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- Team
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Relevance

- Air contaminants in swine CAFO
  - Ammonia (NH₃) – manure pits, urine
  - Hydrogen sulfide (H₂S) – manure pits
  - Dust (respirable, inhalable) – food, animal dander, manure
  - Endotoxin (on dust) – animal dander, manure
  - Carbon monoxide (CO) – heaters
  - Carbon dioxide (CO₂) – heaters, swine respiration
- Workers in swine CAFO exhibit adverse health outcomes
  - Declines in lung function (FEV1 dose-dependent)
  - Increased prevalence of respiratory symptoms (chronic cough, phlegm)
  - Increased prevalence and amount of inflammation (bronchial lavage)
- Clear need to reduce exposures to these workers

Objective

- Can we improve air quality in CAFO to improve worker health?
- Investigate the feasibility of controlling contaminants inside swine farrowing CAFO in winter (Midwest)
  - Use control equipment to reduce concentrations: dust
  - Recirculate treated air: recover heat
- Deploy intervention at test site
  - Dec. 2013 – Feb. 2014 (Year 1)
  - Dec. 2014 – Feb. 2015 (Year 2)
- Assess:
  - Improvements in air quality
  - Risk of increasing gas concentrations when removing dust
  - Distribution of contaminants with new vent system
  - Variability of contaminants by “shift”
Big Picture

• Simulations to optimize
  – Flow rate
  – Fresh air dilution
  – Cost

• Field testing
  – Year 1 (2013-14): Filter as APC
  – Year 2 (2014-15): Cyclone as APC

This presentation will focus on field setup and findings from Yr 1 and 2 (preliminary).
Methods - Intervention

Test Site: Kirkwood’s Mansfield Swine Research Center, Cedar Rapids, IA

19 sow capacity

Remove Air → Treat Air → Return Air to Barn

Air removed from “Head Aisles”
Height = 0.635 m = top of crate
Methods - Intervention

Remove Air → **Treat Air** → Return Air to Barn

Yr 1: Shaker dust collector (SDC-140-3, United Air Specialists) 1000 cfm

Yr 2: Cyclone (Donaldson Model 16) 1000 cfm
Methods - Intervention

Remove Air → Treat Air → **Return Air to Barn**

10" Polyethylene ducts (Air Distribution Concepts)
8 rows of 0.25" holes (2" centers, 1" between rows)

Methods - Monitoring

- Deploy monitors at stations A – F: 1.5 m above floor
Methods - Monitoring

• Deploy monitors at stations A – F: 1.5 m above floor
  – Not shown: VelociCalc (temperature, humidity)

Field Differences:
Yr 1: Problems with VelociCalc at “F” ... limited NH₃
Yr 2: Deployed ToxiRae NH₃ at A/C/E

Methods - Monitoring

• Deploy monitors at stations A – F: 1.5 m above floor
  – Pre- and post-calibrate, in lab
  – Pre- and post-colocation of direct-reading equipment, in barn
  – Start 8 AM, finish 9 AM following day

• Other information
  – Outdoor temperatures
  – Sow and pig count
  – Heater cycling observations (%time on vs off)

• Deploy Dec – Feb:
  – 2013-14: 18 days (7 off, 11 on)
  – 2014-15: 19 days (7 off, 12 on)
Methods – Data Analysis

• Did concentrations exceed limits?
  – OEL from ACGIH TLVs
  – Industry Recommendations
    (Donham et al., 1989, British Journal of Industrial Medicine)

<table>
<thead>
<tr>
<th>Threshold</th>
<th>Inhalable Dust, mg/m³</th>
<th>Respirable Dust, mg/m³</th>
<th>NH₃*, ppm</th>
<th>CO, ppm</th>
<th>CO₂, ppm</th>
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</thead>
<tbody>
<tr>
<td>OEL</td>
<td>10</td>
<td>3</td>
<td>25</td>
<td>25</td>
<td>5000</td>
</tr>
<tr>
<td>50% OEL</td>
<td>5</td>
<td>1.5</td>
<td>12.5</td>
<td>12.5</td>
<td>2500</td>
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<tr>
<td>10% OEL</td>
<td>1</td>
<td>0.3</td>
<td>2.5</td>
<td>2.5</td>
<td>500</td>
</tr>
<tr>
<td>Industry</td>
<td>2.8</td>
<td>0.23</td>
<td>7</td>
<td>-</td>
<td>1540</td>
</tr>
</tbody>
</table>

Recommended

*NH₃ concentration estimates were also compared to STEL = 35 ppm

Methods – Data Analysis

• Normality Tests
• Tested whether the new system:
  – REDUCED dust
  – Increased gas concentrations
  – Caused spatial or shift differences

  YES = ☑
  NO = ☐

  T-test
  LS Multiple Comparison (Tukey-Kramer) and Non-parametric comparison (Kruskal-Wallis)

• Can we relate concentrations to barn parameters?

Multiple linear regression, backward elimination

Today, we will simply focus on these two
Results: Filtration Unit (Yr. 1)

Year 1: Filtration Unit

- Inhalable dust: 1.01 → 0.68 mg/m³ (32% reduction)
- Respirable dust: 0.20 → 0.12 mg/m³ (40% reduction)

Dust Reduced? YES = 😊

Control device selected to control dust – not a gas control

• H₂S, CO: << OELs throughout study
• CO₂:
• NH₃:
Results: Filtration Unit (Yr. 1)

Year 1: Filtration Unit

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- Respirable dust: 0.20 → 0.12 mg/m³ (40% reduction)
- H₂S, CO: << OELs throughout study
- CO₂: All days exceeded 1540 ppm
  - 44% exceeded 50% OEL
  - CO₂ unaffected by APC status
- NH₃: One OEL exceeded
  - 3 "off" days and 8 "on" days > 7 ppm
  - 1.6 ppm mean increase with APC on
    (p > 0.31: Wilcoxon; Non-parametric)

Control device selected to control dust – not a gas control

Dust Reduced? YES = ☺

CO₂ was a problematic...
Results: Filtration Unit (Yr. 1)

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    \((p > 0.31: \text{Wilcoxon; Non-parametric})\)

Dust Reduced?

Did gas concentration increased with system on?

Results: Cyclone/Heater (Yr. 2)

Year 2: Cyclone Unit

- Inhalable dust: 0.85 → 0.59 mg/m³ (t-test \(p=0.004\)) (30% reduction)
- Respirable dust: 0.11 → 0.09 mg/m³ (t-test \(p=0.002\)) (19% reduction)
Results: Cyclone/Heater (Yr. 2)

Year 2: New Vented Heaters

• CO₂:
  – Mean Yr 1: 2480 ppm (SD = 330 ppm)
  – Mean Yr 2: 1401 ppm (SD = 330 ppm)
  
Significant (ANOVA, p < 0.001) and Substantial (43%) reduction with new vented heaters.

Discussion

• The test site did not have particularly dusty environments
  – *Inhalable Dust* reductions similar between devices (30 – 32%)
  – *Respirable Dust* removed better with filtration (40%) than cyclone (19%)
  – The ventilation system did NOT increase concentrations of other gases
  – Proof of concept for livestock producers

• Practical issues
  – No maintenance needed over each entire season
  – Max Pressure (225 Pa) well under unit capacity (1000 Pa)
    • Should last >> 1 season with at these concentrations
  – Cyclone system was noticeably louder than filtration
    • 81 to 83 dBA with cyclone on
Future Work

• Assess long-term performance of new heater
  – Corrosive environment is a concern
  – Assess piglet survivability effects of reduced CO₂

• Obtain feedback from livestock producers
  – Likelihood to adopt?
  – Identify and address barriers
  – Deploy unit(s) long term in producer buildings to demonstrate effectiveness and costs of deploying unit
  – Work with builders to consider addition of system in new buildings.

Questions?