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Author(s)

First Name	Middle Name	Surname	Role	Email
Md	Saidul	Borhan	ASABE member, Postdoctoral Research Associate	mborhan@tamu.edu

Affiliation

Organization	Address	Country
Biological and Agricultural Engineering, Texas A&M University.	2117 TAMU, College Station, TX 77843	USA

Author(s) – repeat Author and Affiliation boxes as needed--

First Name	Middle Name	Surname	Role	Email
Sergio		Capareda	ASABE member, Assistant Professor	scapareda@tamu.edu

Affiliation

Organization	Address	Country
Biological and Agricultural Engineering, Texas A&M University.	2117 TAMU, College Station, TX 77843	USA

Author(s) – repeat Author and Affiliation boxes as needed--

First Name	Middle Name	Surname	Role	Email
Saqib		Mukhtar	ASABE member, Associate Professor	mukhtar@tamu.edu

Affiliation

Organization	Address	Country
Biological and Agricultural Engineering, Texas A&M University.	2117 TAMU, College Station, TX 77843	USA

Author(s) – repeat Author and Affiliation boxes as needed--

First Name	Middle Name	Surname	Role	Email
William	Brock	Faulkner	ASABE member, Research Assistant Professor	faulkner@tamu.deu

Affiliation

Organization	Address	Country
Biological and Agricultural Engineering, Texas A&M University.	2117 TAMU, College Station, TX 77843	USA

Author(s) – repeat Author and Affiliation boxes as needed--

First Name	Middle Name	Surname	Role	Email
Russell		McGee	ASABE member, Assistant Research Scientist	romcgee@tamu.deu

Affiliation

Organization	Address	Country
Biological and Agricultural Engineering Texas A&M University.	2117 TAMU, College Station, TX 77843	USA

Author(s) – repeat Author and Affiliation boxes as needed--

First Name	Middle Name	Surname	Role	Email
Calvin	B	Parnell Jr.	ASABE member, Regents Professor	c-parnell@tamu.deu

Affiliation

Organization	Address	Country
Biological and Agricultural Engineering, Texas A&M University.	2117 TAMU, College Station, TX 77843	USA

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2950 Niles Road, St. Joseph, MI 49085-9659, USA
269.429.0300 fax 269.429.3852 hq@asabe.org www.asabe.org

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Greenhouse Gas Emissions from Ground Level Area Sources in a Dairy Operation

M.S. Borhan, Postdoctoral Research Associate
Biological and Agricultural Eng. Dept., Texas A&M University, College Station, TX.
Sergio Capareda, Assistant Professor
Biological and Agricultural Eng. Dept., Texas A&M University, College Station, TX.
Saqib Mukhtar, Associate Professor
Biological and Agricultural Eng. Dept., Texas A&M University, College Station, TX.
William B. Faulkner, Research Assistant Professor
Biological and Agricultural Eng. Dept., Texas A&M University, College Station, TX.
Russell McGee, Assistant Research Scientist
Biological and Agricultural Eng. Dept., Texas A&M University, College Station, TX.
Calvin B. Parnell, Jr., Regents Professor
Biological and Agricultural Eng. Dept., Texas A&M University, College Station, TX.

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Abstract. *A new protocol similar to EPA method TO-14A was established to quantify and report variations in greenhouse gas (GHG) emissions from different ground level area sources (GLAS) in a free-stall dairy in central Texas. The objective of the study was to estimate and compare methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O) emission factors (EFs) from different GLAS using this new protocol during summer. A week-long sampling was performed during summer and seventy five chromatograms of air samples were acquired from six delineated GLAS (loafing pen, walkway, barn, silage pile, settling basin and lagoon) of the same dairy. Three primary GHGs were identified from the dairy operation during sampling period and the gas chromatograph (GC) was calibrated for CH_4, CO_2, and N_2O. The GHGs concentrations measured at different GLAS during summer were ranged from 4.04±3.4 to 2493±1298, 383±131 to 3107±3878, and 0.06±0.03 to*

1.6±2.0 ppmv for CH_4, CO_2, and N_2O, respectively. These variations in measured gas concentrations within each GLAS were widely varied due to spatially variable manure loading rates at different GLAS in a dairy operation. Average CH_4, CO_2 and N_2O EFs estimated from different GLAS were ranged from 0.10 to 60.5, 21 to 1767, and 0.002 to 2.73 kg hd^{-1} yr^{-1}, respectively, during summer. Estimated overall EFs for CH_4, CO_2 and N_2O during summer for this dairy were, 100±56, 2192±1510, 2.9±3.5 kg hd^{-1} yr^{-1}, respectively.

Keywords. CH_4, CO_2, N_2O, free-stall dairy, EPA Method TO-14A, emissions factors.

Introduction

The reduction of greenhouse gas (GHG) is becoming more important world-wide due to their potential impacts on climate. Agriculture sector is reported to be the greatest contributor of the nitrous oxide and the third greatest contributor of the methane in US (Sedorovich et al., 2007; Burns et al.2008). Therefroe, strategies must be developed for reducing or minimizing net emissions of GHGs. Agricultural GHG emissions primarily occur from cropland and animal facilities. Agriculture is contributing about 6% of the total U.S. GHG as identified by USEPA in 2006 (USEPA, 2008). Combined all sources of agriculture were estimated to have generated 454 Tg (10^{12}g) of CO_2 equivalent GHG emissions in USA during 2006. The USEPA *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (USEPA, 2008) identifies manure management as generating 24% and 5% of CH_4 and N_2O emissions, respectively, from agricultural sources (Burns et al, 2008). A review of published literature identified reports of CH_4, CO_2 and N_2O emissions data from free-stall and naturally ventilated dairy operations (Singurindy, et al., 2007, Sedorovich, et al., 2007; Ngwabie et al., 2009). Based on a review using limited data, emissions of CO_2 from dairy manure storage averaged 72 kg CO_2 m^{-3} yr^{-1} (ranged from 8.6 to 117 kg CO_2 m^{-3} yr^{-1}) (Sedorovich et al., 2007; Hensen et al., 2006; Jungbluth et al., 2001).). Emissions of CO_2 from dairy housing averaged 1989 kg CO_2 hd^{-1} yr^{-1} (1697 to 2281 kg CO_2 hd^{-1} yr^{-1}) (Jungbluth et al., 2001; Sommer and Dahl, 2000). Similarly, the emissions of CH_4 and N_2O from animal housing averaged 54 (1.0-100) kg CH_4 hd^{-1} yr^{-1} and 0.3 (0.0-0.6) kg N_2O hd^{-1} yr^{-1}, respectively (Amon et al., 2001; Amon et al., 2006; Jungbluth et al., 2001). Ngwabie et al. (2009) reported CH_4 emissions ranged from 9 to 114 kg hd^{-1} yr^{-1} in naturally ventilated dairy barn. However, limited published information quantifying GHG emissions from different GLAS in U.S. dairy production systems was found in the literature.

In order to implement policies to control and mitigate greenhouse gases (GHGs) emissions, it is important to learn to collect, report, analyze and verify real data on actual emissions. Greenhouse gases may be measured using infrared spectroscopy, gas chromatography (GC), mass spectroscopy (MS), tunable laser diode technology, open path Fourier Transform Infrared Radiation (FTIR) technologies, and solid-state electro-chemical technology. Infrared analyzers measure GHGs concentration in a steady gas stream. A detailed discussion of the analytical principles involved with infrared analyzer may be found in the McLean and Tobin (1987). Instruments with mass spectrophotometers have very rapid response, can detect many gases at one time, exhibit linear responses over a wide range of concentrations and very accurate and stable (McLean and Tobin, 1987). However, mass spectrophotometers, tunable laser diode, and open path FTIR are expensive. Solid state electrochemical sensors are relatively cheap but they are unstable and require frequent calibration. The shelf life of those sensors varied from 12-18 months. A gas chromatography is recognized to be highly accurate and precise method for measuring GHGs compared to the other method (Johnson and Johnson, 1995). The GHGs are measured using GC equipped with flame ionization (FID) and Electron capture detectors (ECD). In both detectors, quantification of GHGs are accomplished by comparing the area under the response curves (peak height and retention time) of a sample to standards of known concentration. With rapid advancement of the computer technology, relatively low-cost GCs are available for both laboratory and field use (portable).

In this study, the protocol proposes by Capareda et al. (2005) was used to determine GHG emissions. The protocol included using a portable GC in the field where multiple flux measurements are made. All elements essential to Method TO-14A sample analysis (i.e. GC and GC detectors) are included except that the GC was taken to the field to analyze on site rather than storing them in gas canisters and analyzing them in a laboratory. This new protocol showed promising results for determining RVOC fluxes from animal feeding operations (AFOs) (Aquino et al, 2007). The objectives of this research were to: 1) test a new protocol for determining GHG emissions from different GLAS in a free-stall dairy that satisfies EPA's requirements for Method TO-14A and 2) estimate and compare the emission factors of CH_4, CO_2, and N_2O from the same GLAS in a dairy facility during summer.

Materials and Methods

Site Description and Air Sampling

The study was conducted in a dairy (naturally ventilated free-stall barn with open sides and ends) operation in central Texas to determine GHG emissions from different GLAS (fig.1). The size of the barn was 140 m × 31 m (area about 4340 m^2) with about 450-500 milking cows housed in it. The barn was flushed once a day at 6:30 am from a storage tank that recycled waste water from the secondary lagoon. The flushed manure was channeled into a gravitational

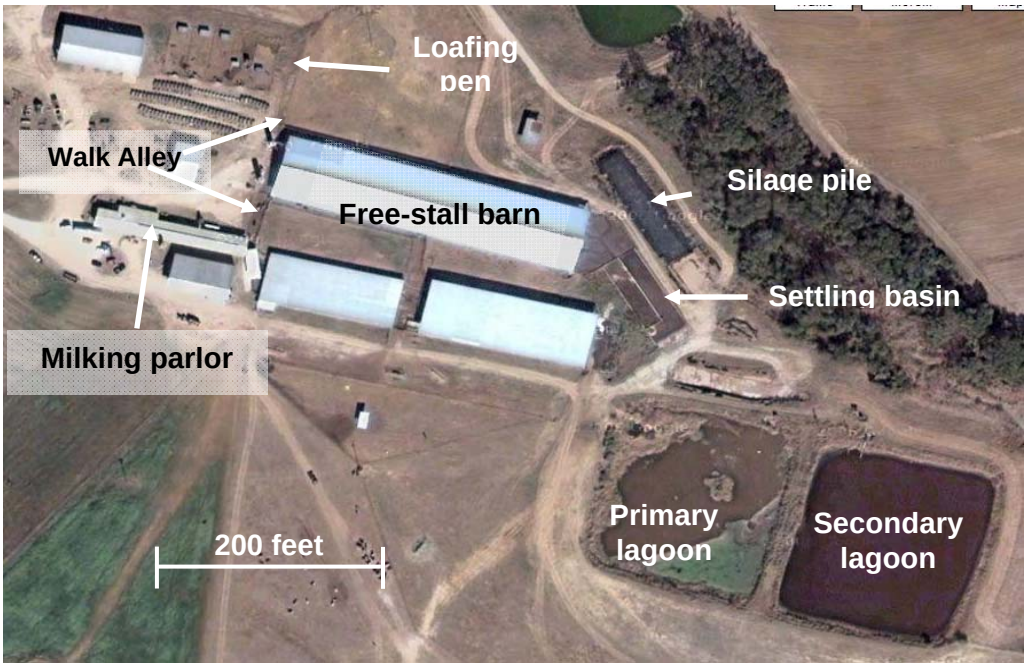

Figure 1. An aerial view of the sampled GLAS at the free-stall dairy.

settling basin for separating liquid and solids. The separated liquid was piped into a primary anaerobic lagoon (primary lagoon) and screened solids were applied to the pasture/crop land. During summer, secondary lagoon was completely dry and primary lagoon was nearly empty (the waterline area of 1/15 of the winter time) due to draught and continuous pumping out of

waste water to the field. The cows were kept in a loafing area for about 6 hours every day from about 12:30am - 6:30 am until flushing the barn and first milking. The loafing area was an unpaved, confined area with access to the milking parlor and barn with a paved walkway around the barn. Air samples were collected from six delineated GLAS namely, loafing pen, walkway (to and from parlor and loafing pen), barn, silage pile, settling basin and lagoons within the dairy operation during summer (August, 2009). Sampling was conducted for five consecutive days during daylight hours (9:00 am to 7:00 pm). Measurements were taken randomly at 3-10 locations of each GLAS and seventy five chromatograms of air samples were collected during summer.

Sampling Protocol

Isolation Flux Chamber, Flux Generation, and Air Sampling

The new GHG sampling protocol consisted of a flux chamber, GC, and associated air sampling accessories (tubing, mass flow controller, vacuum pump, gas cylinder, etc.) as shown in the fig 2. The flux chamber was used to collect air samples from each GLAS (fig. 3). The upper (hemispherical dome) portion of the flux chamber used in the field was made of Plexiglas or polymethylmethacrylate (PMMA), while the bottom (cylindrical skirt) was made of stainless steel. The two portions were flanged together by 6.35 mm (1/4 in.) steel bolts. The footprint area of the flux chamber was 0.192 m^2. The flux chamber was placed at a random location within the sampled GLAS. Before the sampling was initiated, the flux chamber was purged with zero-grade air at a flow rate of 5 L min^{-1} for about thirty minutes. The compressed zero-grade air used for sampling and had O_2 content between 19.5 % and 23.5 % and total hydrocarbon (THC) concentrations below 0.4 ppmv. Teflon tubing (0.635 cm i.d.) was used to convey 5 L min^{-1} zero-grade air ("sweep air") to the flux chamber (fig 2). Three holes on the top of the chamber (fig. 3) allowed air to escape while a fourth hole at the apex of the dome was used to convey sample air into another 45-m long Teflon tube identical to that used to convey sweep air. Sweep air entered the flux chamber through one of the holes in the dome of the chamber. The Teflon tube connected at the apex of the chamber conveyed air sampled at a rate of 2 L min^{-1} from the flux chamber to the GC over a ten minute sampling period by a positive displacement pump. The volume of air samples drawn from the flux chamber were regulated by mass flow controllers connected to the pump. The incoming air from the flux chamber was connected to a splitter that splits incoming air either to a GHG GC or a volatile organic compound (VOC) GC or both GCs concurrently. Of the 2 L min^{-1} of air drawn from the flux chamber, 200 ml min^{-1} was directed to the 1 ml sample loop of the GC for 30s to make sure sample loop was always full. Thus, excess air was purged out of the GC while sample loop with air was ready to be injected to the GC. The moisture in the air samples was filtered during sampling by a Nafion® dryer placed immediately before GCs (fig. 2).

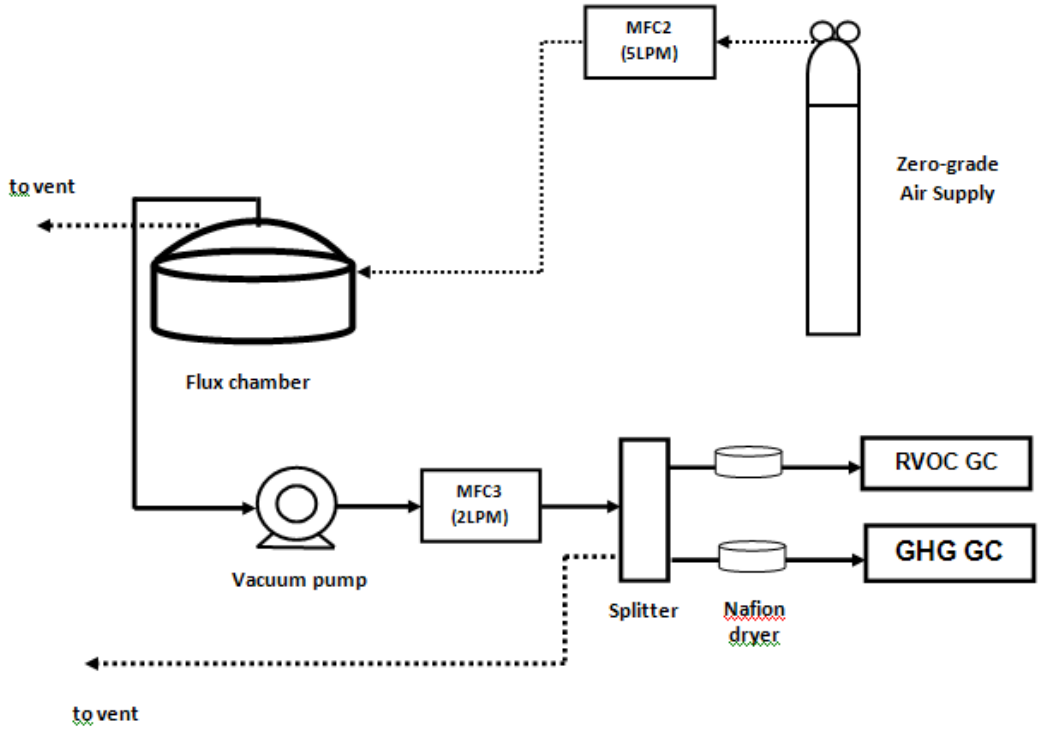

Figure 2. The schematic setup for GHG field measurement (not in scale).

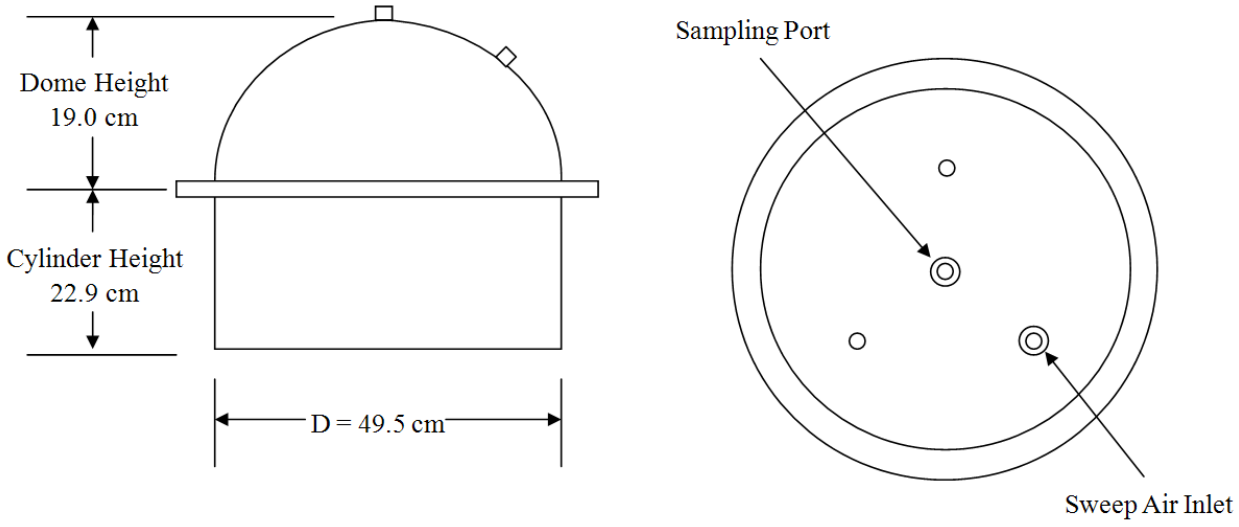

Figure 3. Flux chamber used for air sampling.

Description of GHG GC

A portable GHG GC manufactured by SRI instruments (Model No. 8610C, Torrance, CA) with events programming capabilities was used in this study. The event program mainly includes controlling the duration of sampling by timing the vacuum pump operation, time to inject sampled air into column, and setting of column temperature. Detailed description of the GC can be found at www.srigc.com. This GC has a 10-port valve coupled with a 1ml sample loop. An inbuilt vacuum pump was used to keep sample loop always full with air and injected it to the GC column as desired. A combination of two non-specific detectors (flame ionization detector (FID) and electron capture detector (ECD)) was used to analyze the GHG concentrations sampled directly from the GLAS. The ECD detects N_2O while the FID/Methanizer detects CH_4 and CO_2. The system was operated using nitrogen as carrier gas at 20 psi, which generated a flow rate of 250 ml min^{-1}. Hydrogen and air were supplied to the FID/Methanizer using a built-in air compressor and an external hydrogen generator (Model: PH200-600, Peak Scientific Instrument, Scotland, UK.). The temperatures for FID and ECD were set at 300ºC and 350ºC, respectively. The GC column temperature was programmed to maintain a temperature of 60^0C for 15 min. Compound peaks were recorded and analyzed with PeakSimple Chromatography Data System Software (Ver. 3.72; SRI Instruments, Torrance, CA). Blank samples were run before air sampling began at each location to ensure the column was clean and functioning properly.

Calibration, Minimum Detection Limit, and Percent Recovery

To ensure accurate calculation of the concentrations were made during field sampling tests, the gas standards were introduced into the portable GC following exactly the same field sampling protocol. To generate calibration equations, four concentration levels of each standard gas balanced in nitrogen (0, 5, 10, 15, 20 ppmv for CH_4; 0, 100, 150, 300, 1000 ppmv for CO_2; 0, 5, 10, 20 ppmv for N_2O) were used. Thus, standard curves were developed from four known concentrations of each standard with five to seven replicates at each concentration. Regressions (plots) of the peak areas against concentrations of compound through the origin were used to interpolate the total concentration of compounds in field samples. Minimum detection limits (MDLs) were calculated as per USEPA guidelines as the product of the standard deviation of seven replicates and the Student's t value at the 99% confidence level (USEPA, 1995). The MDL is defined as the minimum concentration of the substance that can be measured and report with 99% confident that the analyte concentration is greater than zero. For seven replicates (6 degrees of freedom), a t value of 3.14 was used. Minimum detection limits are presented in Table 1. For the case where the calculated MDL was less than the minimum standard, the minimum standard was reported as the MDL. The percent recovery (R) was determined by spiking ambient air with known concentration of analyte. Then, the ratio of concentration of spiked sample to the concentration of the analyte expected in the spiked sample expressed in percent was used in this study.

Emission Factor Estimation

The concentration of each GHG in parts per million (ppmv) was converted to a mass concentration (µg m^{-3}) using ideal gas law (eq. 1). Equations 2 to 4 were used to calculate

emission flux (EFlux), emission rates (ER), and emission factor (EF), respectively.

$$C_{mass} = \frac{1000 \times (C_{ppm}) \times MW_p}{24.45} \quad (1)$$

where C_{mass} is concentration of compound per mass basis (µg m^{-3}), C_{ppmv} is volumetric concentration of compound (ppmv), and MW_p is molecular weight of compound at standard temperature and pressure.

$$EFlux = \frac{C_{mass} \times V_{fc}}{A_{fc}} \quad (2)$$

where EFlux is gas **emission flux** in µg m^{-2} sec^{-1}, V_{fc} is the flow rate of air supplied to the flux chamber (m^3 min^{-1}), and A_{fc} is the foot print area of flux chamber (m^2).

$$ER = EFlux \times A_{sc} \quad (3)$$

where ER is the **emission rate** (kg d^{-1}), A_{sc} is the area of source (GLAS, m^2).

$$EF = \frac{ER}{TNA} \times 365 \quad (4)$$

where EF is the emission factor (kg $hd^{-1}yr^{-1}$), and TNA = total number of animals.

Statistical Analyses

Measured gas concentrations and estimated emission factors from each GLAS in this feedyard were compared using the General Linear Model function in SAS (SAS 1999). The null hypothesis tested was that mean concentrations and EFs among different GLAS were equal. Means were compared using the Least Significant Difference (LSD) pair-wise multiple comparison test and a 0.05 level of significance.

Results and Discussion

Quantifications of compounds (chromatograms) collected during field sampling were performed using true standard gases and identification was confirmed by matching retention times. Table 1 shows the standard equations used for quantization of the analyte (GHGs). The regression coefficients (R^2) of the standard equations and percent recovery reflect the accuracy and reliability of the direct GHG measurements using a portable GHG gas chromatograph. The calculated MDL using GHG GC indicated the ability of this measurement system for accurately determining (with 99% confidence) CH_4, CO_2, and N_2O concentration as low as 120, 959, and 12 ppbv, respectively.

GHG Concentrations in Different GLAS

The minimum and maximum concentrations of GHGs measured at different GLAS during summer were 4.04±3.4 to 2493±1298, 383±131 to 3107±3878, and 0.06±0.03 to 1.6±2.0 ppmv for CH_4, CO_2, and N_2O, respectively. The measured gas concentrations within each GLAS were found widely varied due to spatially variable manure loading rates at different GLAS in a dairy operation. Husted (1993) reported that emissions of CH_4 and N_2O from animal manure stored under summer and winter conditions were highly variable due to dispirit distribution of manure between the two seasons. Mukhtar et al. (2008) reported highly variable NH_3 emissions from open-lot sources in a free-stall dairy central Texas due to variable manure loading rates. Similar

variations were also found inside a naturally ventilated dairy barn by Ngwabie et al. (2009). In their study, gas concentrations measured were as follows: 0.16 to 0.75 ppmv N_2O, 1.70 to 17.93 ppmv NH_3, 9 to 283 ppmv CH_4, and 644 to 3530 ppmv CO_2.

Table 1. Three greenhouse gases (GHGs) quantified in this study.

GHGs	CAS No.[a]	MW[b] (g mol^{-1})	Retention Time (min)	Standard Equations	R^2	MDL[c] (ppb)	Percent Recovery
Methane (CH_4)	74-82-8	16.04	1.39	y = 0.131(x)	0.99	120	98.97
Carbon dioxide (CO_2)	124-38-9	44.01	2.82	y = 2.96(x)	0.96	959	102.99
Nitrous Oxide (N_2O)	10024-97-2	44.01	3.66	y = 0.0018(x)	0.99	16	96.18

[a] CAS No. = Chemical Abstracts Service Number; [b] MW = molecular weight; [c] MDL = minimum detection limit

Table 2. Number of samples, GLAS area, ambient temperature, average volumetric concentrations during summer.

GLAS	GLAS components	Number of samples	GLAS area	Ambient temp (°C)	CH_4 (ppmv)	CO_2 (ppmv)	N_2O (ppmv)
Barn	Manure lane	16	1980	23.8	7.04**b**±3.8	443**b**±85	0.06**b**±0.03
	Bedding	6	1524	26.6	5.81**b**±4.9	824**b**±292	0.98**ab**±1
Loafing pen		25	22638	36.1	13**b**±11	1046**b**±743	1.6**a**±2.0
Lagoon	Primary	6	506	34.4	2230**a**±1214	3107**a**±3878	0.07**b**±0.06
	Secondary	-	-	-	-	-	-
Settling basin		12	892	31.2	2493**a**±1298	1395**b**±667	0.11**b**±0.09
Silage		4	942	31.3	4.04**b**±3.4	497**b**±172	0.45**ab**±0.07
Walk way		6	739	36.1	5.34**b**±2.2	383**b**±131	0.28**b**±0.05
Total		75	29221				

Means followed by the same letter in columns for a particular compound are not significant different ($p<0.05$)

In the summer, highest average CH_4 concentration was measured from settling basin followed by lagoon and loafing pen, and those three GLAS constituted about 82% of the total GLAS area. The CH_4 concentrations measured from settling basin and primary lagoon (2493 and 2230 ppmv, respectively) were significantly higher than those in other GLAS ($P<0.05$). High temperature during summer was the main factor persuades CH_4 emissions from those two GLAS since CH_4 formation is truly an anaerobic process. Husted (1993) reported methanogenisis and subsequent methane production in the anaerobic settling basin and lagoon strongly depend on temperature. He (Husted, 1994) also observed that methane emissions were highest in slurry when compared with solid manure (dung heap) as a result of anaerobic decomposition of organic matter. Weiske et al. (2006) also reported that increased microbial

activity due to higher temperature during summer amplified the CH_4 production in a slurry based manure management system. There were no significant different in CH_4 concentrations among barn, loafing pen, silage pile, and walk-way. Similarly, there were no significant difference in CO_2 concentrations among barn, loafing pen, settling basin, silage pile, walk-way ($p>0.05$) (table 2). In contrast, CO_2 concentration measured from primary lagoon was significantly higher than those from other GLAS ($p<0.05$). However, average high CO_2 concentrations were found in barn (bedding area), loafing pen, primary lagoon, and settling basin that constituted about 86% of the total GLAS area.

Highest N_2O concentrations were measured from loafing pen, barn (bedding), and silage pile, although, those concentration values were not statically different ($p<0.05$) (1.6, 0.98, 0.45 ppmv, respectively). In contrast, lowest N_2O concentrations were measured from settling basins and manure lane in the barn (0.06 and 0.07 ppmv, respectively). The semi-solid fresh manures in the manure lanes were the anaerobic product due to enteric fermentation inside the stomach of the ruminant which contained low N_2O. Similarly, a true anaerobic condition in the slurry (settling basin) and liquid manure in the lagoon showed low N_2O emissions. This was because N_2O is formed during aerobic nitrification and anaerobic denitrification. These results showed a good agreement with previous work by Osada et al. (1998) who observed that slurry manure emits a small amount of nitrous oxide due to poor aerobic conditions.

Estimation of Emission Factors (EFs) in Different GLAS

Average CH_4, CO_2 and N_2O EFs estimated from different GLAS of this dairy ranged from 0.10 to 60.5, 21 to 1767, and 0.002 to 2.73 kg hd^{-1} yr^{-1}, respectively, during summer. Similar to GHG concentrations (Table 2), the estimated EFs in each GLAS were found to vary widely as indicated by standard deviation (Table 3). This was due to temperature and spatially variable loading rates of manure at different GLAS in a dairy operation. The CH_4 EFs estimated from manure lane, bedding area, silage pile and walk-way were 0.38, 0.24, 0.1 and 0.11, respectively, and those EFs were not significantly ($p>0.05$) different (Table 3). Calculated average CH_4 EF from settling basin was significantly higher than those from other GLAS in the dairy operation during summer. Highest CH_4 EFs was estimated from settling basin followed by lagoon and loafing pen, and the corresponding EFs were 60.5, 31, and 7.85 kg hd^{-1} yr^{-1}, respectively. Thus, covering lagoons and settling basin surfaces can capture CH_4 and assist to reduce CH_4 emissions and odors substantially. Estimated average CH_4 EF from the settling basin was about 2, 8, and 98 times higher than those estimated from primary lagoon, loafing pen, and barn (manure lane and bedding area), respectively (Table 3). The settling basin and lagoon together contributed about 91% of the overall CH_4 emissions in this dairy during summer. The loafing pen alone contributed about 8% of the overall CH_4 emissions.

Average CO_2 EF estimated from loafing pen was significantly ($p<0.05$)) higher than those from other GLAS and loafing pen alone contributed about 81% of the overall CO_2 emissions during summer. Higher CO_2 in the loafing may due to the incomplete anaerobic decomposition of the manure. Average CO_2 EF estimated from the loafing pen was 11, 15, 19, 50, and 84 times higher than those from barn (manure lane and bedding area), primary lagoon, settling basin, silage-pile and walk-way, respectively (Table 3). However, there were no significant differences in CO_2 EFs estimated from barn (manure lane and bedding area), primary lagoon, settling basin, silage pile and walk-way. Estimated average N_2O EF at loafing pen was

significantly higher than those from other GLAS and contributed about 94% of the overall N_2O EF for summer. Lowest N_2O EFs were estimated from barn (manure lane), primary lagoon, and settling basin. This was because poor anaerobic conditions of semi-solid and liquid manure limit N_2O emissions from those two GLAS. The overall calculated CH_4, CO_2, and N_2O EFs were 100±56, 2192±1510, and 2.9±3.5 kg hd^{-1} yr^{-1}, respectively, in summer (Table 3). Those EFs factor showed good agreement with the previous findings in similar condition using other measurements techniques.

Table 3. Estimated average emission factor for GHGs in a free-stall dairy during summer.

GLAS	GLAS components	GLAS area (m^2)	Emission Factor (kg hd^{-1} yr^{-1})	Emission Factor (kg hd^{-1} yr^{-1})	Emission Factor (kg hd^{-1} yr^{-1})
			CH_4	CO_2	N_20
Barn	Manure lane	1980	0.38**c**±0.20	65**b**±13.0	0.01**b**±0.01
	Bedding	1524	0.24**c**±0.2	94**b**±33	0.11**b**±0.11
Loafing pen		22638	7.85**c**±6.6	1767**a**±1255	2.73**a**±3.4
Lagoon	Primary lagoon	506	31**b**±17	117**b**±146	0.002**b**±0.002
	Secondary lagoon		-	-	-
Settling basin		892	60.5**a**±31.5	93**b**±44	0.01**b**±0.01
Silage		942	0.10**c**±0.09	35**b**±12	0.03**b**±0.01
Walk way		739	0.11**c**±0.04	21**b**±7	0.015**b**±0.01
Total		29221	100±56	2192±1510	2.9±3.5

Means followed by the same letter in columns for a particular compound are not significant different ($p<0.05$)

Conclusion

A new protocol was successfully used for quantifying GHG emissions from different ground level area sources (GLAS) of a free-stall dairy operation in central Texas. This protocol is a modification of the EPA Method TO-14A, which employed a flux chamber and a portable GC to quantify GHGs directly in the field. Three GHGs namely CH_4, CO_2 and N_2O were quantified from same GLAS of a free-stall dairy during summer. The minimum and maximum concentrations of GHGs measured at different GLAS were 4.04±3.4 to 2493±1298, 383±131 to 3107±3878, and 0.06±0.03 to 1.6±2.0 ppmv for CH_4, CO_2, and N_2O, respectively. The EFs for CH_4, CO_2 and N_2O estimated from different GLAS ranged from 0.10 to 60.5, 21 to 1767, and 0.002 to 2.73 kg hd^{-1} yr^{-1}, respectively. These variations were due to variable dairy waste loading rates and microbial activity of manure at the GLAS. For this dairy, estimated overall EFs for CH_4, CO_2 and N_2O were, 100, 2192, 2.9 kg hd^{-1} yr^{-1}, respectively, in summer. Highest CH_4 EFs was estimated from

settling basin followed by lagoon and loafing pen and the corresponding EFs were 60.5, 31, and 7.85 kg hd^{-1} yr^{-1}, respectively. Highest CO_2 and N_2O EFs estimated from loafing pen and this GLAS alone contributed about 81% and 84% of the overall CO_2 and N_2O emissions, respectively, during summer.

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