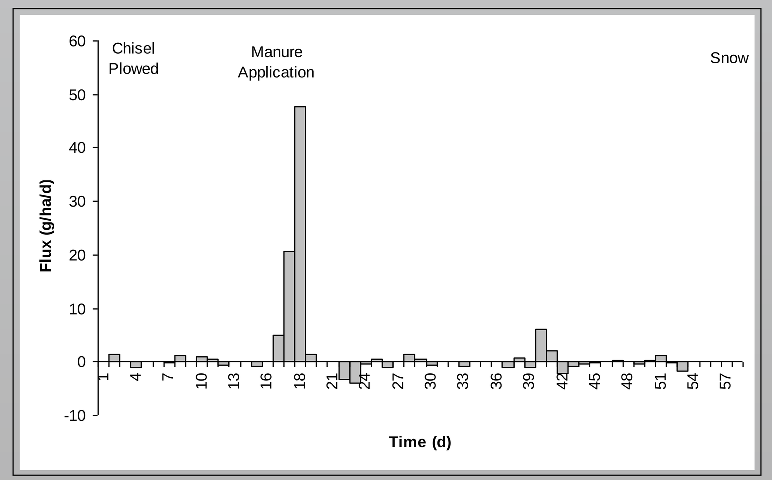

Figure 6: Average Daily Flux Calculated of the four Models for Methane, Net Flux Mean = 1.50 +/- 2.58 g/ha/d, Cumulative Net Flux = 55.5 +/- 95.5 g/ha/d

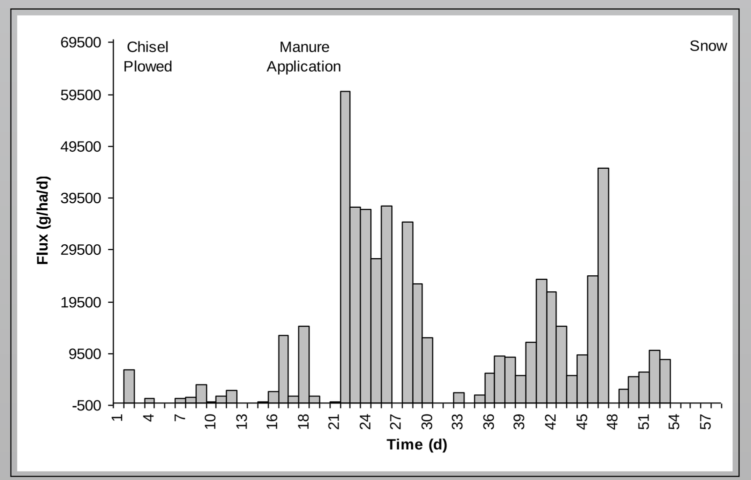

Figure 7: Average Daily Flux Calculated of the four Models for Carbon Dioxide, Net Flux Mean = 13,400 +/- 12,300 g/ha/d, Cumulative Net Flux = 494,000 +/- 456,000 g/ha/d

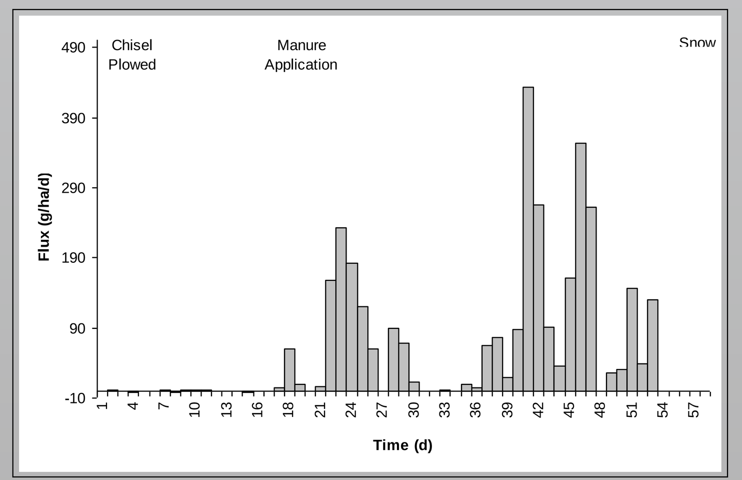

Figure 8: Average Daily Flux Calculated of the four Models for Nitrous Oxide, Net Flux Mean = 94.3 +/- 81.0 g/ha/d, Cumulative Net Flux = 3,490 +/- 3,000 g/ha/d

CONCLUSIONS

GHG flux estimates are within the range of values reported in literature for similar studies. It is noteworthy, that very few studies exist that report GHG flux from 'real' fields like this study. Most of the reports are based on research plots.

The temperature or the moisture did not have a strong correlation with the fluxes observed during the pre-application sampling. Strongest correlations were found between gases and also between CO2 and environmental parameters. It was observed that after the manure application with the temperature dropping low that was followed by a warm up – the was a significant increase in flux with the warm up suggesting that gas was building up in the frozen soil and was then be released quickly when the ground unfroze.

FUTURE PLANS

The developed greenhouse gas emissions procedure will be put in to place at the Ag 450 farm for the Spring 2013 swine manure application (late March – early May 2013).

Final report including Spring 2013 measurements will be completed before June 30, 2013.

LITERATURE CITED

United States Department of Agriculture (USDA). February 2012. Farms, Land in Farms, and Livestock Operations. ISSN:1930-7128.

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