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Abstract
Aerial emissions from livestock production continue to be an area of concern for both the potential health and environmental impacts. However, information on gaseous, especially greenhouse gas (GHG) emissions for swine breeding/gestation and farrowing production facilities is meager. A 4300-sow breeding, gestation, and farrowing facility in Iowa was selected for extensive field monitoring. A Mobile Air Emission Monitoring Unit (MAEMU) was installed to monitor the deep-pit breeding-early gestation barn (1800 head), the deep-pit late gestation barn (1800 head), and two shallow-pit (pull-plug) farrowing rooms (40 head per room). This paper reports on data collected from January 12, 2011 to March 31, 2012.

Keywords
Swine, Ammonia, Greenhouse Gas, Aerial Emissions, Deep-pit

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Ammonia and Greenhouse Gas Emissions of a Swine Breeding-Gestation-Farrowing Facility in the Midwestern USA

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Abstract. Aerial emissions from livestock production continue to be an area of concern for both the potential health and environmental impacts. However, information on gaseous, especially greenhouse gas (GHG) emissions for swine breeding/gestation and farrowing production facilities is meager. A 4300-sow breeding, gestation, and farrowing facility in Iowa was selected for extensive field monitoring. A Mobile Air Emission Monitoring Unit (MAEMU) was installed to monitor the deep-pit breeding-early gestation barn (1800 head), the deep-pit late gestation barn (1800 head), and two shallow-pit (pull-plug) farrowing rooms (40 head per room). This paper reports on data collected from January 12, 2011 to March 31, 2012.

Preliminary results from the study show the following average daily emissions per animal unit (AU = 500 kg body mass): 31.1 g NH\textsubscript{3}, 7.32 kg CO\textsubscript{2}, 1.0 g N\textsubscript{2}O, and 260.8 g CH\textsubscript{4} for sows in the breeding/early gestation barn; 31.5 g NH\textsubscript{3}, 7.66 kg CO\textsubscript{2}, 0.2 g N\textsubscript{2}O, and 243.4 g CH\textsubscript{4} for sows in the late gestation barn; 78.6 g NH\textsubscript{3}, 21.2 kg CO\textsubscript{2}, 0.8 g N\textsubscript{2}O, and 108.2 g CH\textsubscript{4} for sows and litters in farrowing room 1; and 72.7 g NH\textsubscript{3}, 21.0 kg CO\textsubscript{2}, 0.8 g N\textsubscript{2}O, and 145.1 g CH\textsubscript{4} for sows and litters in farrowing room 2. The average daily emissions per AU for the external manure storage for the farrowing facility are 0.839 g NH\textsubscript{3}, 167.2 g CO\textsubscript{2}, 0.137 g N\textsubscript{2}O, and 105.7 g CH\textsubscript{4}.

Keywords. Swine, Ammonia, Greenhouse Gas, Aerial Emissions, Deep-pit
Introduction

Gaseous emissions from livestock production have received increasing attention as concern has grown over their environmental and health impacts. It is important to study these emissions to understand the quantity and composition of gasses being emitted to the atmosphere. The three biggest gasses of concern in terms of having potential to affect climate change are the greenhouse gasses (GHG): carbon dioxide (CO₂), nitrous oxide (N₂O), and methane (CH₄). In order to understand the magnitude of GHG emissions from livestock production, reliable emission factors for different livestock production systems in different geographic/climatic areas must be determined. Currently, there is a gap in the swine data for the breeding/gestation and farrowing stages of production.

The US breeding pig inventory was 5.82 million head as of March 30, 2012 and Iowa leads the US with over 17% of the breeding inventory (USDA NASS, 2012). The US EPA estimates that agriculture is responsible for 6.3% of the total GHG emissions in the US (2011 US Greenhouse Gas Inventory Report).

There literature on GHG emissions from swine gestation and farrowing facilities is limited. The gestation side is particularly sparse as many of the studies done are for shallow-pit or flush systems, not the deep-pit system common in the Midwest. The literature for farrowing facility emissions is more comparable due to the common manure management practice of shallow-pit systems but is still meager. Additionally, many of these studies involved intermittent air sampling, which can struggle to capture the diurnal fluctuations of gaseous emissions and can be significantly impacted by short-term weather conditions.

Therefore, the objective of this study was to quantify the emissions of GHG and ammonia from a Midwestern production breeding/gestation/farrowing swine facility. One year of data collection has been completed and collection will continue for one more year.

Materials and Methods

Site Description and Instrumentation

A 4300 sow capacity breeding/gestation/farrowing facility in central Iowa was used in this monitoring study. A full description of the facility and instrumentation can be found in Stinn et al. (2011). In brief, the facility consisted of two farrowing buildings with 9 farrowing rooms each, a breeding/early gestation barn, a late gestation barn, and an external manure storage vat for the farrowing facility. Two farrowing rooms, designated Room 1 and Room 2, were selected to be monitored. The farrowing rooms were each 15.5m x 13.9m (51ft x 45.5ft) with a shallow-pit system (0.61m deep) that was flushed out after every turn (approx. every 21 days). Figure 1 shows the monitoring system layout for the farrowing rooms. Each room's exhaust air was sampled identically, with one composite sample from the shallow-pit fans and one composite sample from the lowest stage wall fans.

The breeding/early gestation barn and the late gestation barn, designated as Barns 1 and 2 respectively, had the same dimensions, ventilation design, and 1800 head capacity. The barns had dimensions of 121.9m x 30.5m (400ft x 100ft) and used mechanical ventilation year-round. Each barn had a deep pit (3.05 m) and the manure was pumped out semi-annually, in the fall and spring. Figure 2 shows the monitoring system layout for Barns 1 and 2. Exhaust air samples from each barn were drawn as a composite from four of the lowest ventilation stage pit fans with a second sample from the lowest stage endwall fan.
Figure 1. Diagram of Farrowing Rooms 1 and 2 showing air sampling, temperature, static pressure, and relative humidity measurement locations.

Figure 2. Diagram of Barns 1 and 2 showing air sampling, temperature, static pressure, relative humidity, and barometric pressure measurement locations.
A Mobile Air Emissions Monitoring Unit (MAEMU) was used to continuously collect emissions data from the previously described barns and farrowing rooms. A detailed description of the MAEMU and its operation can be found in Moody et al. (2008). The MAEMU housed, among other measurement and data acquisition equipment, a photoacoustic multi-gas analyzer (INNOVA Model 1412, INNOVA AirTech Instruments A/S, Ballerup Denmark) to measure NH₃, CO₂, N₂O, and CH₄ concentrations. The analyzer was challenged weekly with calibration gases and recalibrated as needed.

Samples were drawn from the 8 in-house locations and 1 outside location to provide ambient background data. Samples were drawn from each in-house location every 16 min (2 min per location) with the outside air being sampled every two hours for 6 min (12 samples). The outside location can be seen in Figure 2 on the north side of Barn 2. Pit fan sampling ports were located below the slats/floor directly under each fan. Wall fan sampling ports were located approximately 1.0 m (3.28 ft) in front of each wall fan. The sample port locations were chosen to best represent the exhaust air leaving each barn/room. The MAEMU utilized a positive-pressure gas sampling system to minimize potential infusion of unwanted air to the sample line. All pumps and sample lines were checked weekly for leaks and blockages.

The fans were calibrated in situ at multiple operating points to develop a performance curve for each fan using a Fan Assessment Numeration System (FANS) (Gates et al., 2004). The on/off status of each fan was monitored continuously by an inductive current switch on the each fan motor's power cord (Muhlbauer et al., 2011) with its analog output connected to the data acquisition system. The speed of the variable speed fans was measured by Hall Effect speed sensors (GS100701, Cherry Corp, Pleasant Prairie, WI). Static pressure sensors were located near the south wall of each farrowing room and near the middle of the north and south walls in Barns 1 and 2.

The external manure storage vat had a diameter of 54.8m (180 ft) and a depth of 4.57m (15 ft), but management did not allow manure depth to exceed 3.05m (10 ft). Manure originated in the farrowing rooms and was added every day from the farrowing room that was being weaned. The vat was pumped twice a year, in the fall and spring. A dynamic flux chamber system was developed similar to Acevedo et al. (2009). The chamber was floated on the vat manure surface for a range of ambient conditions and gas concentrations were measured with an Innova 1412 photoacoustic analyzer. Figure 3 shows the floating dynamic flux chamber.

**Gaseous Emission Rate Determination**

Emission rates from the barns for each measured constituent were calculated as mass of the gas emitted per unit time using Equation 1 (Stinn, et al. 2011):

\[
ER_{\text{aq}} = \sum Q \left( [G]_a - \frac{\rho_a}{\rho_l} [G]_l \right) \times 10^{-6} \times \frac{T_{\text{std}}}{T_a} \times \frac{P_a}{P_{\text{std}}} \times \frac{W}{P}
\]

Emission flux rates (F) from the manure storage vat were calculated as mass of gas emitted per unit time per unit area using Equation 2 (Acevedo et al. 2009):
Results and Discussion

The results discussed below are from data collected January 12, 2011 to March 31, 2012 and are considered to be preliminary. Figure 3 shows the average daily ventilation rates for each monitored barn and room over the monitoring period along with the average daily ambient temperature. Table 1 shows the average daily ventilation and emission rates of each constituent for each barn and room and average values for the two farrowing rooms combined.

![Figure 3: Average daily ventilation rates for each monitored barn and room over the monitoring period.](image)

![Figure 4: Average daily ventilation rate of (a) barns 1 and 2 and (b) rooms 1 and 2, along with outside temperature, during the monitored period.](image)

Table 1. Average (SD) gaseous emission rates (g/d-AU) of the two monitored breeding/gestation barns and two monitored farrowing rooms (AU = animal unit = 500 kg body mass).

<table>
<thead>
<tr>
<th>Description</th>
<th># of Days Monitored</th>
<th># Pigs or Crates</th>
<th>VR (m³/hr-pig)</th>
<th>Gaseous Emission Rate (g/d-AU)</th>
<th>NH₃</th>
<th>CO₂</th>
<th>N₂O</th>
<th>CH₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barn 1</td>
<td>128</td>
<td>1625</td>
<td>92.90</td>
<td>31.1</td>
<td>7323.6</td>
<td>1.0</td>
<td>260.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(69.10)</td>
<td>(11.0)</td>
<td>(2718.9)</td>
<td>(0.4)</td>
<td>(105.5)</td>
<td></td>
</tr>
<tr>
<td>Barn 2</td>
<td>128</td>
<td>1800</td>
<td>107.28</td>
<td>31.5</td>
<td>7656.0</td>
<td>0.2</td>
<td>243.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(76.60)</td>
<td>(11.8)</td>
<td>(2817.3)</td>
<td>(0.3)</td>
<td>(114.6)</td>
<td></td>
</tr>
<tr>
<td>Room 1</td>
<td>128</td>
<td>40</td>
<td>351.95</td>
<td>78.6</td>
<td>21198.9</td>
<td>0.8</td>
<td>108.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(245.70)</td>
<td>(39.8)</td>
<td>(12505.7)</td>
<td>(1.2)</td>
<td>(55.8)</td>
<td></td>
</tr>
<tr>
<td>Room 2</td>
<td>128</td>
<td>40</td>
<td>375.45</td>
<td>72.7</td>
<td>20965.0</td>
<td>0.8</td>
<td>145.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(301.4)</td>
<td>(34.4)</td>
<td>(12073.2)</td>
<td>(1.2)</td>
<td>(74.9)</td>
<td></td>
</tr>
<tr>
<td>Farrowing Room Average</td>
<td></td>
<td></td>
<td>363.70</td>
<td>75.65</td>
<td>21081.91</td>
<td>0.80</td>
<td>126.66</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(273.55)</td>
<td>(37.12)</td>
<td>(12289.44)</td>
<td>(1.19)</td>
<td>(65.32)</td>
<td></td>
</tr>
</tbody>
</table>
Figure 5 shows emission rates from the external manure storage as measured by the dynamic flux chamber at an air exchange rate of 30 air changes per hour (ACH). The emissions rates were correlated to the average daily ambient temperature, which allowed the flux values to be extrapolated for the entire monitoring period. Table 2 shows the average flux rates from the manure surface using the best fit lines from Figure 5 and the average daily ambient temperatures in g/hr-AU. This rate can then be converted to an emission rate on a per AU basis for easier comparison to the monitored farrowing rooms.

![Figure 5. Average emission rates for (a) ammonia, (b) carbon dioxide, (c) nitrous oxide, and (d) methane from external manure storage measured with dynamic flux chamber at 30 air changes per hour.](image)

<table>
<thead>
<tr>
<th>Emission Rate Unit</th>
<th>NH$_3$</th>
<th>CO$_2$</th>
<th>N$_2$O</th>
<th>CH$_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>g/m$^2$-hr</td>
<td>0.0148</td>
<td>2.96</td>
<td>0.00243</td>
<td>1.87</td>
</tr>
<tr>
<td>(0.0127)</td>
<td>(2.54)</td>
<td>(0.0021)</td>
<td>(1.64)</td>
<td></td>
</tr>
<tr>
<td>g/d-AU</td>
<td>0.839</td>
<td>167.2</td>
<td>0.137</td>
<td>105.7</td>
</tr>
<tr>
<td>(0.718)</td>
<td>(143.3)</td>
<td>(0.118)</td>
<td>(92.68)</td>
<td></td>
</tr>
</tbody>
</table>
Zhu et al. (2000) measured NH$_3$ emissions from several swine facilities in Minnesota, including a deep-pit gestation and deep-pit farrowing building. The gestation building had an emission rate of 0.007 to 0.014 g/h-m$^2$, which when scaled to Barns 1 and 2 gave a range of 0.757 to 1.516 kg/d-barn. This is far below the measured 20.5 and 24.2 kg/d-barn from Barns 1 and 2. For the farrowing barns, Zhu et al. reported a range of 0.01 to 0.18 g/h-m$^2$, which would scale to 0.362 to 0.931 kg/d-room. This was again lower than the measured 1.5 and 1.4 kg/d-room for Rooms 1 and 2. Zhang et al. (2007) measured GHG emissions from two mechanically ventilated farrowing farms. The farrowing barns followed the same 3-week pit-flushing period as used for Rooms 1 and 2. Emission rates of CH$_4$ ranged from 73 to 351 g/d-AU, encompassing the measured emission rates of 108 and 145 g/d-AU of our current study. Zhang et al. also reported CO$_2$ emission rates of 16,588 and 11,576 g/d-AU, which were lower than the measured 21,199 and 20,965 g/d-AU emission rates in the current study. Zhang et al. did not measure any significant N$_2$O emissions, while the emissions from Rooms 1 and 2 averaged 0.8 and 0.8 g/d-AU.

As discussed previously, this study's NH$_3$, CO$_2$, and N$_2$O emissions were higher than literature values for comparable systems. One major difference between this study and previous studies is the sampling intervals used for both gas concentrations and ventilation rates. Zhang et al. (2007) collected one air sample per farrowing room per day for 19 different dates from September to October 2003 and from June to September 2004. At the time of each air sample, the ventilation rate was measured for each running fan using a hot-wire anemometer. Zhu et al. (2000) collected air samples every two hours for a single 12-hour period. Ventilation rate was estimated by measuring static pressure difference across each running fan and referring to fan rating tables. Neither of these studies accounted for both seasonal and diurnal variations in emission rates. The more frequent sampling used in the current study at each location (every 16 min) and constant monitoring of building and environment conditions (fan status, static pressure, temperature, etc.) is expected to better capture the emission dynamics and thus give a more accurate estimation of the daily emission rate.

**Conclusion**

The results of this study to date indicate that gaseous emission rates from the Midwest swine breeding, gestation and farrowing facility are possibly higher than the current literature values in all cases except for CH$_4$ emissions from the farrowing rooms. The higher emission rates are likely due to this facility being a deep-pit system for Barns 1 (breeding and early gestation) and 2 (late gestation) and the nearly continuous sampling employed in this study as compared to the intermittent sampling used in the literature studies. The project has been extended for an additional year of monitoring with data collection continuing through early spring of 2013.

**Acknowledgements**

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References


