Measurement Accuracy of a Multiplexed Portable FTIR-Surface Chamber System for Estimating Gas Emissions

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ABSTRACT

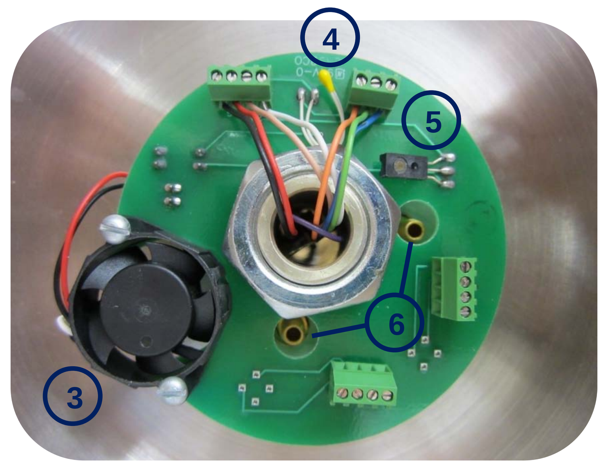
An automated multiplexing system for chamber-based monitoring of greenhouse and regulated gas emissions from manure sources was developed to examine spatial and temporal variability of emissions associated with manure management practices. The measurement system uses a Fourier Transformed Infrared (FTIR) spectroscopy analyzer for determination of 15 pre-programmed gas concentrations for flux determination. Multiple chambers provide estimates of variance for emissions from manure sources. The objective of this study was to demonstrate the robustness and reliability of the described system for monitoring gas emissions from manure sources. Evaluation of system performance was based on laboratory experiments using methane gas (CH_4) to assess the accuracy of the chamber-based measurement system. Evaluation procedures were refined by examining (a) measurements from each chamber at three different emission rates and (b) by comparing chamber-based measurements with fluxes estimated with a gradient-based technique.

We developed an apparatus to generate constant flux of methane gas using a gradient-based technique for the reference gas. Three different emission rates were generated. Statistical analysis, including ANOVA, was performed to determine the significance of gas flux estimates using the chamber-based estimate. A p-value = 0.05 was considered to be statistically significant. The ANOVA tests indicated no statistically significant differences among estimated fluxes from each of the 12 evaluated chambers, with resulting p-values of 0.54, 0.58, and 0.80 for measurements of three different emission rates. The multi-chamber system measurements referenced to gas fluxes estimated with the gradient-based method showed excellent accuracy with measurement biases of less than 1%. In addition, the outputs from all sensors, including the dielectric permittivity, electrical conductivity, relative humidity, and temperatures, demonstrated high accuracy with statistical biases of less than 2%.

CHAMBER COMPONENTS

We designed, constructed, and tested a multiplexed automated-chamber system for determination of gaseous emissions from surface sources from a variety of animal waste treatment practices. The multiplexing system, based on the closed dynamic chamber principle, includes state-of-the-art moisture content sensors, thermistors, and relative humidity sensors to monitor and examine the primary physical factors directly influencing gas production and transport mechanisms.

1. GS3 sensor (Decagon Devices, Inc.) outputting dielectric permittivity (for moisture content), electrical conductivity (EC), and temperature
2. External 10K ohm yellow bead thermistor (Apogee Instruments, Inc.)
3. 12 VDC 3-pin wire connector mixing fan (model DF122510BL, Top motor)
4. Internal 10K ohm yellow bead thermistor (Apogee Instruments, Inc.)
5. Relative humidity sensor (model HIH-4021-001, Honeywell Sensing and Control)
6. Bulkhead fittings for sample tubing lines



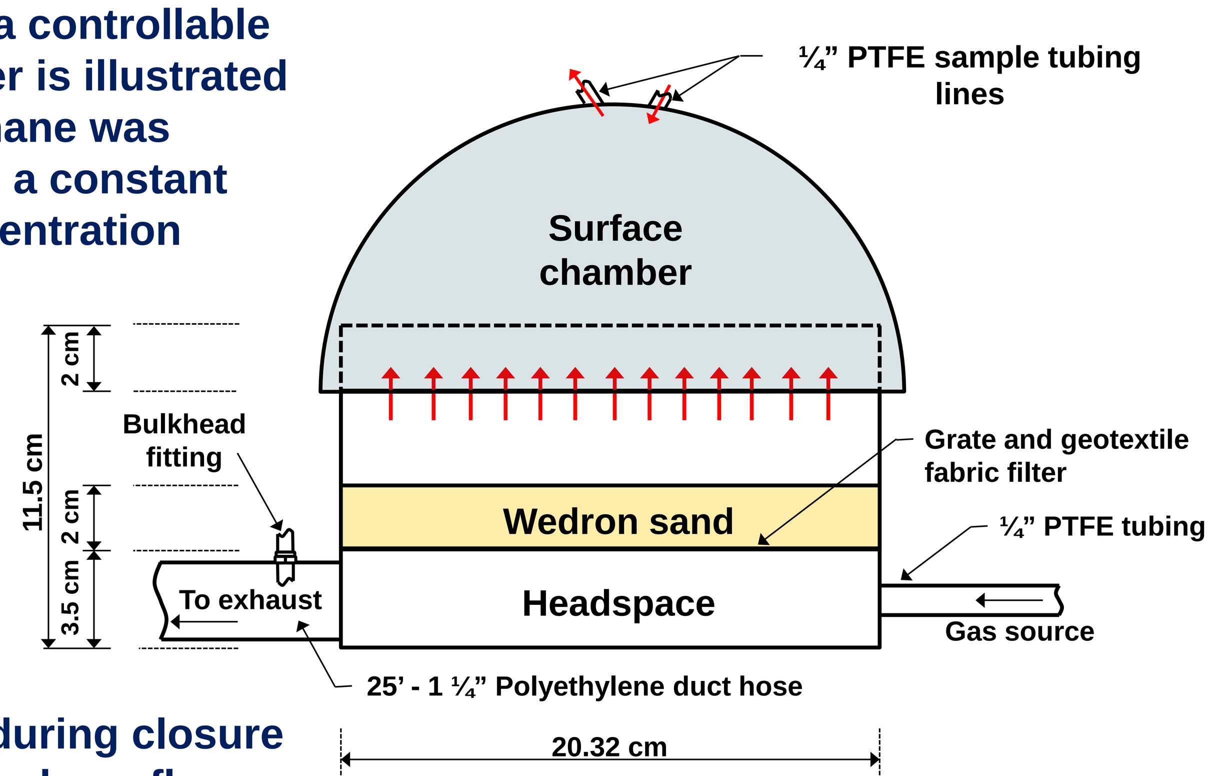
Each customer-made chamber is equipped with an external GS3 moisture sensor and thermistor (above left). The surface chamber is designed to house a circuit board with a mixing fan and attached sensors outputting temperature and relative humidity inside the chamber (above right).

EXPERIMENTAL SETUP

The experimental calibration unit generating a controllable steady-state gas flux into the surface chamber is illustrated on the right. Certified standard 100 ppm methane was continuously fed through the headspace with a constant flow rate resulting in an equilibrium gas concentration within the headspace.

The bulkhead fitting was for a ¼" PTFE sampling tube to measure the methane concentration exhausted from the headspace. Methane gas diffused from the headspace into the uniform dry Wedron sand with at a constant rate.

Fluxes of CH_4 from the sand were measured during closure of the chamber. The depth of the sand layer and gas flow rate can be adjusted to produce the desired gas flux.

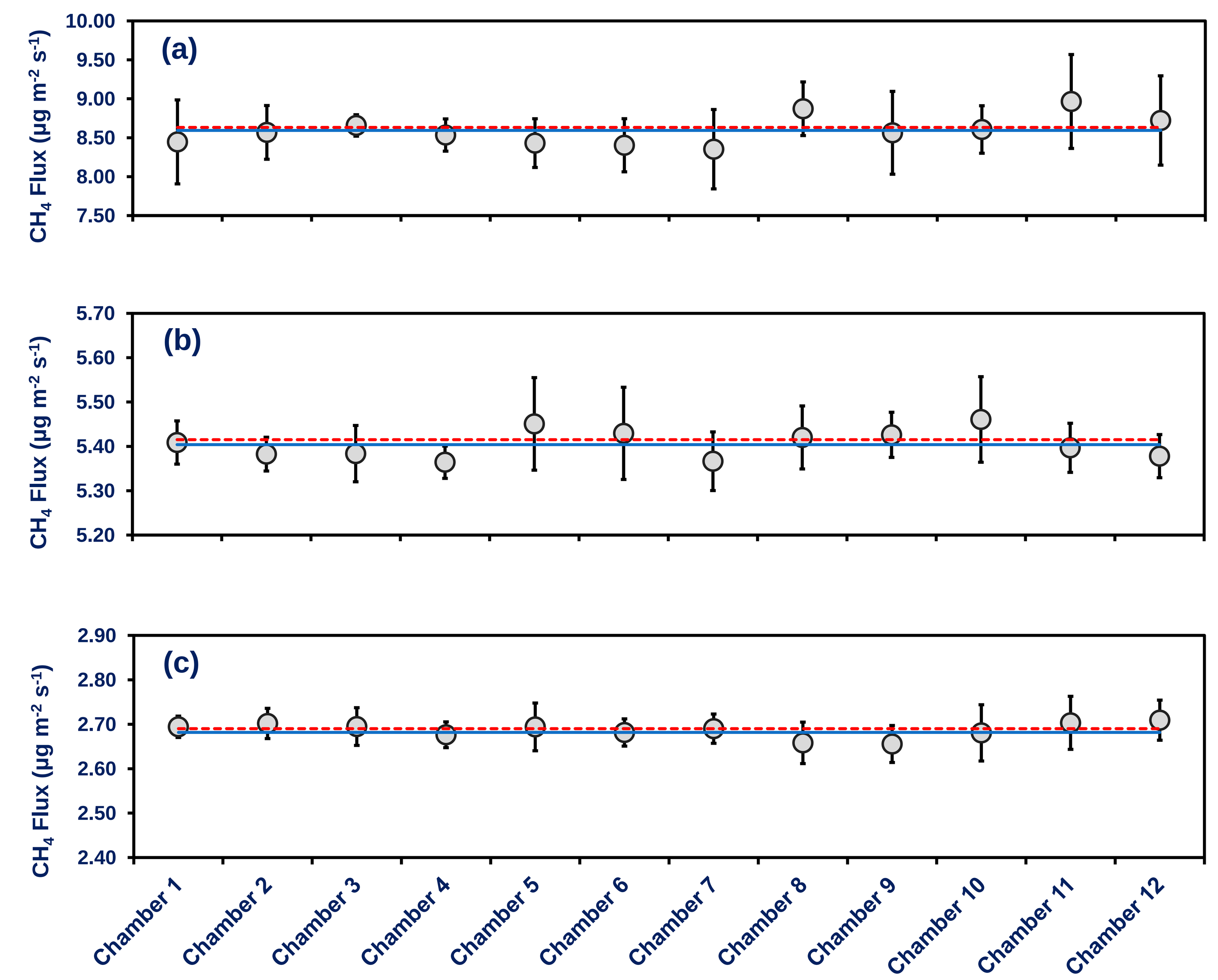


Estimated CH_4 emission fluxes for conducted experiments			
Experiment	Flow rate of certified 100 ppm CH_4 (cm³ min⁻¹)	Sand Depth (cm)	Estimated CH_4 emission flux (μg m⁻² s⁻¹)
A	2,000	2	8.63
B	300	2	5.42
C	300	4	2.69

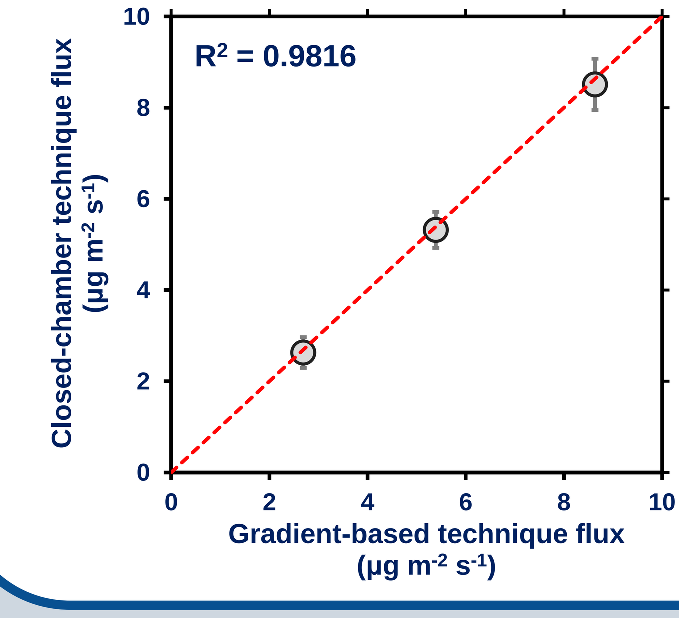
For steady-state conditions, the diffusive transport can be described by Fick's law with the soil-gas diffusion coefficient for methane travelling through the oven-dried Wedron sand.

Three experiments were setup to cover a range of gas fluxes anticipated under field conditions as summarized in the table above. The estimated CH_4 fluxes identified in the table are theoretically determined using the gradient-based method.

RESULTS AND DISCUSSION



Mean of the methane flux measurements from 12 chambers (n=36): (a) Experiment A, (b) Experiment B, and (c) Experiment C are shown in the blue-solid line (above). The red-dashed lines show the methane fluxes estimated with the gradient-based technique.



A comparison between gradient-based surface CH_4 flux estimates and closed-chamber measurements (left) shows excellent agreement. The mean of the flux measurements in Experiments A, B, and C was within 0.79%, 0.47%, and 0.37% of the gradient-based flux estimates, respectively.

ACKNOWLEDGEMENTS

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