Written Testimony for the
U.S. House of Representatives Committee on Science and Technology's Hearing on
"Monitoring, Measurement and Verification of Greenhouse Gas Emissions II: The Role of Federal and Academic Research and Monitoring Programs".

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Introduction

Chairman Gordon, Ranking Member Hall, and other Members of the Committee, I am Dr. Albert Heber, Professor of Agricultural and Biological Engineering at Purdue University, and Director of the National Air Emissions Monitoring Study. Thank you for the invitation and opportunity to speak to you about measurements and mitigation of GHG on livestock operations.

My statement will cover the following topics:

1. Agricultural sources of greenhouse gases.
2. Description of National Air Emission Monitoring Study.
3. Estimated costs of on-farm GHG monitoring.
4. Potential for using NAEMS infrastructure for follow-on GHG studies.
5. Measuring GHG emissions.
6. Uncertainty of on-farm GHG monitoring.

Agricultural Sources of Greenhouse Gases

1. Methane (CH_4) from ruminant livestock (sheep and cattle) and from anaerobic digestion of organic wastes.
2. Carbon dioxide (CO_2) from anaerobic digestion of organic wastes and from animal exhalation.
3. Nitrous oxide (N_2O) from conversion of nitrogen compounds in nitrification (NH_4 to NO_3) and denitrification (NO_3 to N_2) processes (McGinn, 2006).
4. GHG emission from agricultural land.

Research on quantifying GHG from agricultural sources started in the 1970s (e.g., Bremner and Blackmer, 1978). The International Atomic Energy Agency published a manual on measurement of methane and nitrous oxide emissions from agriculture in 1992 (IAEA, 1992). The First International Greenhouse Gas Measurement Symposium was held in San Francisco, CA from March 23-25, 2009. Research on mitigation of agricultural GHG emissions from soil started in the 1990s (e.g., Mosier *et al.*, 1996; Mosier *et al.*, 1998). Recent investigations on GHG emission reductions were conducted in animal barns and manure treatment facilities (e.g., Tada *et al.*, 2005; Weiske *et al.*, 2006; VanderZaag *et al.*, 2008; Cabaraux *et al.*, 2009). The warming potential of greenhouse gases (N2O + CH4) were about 22, 34 and 168 g CO2 equivalents per day and per pig on fully slatted floor, straw or sawdust deep litter respectively (Cabaraux *et al.*, 2009).

The latest inventory of GHG emissions and sinks in U.S. was published by USEPA (2009).

National Air Emissions Monitoring Study

BACKGROUND

Animal feeding operations (AFOs) commonly emit certain amounts of particulate matter (PM), ammonia (NH_3), hydrogen sulfide (H_2S), volatile organic compounds (VOCs), greenhouse gases (GHG), and odorous compounds. Historically, concern about non-GHG pollutants arose first from potential worker and animal health issues, and with nuisance complaints. The U.S. government assumed a greater role in regulating air emissions from agriculture during the last decade. The U.S. Environmental Protection Agency (EPA) began applying federal air quality regulations to AFOs around the year 2000 (Schutz, et al., 2005). Particulate matter and non-methane VOCs are criteria air pollutants under the U.S. Clean Air Act (CAA) of 1990 (U.S. EPA, 1990). The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Emergency Planning and Community Right-to-Know Act (EPCRA) required reporting of NH_3 and H_2S emissions exceeding 100 lb/day. However the U.S. EPA recognized a lack of reliable data for emissions of these pollutants from AFOs (Schutz, et al., 2005).

As the EPA began enforcing air laws at AFOs, the agricultural community voiced their concern that the current air contaminant emission estimates for AFOs were either based on data from outdated studies or did not represent modern livestock farms (Schutz, et al., 2005). The National Research Council (National Research Council, 2003) shared this concern, and recommended that EPA improve its methods of estimating AFO air emissions. In January, 2005, the Air Consent Agreement (ACA) was announced in the Federal Register (U.S. EPA, 2005). The ACA is an agreement between livestock (dairy, pork, egg, and broiler chicken) commodity groups and U.S. EPA. The ACA required an industry-funded nationwide AFO emission study that would provide a scientific basis for the determination of compliance with the air laws. Industry participation in the ACA included 2,568 livestock production operations representing a total of 6,267 farms.

The objectives of the NAEMS were to: 1) quantify rates of air emission from pork, dairy, egg, and broiler production facilities, 2) provide reliable data for developing and validating models for estimating emissions from livestock operations, and 3) promote standardized methodology for measuring livestock and poultry farm emissions.

Unique Characteristics of the NAEMS

The barn portion of the NAEMS has several unique characteristics compared to previous baseline studies.

1. It is measuring a comprehensive set of pollutants ($PM_{2.5}$, PM_{10}, TSP, NH_3, H_2S, and CO_2 at all 15 barn sites, CH_4 at five sites, and non-methane VOC at two sites).
2. The monitoring period is 24 months. The longest previous baseline study was 15 months long (Jacobson, et al., 2004).
3. Largest number of farm buildings (38) measured among four livestock species using the same protocols. Jacobson et al. (2004) monitored 12 buildings among three livestock species in their study of PM_{10}, TSP, NH_3, H_2S, and odor.
4. Sites were selected to maximize representativeness under the constraints of the other site selection criteria.
5. Quality assurance and quality control was improved with a Category 1 Quality Assurance Project Plan (QAPP).
6. The EPA-approved QAPP (barn portion) included 57 standard operating procedures (SOPs) and 14 site monitoring plans (SMPs).
7. Novel methods include the use of ultrasonic technology to measure the ventilation airflow of naturally ventilated barns (Ndegwa et al., 2008).
8. The NAEMS is measuring gas and PM emissions from barns (Heber et al., 2008) and gas emissions from lagoons, basins and dairy corrals (Grant et al., 2008) and both measurements are being conducted at four of the twenty farms.

<u>BARN MONITORING SITES (taken from Heber et al., 2008)</u>

The barn monitoring sites (Table 1) were selected based on the following criteria:

1. Producer participation in the ACA.
2. Representativeness of the farm for its livestock type.
3. Proximity to academic expertise in air quality research.
4. Conduciveness and suitability of the site for collecting reliable data.
5. Producer collaboration (very important to successful long-term, on-farm studies)
6. Potential for measurement of outdoor manure storage systems at the same site.

The sow farms in North Carolina (NC4) and Oklahoma (OK4) have pull-plug pits with outdoor (lagoon) manure storages (Table 1). The Iowa sow farm (IA4) uses deep pits in the barns to store manure. The North Carolina and Indiana finisher operations are flush and deep pit barns, respectively. Emissions at sow farms are measured at two gestation barns and one farrowing room. Three separate barns (NC) or four rooms of a “quad” barn (IN) are being monitored at swine finishing sites.

Egg laying buildings are either high-rise houses, in which manure accumulates in the lower level, or manure belt houses with belts under the cages that transfer manure to an external storage. Two high-rise houses and two manure belt houses with the associated manure shed are being monitored in Indiana (IN2). The layer sites in California (CA2) and North Carolina (NC2) are each monitoring two high-rise houses. Two barns monitored at a broiler ranch in California (CA1) consist of broiler chickens raised on a concrete floor covered with litter.

Table 1. NAEMS barn sites. All barns mechanically-ventilated unless indicated NV. Source: Heber et al. (2008).

Site	Barn type (date)	# of barns	# hd/barn	GSL	Fans
Broilers					
CA1	TV litter on floor ('02)	2	21,000	7	24
Layers					
CA2	High-rise, DB ('03)	2	38,000	7	24
IN2	High rise, CBC ('97)	2	250,000	15	220
	Manure belt ('04)	2	280,000	18	192
	Manure shed ('04)	1	-	1	0
NC2	High rise, CBC ('03)	2	103,000	7	68
Swine					
IN3	TV finishing, deep pit ('03)	4	1000	17	32
NC3	TV finishing, PPR ('95)	3	800	4	15
IA4	TV gestation, deep pit ('98)	2	1100	18	42
	Farrowing room, PPR ('98)	1	24		3
NC4	TV gestation, PPR ('94)		850	6	20
	Farrowing room, PPR ('95)	1	24		3
OK4	TV gestation, PPR ('94)	2	1200	12	26
	Farrowing room, PPR ('94)	1	24		2
Dairy					
CA5	NV freestall, flushing ('01)	2	600	45	0
IN5	TV freestall, scrape ('04)	2	1600	23	152
	Milking center, flushing ('04)	1	562		26
NY5	TV freestall, scrape ('98)	1	470	7	30
	Milking center, deep pit ('90)	1	187		8
WA5	NV freestall, flush ('02)	2	650	33	0
WI5	Freestall, scrape ('07)	2	325	11	125
	Milking center ('90)	1	80		0

PPR: pull-plug with recharge, DB: dropping board, CBC: curtain-backed cages. GSL: gas sampling locations, TV: tunnel-ventilated, NV: naturally-ventilated. All barns mechanically-ventilated with sidewall fans unless indicated NV.

Two western dairy sites have naturally-ventilated freestall dairy barns with outdoor exercise lots. The freestall barns in California (CA5) have open walls. The freestall barns in Washington (WA5) have open end walls and adjustable curtains on most of the sidewalls (Heber et al., 2008). Two MV freestall barns per site are being monitored in Wisconsin (WI5) and Indiana (IN5). The New York (NY5) site is monitoring one MV freestall barn. MV milking centers are also monitored at IN5 and NY5. Sites NY5 and IN5 have tunnel-ventilated barns and Site WI5 uses cross-flow ventilation (Heber et al., 2008).

Methodology and Instrumentation

An on-farm instrument shelter (OFIS) houses instruments and equipment for measuring pollutant concentrations at representative air inlets and outlets, barn airflows, operational processes, and environmental variables.

A multipoint gas-sampling system (GSS) inside the OFIS draws air sequentially from various barn locations and ambient air, and sequentially delivers selected streams to a manifold from which gas monitors draw continuous subsamples. The number of sampling points per site ranges from 4 to 45. The average sampling tube length is 77 m. The sampling periods for exhaust air are typically 10 min long.

Gas sensors include a photoacoustic multigas analyzer (Innova Model 1412, California Analytical Instruments, Orange, CA) for NH_3 and CO_2, a pulsed-fluorescence analyzer (Model 450I , Thermo Environmental Instruments, Franklin, MA) for H_2S, and a gas chromatograph - flame ionization detector (Model 55C, Thermo Environmental Instruments, Franklin, MA) for CH_4 and non-CH_4 hydrocarbons. The Model 55C is used only at sites IN3 and CA5.

The ambient PM concentrations are measured with a beta attenuation PM monitor (Model FH62 C-14, Thermo Scientific, Waltham, NY). Exhaust PM concentrations are measured continuously with a tapered element oscillating microbalance (Model 1400a, Thermo Scientific, Waltham, NY) at a minimum winter ventilation fan in each MV barn and in the ridge exhaust of each NV barn. The sampling location inside MV barns is near the fan inlet. PM_{10} is measured 7 of 8 weeks and TSP is measured every 8th week. $PM_{2.5}$ is monitored during 2-wk periods during winter and summer.

Fan airflow rates are spot checked using the portable fan tester (Gates et al., 2004), or a traverse method using a portable anemometer. Airflow data from spot checks are correlated with continuous data from rpm sensors and/or impeller anemometers. At least one fan per fan model is continuously monitored using a bi-directional impeller anemometer. The impeller anemometer accounts for the significant effects of wind and building static pressure. Individual fans are monitored using rpm sensors, current switches, or vibration sensors. At most sites, the operation of fan stages is monitored via fan motor control relays. Airflow through NV barns is measured using 3-dimensional sonic anemometers.

All measured variables are listed in Table 2. Meteorological measurements (solar radiation, wind direction and velocity, temperature, humidity) are needed to study the influence of weather on emissions. Measurements such as feed composition, manure characteristics, pit flushing, and animal activity help to determine methods of abating emissions. The effect of weather on air emissions is coupled with the effect of manure accumulation, animal age and growth cycles, moisture content in manure storages, and animal live weight and feed consumption.

Standard operating procedures were written for all measurements and instrumentation to assure that the same methods would be used at all sites, and to maximize data comparability. The total number of monitored variables varies from 85 at sow site NC4 to 466 at layer site IN2. The data acquisition system reads data at 1.0 Hz, and records 15-s and 60-s data averages.

Milk, feed, bedding, manure, water and VOC are collected for ex-situ analysis. VOC samples are also collected in passivated canisters and multi-sorbent tubes, and analyzed by gas chromatography and mass spectrometry. Manure is analyzed for pH, total solids and ash content, and concentrations of total nitrogen (N) and ammoniacal N. Total manure N will be used in conjunction with total feed, bedding, milk, eggs, and/or meat nitrogen contents to generate a nitrogen mass-balance for each barn as a whole. Ash contents will be used at some sites to estimate manure volume (Keener and Zhao, 2008) which cannot be measured directly at some sites. The validity of the ash-balance method will be validated at sites where manure volume can be measured.

Table 2. Measured variables (Heber et al., 2008).

Variable	Measurement Method/Instrument(s)	Units
NH_3*, CO_2*	Infrared photo-acoustic	ppm
H_2S*	Pulsed fluorescence	ppb
NMHC*, CH_4*	GC-FID	ppb
EtOH*, MeOH*, CH_4*	Infrared photo-acoustic	ppb
VOCs*	GC/MS (mass spectrometer)	ppb
VOCs (amines)*	Ion chromatography	ppb
$PM_{2.5}$*, PM_{10}*, TSP*	TEOM, C-14 Beta attenuation	$\mu g/m^3$
Fan air speed	Anemometer	m/s
Fan run time	Vibration or rpm sensor, stage relays	% time
Vent air velocity	Ultrasonic anemometer	m/s
Barn static pressure	Capacitive/diaphragm sensor	Pa
Exhaust temperature	Thermistor or RTD	°C
Temperature*	Thermocouple type T	°C
Exhaust RH	Thin-film capacitor (TFC)	%RH
Ambient temperature	Thermistor/RTD, Passive shielded	°C
Outdoor humidity	TFC, Passive shielded	%RH
Atmospheric pressure	Electronic barometer	atm
Solar radiation	Pyranometer	W/m^2
Wind speed	Cup anemometer	m/s
Wind direction	Vane	degrees
Barn inventory, animal mortality	Farm records	head
Animal weight	Truck balance	kg
Manure volume	Farm records	gal
Manure pH	Electrochemical pH meter	pH units
Manure solids	Gravimetric	wt%
Manure NH_3 & N	Kjeldahl/titrimetric	wt%
Feed, bedding, milk, egg N	Kjeldahl/titrimetric	wt%
Feed input to barn	Farm records	kg
Animal activity in barn	Passive infrared detector	VDC
GSS sample and lab pressures	Capacitive/diaphragm sensor	Pa
GSS sample flow rate	Mass flow meter	L/min
Lab and raceway temperatures	Thermocouple	°C
Instrument filter pressure	Capacitive/diaphragm sensor	%

*Barn inlet and exhaust

The final processing of NAEMS data is facilitated with CAPECAB, a custom-written data analysis program. Data is invalidated for various reasons including: calibration of a sensor or analyzer, low flow through the GSS, sensor malfunction, electronic noise, DAC hardware or software problem, condensation in sampling lines, or gas analyzer equilibration. CAPECAB allows users to adjust gas concentration data based on calibration, extract equilibrium data, calculate ventilation rates, and calculate emission rates. Hourly and daily averages of emission rates and other parameters will be provided to the EPA.

OPEN SOURCE MONITORING SITES (taken from Grant et al. 2008)

Emissions of NH_3, H_2S, and CH_4 are being measured throughout the year at dairy and swine farms, along with other parameters that affect emissions such as time of year, atmosphere stability, and farm operation (Grant et al., 2008).

Experimental Methods

Instruments used with open sources include ultrasonic (sonic) anemometers to characterize the wind, sensors to measure the atmosphere (temperature, relative humidity, solar radiation, barometric pressure, wetness), sensors to characterize the source (temperature, pH, and oxidation-reduction potential for lagoons), and state-of-the-art instruments for measuring concentrations of target gases along open paths near the source. Manure samples from corrals and basins are analyzed for pH, and concentrations of solids, and NH_4^+-N.

Measurements at 10 sites in 7 states began in the summer of 2007, and will continue through the summer 2009. Two sites are each measured continuously for one year. Eight sites are sequentially measured for 10 to 20 days during each season for two years.

Scanning NH_3 TDLAS

At a typical open source, TDLAS units are set up at opposite corners and 16-m towers at the other two corners. Six retro-reflectors are mounted on each tower, with 3 facing each TDLAS system at heights of about 1, 7, and 15 m. Two additional retro-reflectors are placed at 1-m heights on tripods at 1/3 and 2/3 of the distance down each side of the source. Thus, each side of the source has three near-surface paths and two elevated paths. A computer-controlled scanner sequentially aims a TDLAS at each retro-reflector among two adjacent sides of the source. The advantage of scanning open-path TDLAS for continuous long-term measurements of NH_3 is that wind direction becomes a minor factor in determining the emitted gases because the plume location is not needed to properly measure it (Grant et al., 2008). Quality control (QC) procedures of the TDLAS measurements include checks for path obstruction, internal calibration checks, spectral feature checks and single-point calibration verifications, and multi-point calibrations. The minimum detection limits of the TDLAS units are about 2 ppm-m or less.

S-OPS/GSS

The synthetic open-path system (S-OPS) consists of a 50-m section of Teflon tubing, outfitted with 10 equally-spaced, flow-balanced inlets, through which a blended air sample of a plume is drawn and sampled by gas analyzers in the trailer. Two S-OPS are placed on opposite sides of the source. Proper sample flow is verified by continuously monitoring sample pressure, flow rate and direction. Extensive QC checks are conducted to maintain system integrity.

A multigas analyzer using the photoacoustic spectroscopy is used to measure NH_3 and CH_4 for which the stated detection limits for CH_4 and NH_3 are 100 and 200 ppb, respectively. A pulsed fluorescence SO_2/H_2S analyzer is used to measure H_2S. The manufacturer stated MDL is 1 ppb. Interferents include methyl mercaptan and water vapor. The difference between the upwind and downwind gas concentration in the S-OPS air samples is used to determine gas flux from the area source.

Weather Measurements

In a typical setup, three-dimensional sonic anemometers are mounted at heights of 2, 4, and 16 m and measurements in the three orthogonal directions are made at 16 Hz. Field intercomparisons are made at least every 21 days by mounting the three anemometers next to each other and measuring wind for one hour. Typically, differences between sensors are less than 0.1 m/s.

Emissions of NH_3

Emissions of NH_3 are determined at ½ hr intervals from wind profiles based on the three anemometers, and concentration profiles obtained by multiple TDLAS-measured path-integrated concentrations (PIC) using the vertical radial plume mapping (RPM) method. This method is limited by the need to have valid data for all five PIC and all three wind sensors. Weather conditions such as fog, heavy rain, high winds, and low winds (<0.2 m/s) limit the availability of both PIC and wind data, thus limiting the periods during which emissions can be calculated.

Emissions of H_2S and CH_4

The gaseous emissions of H_2S and CH_4 are determined from ½ hr averages of concentration measurements of the air sequentially sampled from upwind and downwind S-OPS systems and either: 1) the bLS emission model using wind turbulence measurements of the 2-m sonic anemometer, or 2) the ratio of the S-OPS measurement of H_2S and CH_4 concentrations to TDLAS PIC measurement of NH_3 of the nearest path to the S-OPS inlets multiplied by the RPM-measured NH_3 emission. Fog, heavy rain, high winds, and low winds limit the availability of both PIC and wind measurements, thus limiting the periods during which emissions based on the RPM emissions can be calculated. Emissions based on the bLS model are limited by low winds, very unstable or stable conditions, and upwind fetch.

COSTS OF ON-FARM GHG MEASUREMENTS

Costs for on-farm measurements of GHG's vary with the complexity of the farm. Factors include the number, size and ventilation type of the barns, and the presence, number, and type of other external or outside sources.

The following conservative cost estimates for monitoring enclosed building sources assume a focus on GHG emissions only, and are based on the costs to conduct the

NAEMS at various types of barn sites (2-4 buildings per site), including a “simple” barn site (e.g. a small broiler operation) and a “complex” one (a large dairy or egg-layer facility). Naturally-ventilated facilities (most frequently dairies) present special challenges and additional costs, mostly due to the need to measure barn airflow with a large array of ultrasonic anemometers.

Barn site type	Equipment cost	Maintenance/mon
Simple	$150K	$14K
Complex	$200K	$18K
Naturally-ventilated	$250K	$18K

These estimates include a climate-controlled mobile laboratory, gas analyzer(s) for CO_2, CH_4 and N_2O, calibration equipment and supplies, site-customized systems for gas sampling and data acquisition, and sensors and equipment for monitoring building airflow. Setup time estimates above include both the time to design and customize these systems, and to deploy them in the field. Maintenance time estimates include equipment maintenance and calibration, and processing and interpretation of the data.

Monitoring of outside sources can be conducted in different ways. If CH_4 is the only gas of interest, the initial cost of open-path spectroscopy with methane-specific lasers is approximately $60,000 and monthly cost is approximately $14,000. This approach might be sufficient for sources such as anaerobic manure lagoons, which may (Monteny et al 2001) or may not (Jones et al 2000; Berg et al 2006) have minimal emissions of N_2O. Expanding monitoring to CO_2 and N_2O in addition to CH_4 would most likely be done by open-path Fourier Transform Infrared (FTIR) spectroscopy, or by deploying synthetic open-path systems (Grant et al. 2008). The approximate cost of a fully-automated FTIR system to measure gas concentrations on all sides of a source such as a lagoon, feed storage pile, etc could be as high as $300,000. A synthetic open-path system, with its associated gas analyzer(s), can be set up for approximately $75,000.

UTILIZING NAEMS INFRASTRUCTURE FOR GHG STUDIES

It required about one year (2006) to develop the 2000-page NAEMS Quality Assurance Project Plan and gain EPA’s approval, and another year (2007) to set up the monitoring equipment at 20 farms across the U.S. The two years of monitoring (2008-09) will be completed in about eight months, at which time the monitoring sites will dismantled or used in follow-on studies.

The NAEMS was not designed to measure baseline greenhouse gas emissions. In the process of determining non-methane hydrocarbons, methane was measured at 5 of 15 barn sites and in less than 1/3 of the open source measurements. Carbon dioxide was measured at the barn sites but not at the open source sites. Nitrous oxide was measured at only a sow operation and at a dairy site with local add-on studies.

To take advantage of the existing NAEMS infrastructure and expertise, the dairy industry funded a project to add all three major GHG to all the dairy sites for the last few months of the NAEMS and to extend three of the barn sites until January 31, 2010 to obtain some baseline GHG emissions data over a limited period of time.

Federal support of follow-on GHG studies using the NAEMS infrastructure and expertise could provide:

1. Long-term monitoring of baseline GHG emissions at existing or other sites.
2. Tests of GHG mitigation strategies at existing or other sites.
3. Expansion of monitoring to all sources at the farms, e.g. land application, feed storage, feedlots, lagoons, etc.
4. Refinement of on-farm GHG measurements.

The GAO (2008) recommended that, at a minimum, a comprehensive study of greenhouse gas emissions from AFOs would require a study, or combination of studies, of similar scope and size to the NAEMS.

MEASURING GHG EMISSIONS

Emissions cannot be directly measured. Emissions can only be estimated/calculated based on concentration measurements and airflow measurements. Accurate concentration and airflow measurements in barns are challenging in barns because of the number of emitting locations (i.e. fans) and/or the lack of well-defined emitting locations (i.e. a naturally-ventilated barn).

The comprehensive emission measurements for the NAEMS sites require between 80 to 300 measured variables at each site (includes concentration, temperature, weather information, fan operation, and site operation variables), with each variable monitored on a 1-min basis. The number of data points in the NAEMS is expected to exceed 2.4 billion (Ni et al, 2008). All data collected requires evaluation and further processing by trained individuals to generate the required emission data.

UNCERTAINTY OF ON-FARM GHG MONITORING

Multi-gas analyzers based on photoacoustic infrared (PIR) detection are commercially available, and are designed for simultaneous detection/measurement of all the greenhouse gases relevant to agriculture (CO_2, CH_4, N_2O). Preliminary CO_2 concentration control chart data from three out of fourteen sites of the NAEMS indicate that the total relative uncertainties for the CO_2 concentration were between 4 and 9%. The order of magnitude of these values are representative of the expected uncertainty in the concentration of the other GHG being monitored (CH_4, N_2O). This determination is based on calibration with a single gas standard in dry air.
However, besides the typical uncertainty of measurements of single gases, there is the added uncertainty caused by interferences of other gases including water vapor. The analyzer manufacturer has corrections in place for those interferences but improvements are needed in the compensations to reduce the uncertainty incurred when measuring at

livestock facilities as compared with other applications of the multigas analyzer. For example, cross-compensation calibrations are generally performed with single concentrations of gases (or a single humidity level), but if the relationship between the interfering gas concentration and light absorbance is not linear over the relevant concentration/humidity range, errors will be introduced. As compared with other applications for the multigas analyzer, carbon dioxide and water vapor (major interferents) concentrations are high. The effects of these interfering gases need to be carefully accounted for in GHG measurements.

SUMMARY

The NAEMS consists of two components: measurement of gas and particulate emission from barns (Heber et al., 2008) and the measurement of gas emissions from open-air sources (Grant et al., 2008) including dairy corrals and manure storage lagoons and basins. In the open-source component, gaseous emissions of NH_3, H_2S, and CH_4 are being measured throughout the year at four dairy and six swine operations, along with a range of other parameters that affect emissions such as time of year, stability of the atmosphere, and facility operation.

In the barn component, the NAEMS is collecting continuous air emission data from 38 barns at five dairies, five pork production sites, three egg layer operations, one layer manure shed, and one broiler facility for a period of 2 years. Concentrations of NH_3, H_2S, VOC, and PM (PM_{10}, $PM_{2.5}$, and TSP), building ventilation rate, and supporting parameters are monitored. Motion sensors monitor animal, worker and vehicle activity. Barn ventilation rate is assessed by monitoring fans and barn static pressure in MV barns, and air velocities through ventilation openings in naturally-ventilated buildings. Custom software (CAPECAB) efficiently handles large amounts of data being generated by NAEMS, and is used to validate, and process the data.

The costs of conducting long-term continuous emission monitoring studies at commercial farms are significant. There is a significant cost savings if the existing setups at farms are used to conduct needed additional studies. While a limited number of GHG measurements were obtained at some of the farms, a comprehensive GHG study conducted at existing NAEMS sites or with the NAEMS equipment and expertise could potentially answer a lot of important questions in a timely manner.

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