Air Emissions from Swine Operations

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The conversion efficiency of N in animal production may range from 20 to 40% (Rotz, 2004).
Air emissions from animal production

- Odor
- H₂S
- PM
- VOC
- NH₃
- N₂O
- CH₄

Local
Regional
Global
Regulating air emissions from animal operations

Emergency Planning and Community Right-to-Know Act (EPCRA)

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

Operations that exceed 100 lb/day \( \text{H}_2\text{S} \) or \( \text{NH}_3 \) emissions are required to report

  - Facilities are not required to report GHG when annual average swine population below 34,100 head
Emission measurements

Air emissions from individual farm can vary a lot depending on many factors

Direct measurements of emissions from each individual farm are expensive and difficult

The National Air Emissions Monitoring Study (NAEMS)

- Under the Air Consent Agreement with 2,600 participating AFOs
- 24 sites in 9 states over a 2-yr period (2007-2009)
  (11 swine sites)
Air Emission Estimation Methodologies

• The purpose of the NAEMS study was to gather emissions data that would be used by the EPA to develop emissions-estimating methodologies (EEMs), which can be used by farm to estimate daily and annual emissions for use in determining their regulatory responsibilities.

• EPA has drafted NH$_3$ EEMs for lagoons, and is working on H$_2$S.
Emissions of NH$_3$, H$_2$S, PM$_{10}$, VOC from swine buildings

<table>
<thead>
<tr>
<th></th>
<th>Emission rates (lb/yr-head)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NH$_3$</td>
</tr>
<tr>
<td><strong>Sow gestation</strong></td>
<td>5.2-23.7</td>
</tr>
<tr>
<td><strong>Farrow</strong></td>
<td>1.5-8.0</td>
</tr>
<tr>
<td><strong>Finishing</strong></td>
<td>5.4-6.8</td>
</tr>
</tbody>
</table>

Data was adapted from the NAEMS report (2007-2009).
The farm sizes that may trigger the need for a farm to report under EPCRA (based on NH$_3$ or H$_2$S emission threshold: 100 lb/day)

<p>| | |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td><strong>Sow gestation</strong></td>
<td>1,500-7,000 head</td>
</tr>
<tr>
<td><strong>Farrow</strong></td>
<td>4,500-24,000 head</td>
</tr>
<tr>
<td><strong>Finishing</strong></td>
<td>5,400-6,800 head</td>
</tr>
</tbody>
</table>

(Only building emissions were accounted)
Meta-analysis:
Quantitative statistical analysis of a large collection of results from various independent studies for the purpose of integrating the findings.
• Overall average
• Variances across studies
Meta-Analysis of GHG Emissions from Swine Operations  
(NPB Project #10-104)

<table>
<thead>
<tr>
<th>Emission source</th>
<th>Number of studies in North America (World)</th>
<th>Author, year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swine building</td>
<td>12 (35)</td>
<td>Ball and Mohn, 2003; Desutter and Ham, 2005; Kai et al., 2006; Lague et al., 2003; Li et al., 2011; Ni et al., 2008; Pepple et al., 2010; Powers et al., 2008; Sharpe and Harper, 2001; Zahn et al., 2001; Zhang, et al., 2007; Unpublished study at MSU.</td>
</tr>
<tr>
<td>Manure storage facilities</td>
<td>16 (21)</td>
<td>Clark et al., 2005; Desutter and Ham, 2005; Hamilton et al., 2005; Harper et al., 2000; Harper et al., 2004; Kaharabata et al., 1998; Lague et al., 2005; Masse et al., 2003; Park et al. 2006; Park et al. 2010; Pelletier et al., 2004; Sharpe and Harper, 1999; Sharper et al., 2002; Shores et al., 2005; Zahn et al., 2001; Zhang et al., 2007.</td>
</tr>
<tr>
<td>Manure land application</td>
<td>16 (43)</td>
<td>Bender and Wood, 2007; Chan and Parkin, 2001; Chantigny et al., 2001; Chantigny et al., 2007; Chantigny et al., 2010; Hernandez-Ramirez et al., 2009; Jarecki and Lal, 2006; Jarecki et al., 2008; Jarecki et al., 2009; Mkhabela et al., 2009; Parkin et al., 2006; Rochette et al., 2004; Sharpe and Harper, 1997; Sharpe and Harper, 2002; Sistani et al., 2010; Sullivan et al., 2005.</td>
</tr>
<tr>
<td>Emission source</td>
<td>Mean emission rates in North American studies</td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>-----------------------------------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CH$_4$</td>
<td>N$_2$O</td>
</tr>
<tr>
<td>Swine building (kg yr$^{-1}$ hd$^{-1}$)</td>
<td>8.4±11.0</td>
<td>0.01±0.01</td>
</tr>
<tr>
<td>Manure storage facilities (kg yr$^{-1}$ hd$^{-1}$)</td>
<td>17.5±19.5</td>
<td>0.01±0.03</td>
</tr>
<tr>
<td>Manure land application (kg ha$^{-1}$)</td>
<td>3.5±7.7</td>
<td>5.3±4.5</td>
</tr>
</tbody>
</table>
Total GHG Emissions in CO$_2$ Equivalent Unit
\[(\text{CH}_4 \times 25 + \text{N}_2\text{O} \times 298)\]

- CH$_4$: 651 kg CO$_2$-eq yr$^{-1}$ hd$^{-1}$
- N$_2$O: 61 kg CO$_2$-eq yr$^{-1}$ hd$^{-1}$

712 kg CO$_2$-eq yr$^{-1}$ hd$^{-1}$

Swine building: 67%
Manure storage facilities: 32%
Manure land application: 90%

9 kg CO$_2$-eq per gallon of gasoline

(Source: M. L. Walser, 2010)
Relative difference between measured and IPCC estimated CH₄ emissions.

Average PRD -16.0%
Methane conversion factor for lagoons

![Graph showing methane conversion factor vs. average temperature (°C)]

- **IPCC values**
- **Estimated from measurements**

- The graph plots the methane conversion factor on the y-axis against the average temperature (°C) on the x-axis.
- The IPCC values are represented by orange circles, while the estimated values from measurements are shown as blue triangles.

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**Average temperature (°C)**

- 5
- 10
- 15
- 20
- 25
- 30
- 35

**Methane conversion factor**

- 0.0
- 0.2
- 0.4
- 0.6
- 0.8
- 1.0
N$_2$O emission factors in Swine building

Average value 0.06%

IPCC value 0.2%

Summary of swine buildings (95% CI)
Lague et al., 2003
Zhang, et al., 2007
Li et al., 2011
Pepple et al., 2010

Summary of lagoons (95% CI)
Harper et al., 2000
Harper et al., 2004

Summary of slurry storage facilities (95% CI)
Lague et al., 2005
Park et al. 2006
Zhang et al., 2007

Overall (95% CI)
N$_2$O emission factors in Manure land application

- Average value: 1.4%
- IPCC value: 1.0%

<table>
<thead>
<tr>
<th>Study</th>
<th>N$_2$O Emission Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharpe and Harper, 2002</td>
<td>1.5%</td>
</tr>
<tr>
<td>Rochette et al., 2004</td>
<td>1.2%</td>
</tr>
<tr>
<td>Sullivan et al., 2005</td>
<td>1.1%</td>
</tr>
<tr>
<td>Parkin et al., 2006</td>
<td>1.4%</td>
</tr>
<tr>
<td>Bender and Wood, 2007</td>
<td>1.3%</td>
</tr>
<tr>
<td>Chantigny et al., 2007</td>
<td>1.2%</td>
</tr>
<tr>
<td>Jarecki et al., 2008</td>
<td>1.1%</td>
</tr>
<tr>
<td>Hernandez-Ramirez et al., 2009</td>
<td>1.3%</td>
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<td>1.2%</td>
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<tr>
<td>Chantigny et al., 2010</td>
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</tr>
<tr>
<td>Sistani et al., 2010</td>
<td>1.2%</td>
</tr>
<tr>
<td>Overall (95% CI)</td>
<td>1.4%</td>
</tr>
</tbody>
</table>
Cause of variation in GHG emissions

Swine facilities
- Different Manure Handling Systems
- Manure Removal Frequency
- Temperature
- Stage of production
- Geographic region

Manure land application
- Rainfall event
- Soil temperature
- Soil properties (moisture, texture, organic matter content)
- Manure application time
- Manure application method
- Manure treatment
Meta-Analysis of $\text{H}_2\text{S}$, $\text{NH}_3$, VOC, $\text{PM}_{10}$ and $\text{PM}_{2.5}$ Emissions from Swine Productions in North America (NPB Project #12-022)

- Collect currently available measured emission data
- Analyze the uncertainty associated with the data
- Interpret the implication of the data
- Identify the research gaps

Over 145 papers have been reviewed ... ...
## Mitigation strategies
(Combination of BMPs and engineered solutions)

<table>
<thead>
<tr>
<th>Strategies ready for producer implementation</th>
<th>Strategies need refinement</th>
<th>Strategies need further evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Frequent manure removal</td>
<td>• Diet strategies</td>
<td>• Vegetative buffer (Shelterbelts)</td>
</tr>
<tr>
<td>• Manure storage covers</td>
<td>• Oil sprinkling</td>
<td>• UV/TiO$_2$</td>
</tr>
<tr>
<td></td>
<td>• Digester</td>
<td>• Urine/feces segregation</td>
</tr>
<tr>
<td></td>
<td>• Exhaust air treatment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(biofilters, wet scrubbing, etc.)</td>
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</table>
Acknowledgements: National Pork Board

THANK YOU!

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