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Controlling Exposures in CAFO: An Engineering Approach

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June 3, 2015 | RT 235 | 1:00 – 4:30 PM

RT 235

Acknowledgements

- CDC/NIOSH U54 OH007548
  - Great Plains Center for Agricultural Health
- Kirkwood's Mansfield Swine Research Center
  - Rich Rourke, students
- Team
  - Ralph Altmaier, Rich Gassman, Sam Jones, Anthony Yang, Changjie Cai, Jae Hong Park, Tom Peters

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Relevance

- Air contaminants in swine CAFO
  - Ammonia (NH_3) – manure pits, urine
  - Hydrogen sulfide (H_2S) – manure pits
  - Dust (respirable, inhalable) – food, animal dander, manure
  - Endotoxin (on dust) – animal dander, manure
  - Carbon monoxide (CO) – heaters
  - Carbon dioxide (CO_2) – 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

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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"

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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
  - Year 2 (2014-15): "Heater Intervention"

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Big Picture

- Simulations to optimize
  - Flow rate
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  - Year 2 (2014-15): Cyclone as APC
  - Year 2 (2014-15): "Heater Intervention"

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

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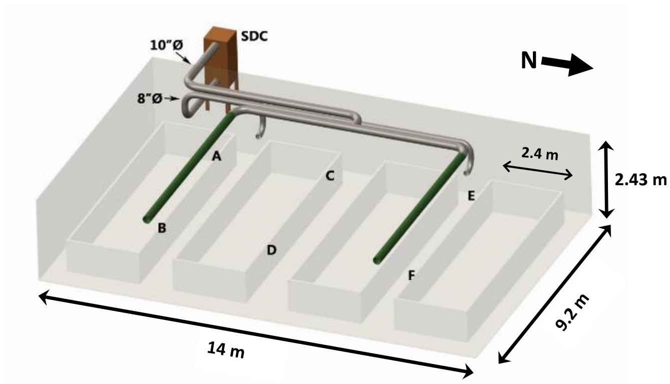
Methods - Intervention

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

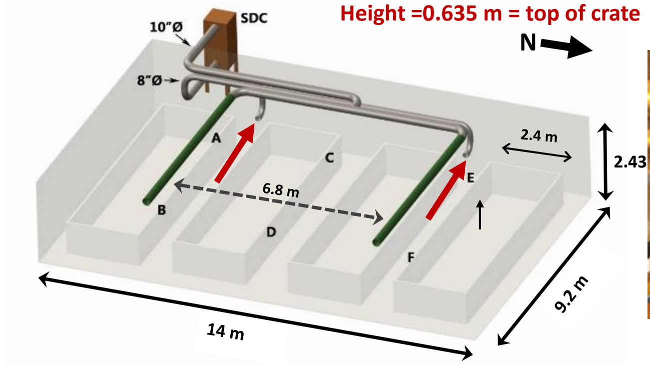
19 sow capacity



Methods - Intervention

Remove Air → Treat Air → Return Air to Barn

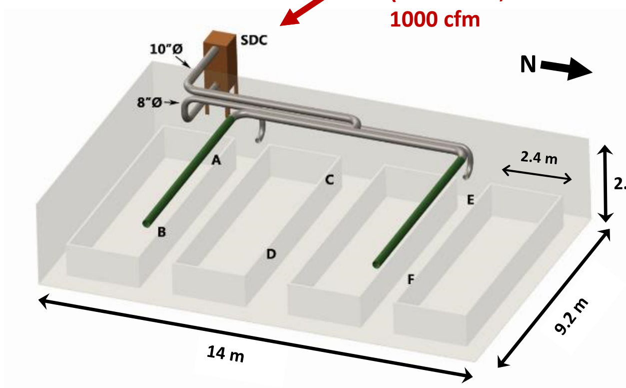
Air removed from "Head Aisles"
Height =0.635 m = top of crate

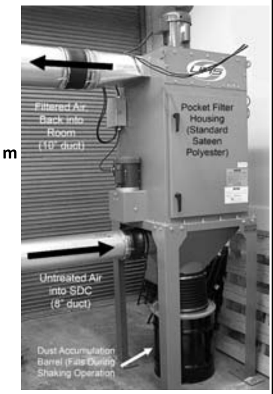


Methods - Intervention

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

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





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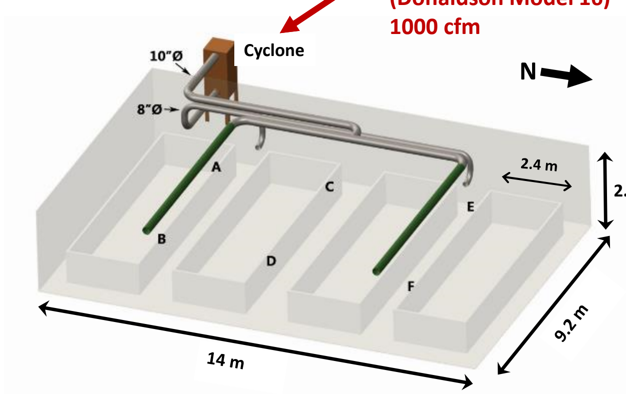
Methods - Intervention

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

Yr 2: Cyclone (Donaldson Model 16) 1000 cfm



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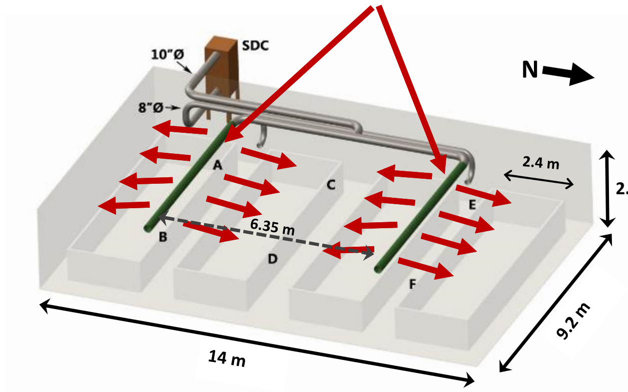
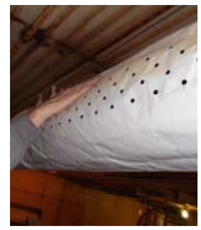
Methods - Intervention

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

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





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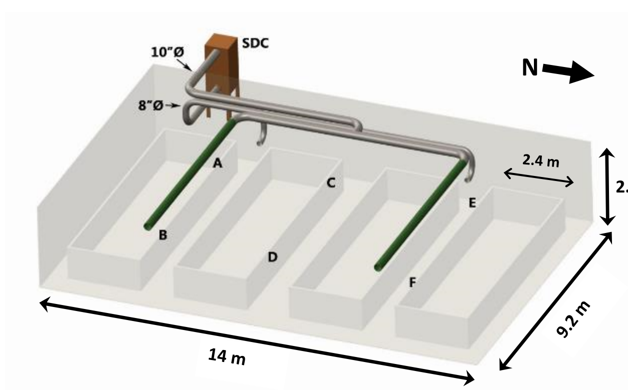
Methods - Monitoring

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



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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 NH_3
Yr 2: Deployed ToxiRae NH_3 at A/C/E

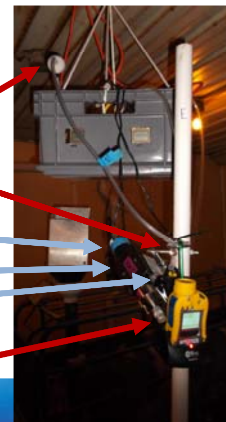
VRae (NH_3, H_2S, CO, O_2, LEL)

BGI GK2.69 Cyclone (4.2 Lpm, respirable dust)

pDR (4.2 Lpm, respirable dust)

IOM (2.0 Lpm, inhalable dust)

ToxiRae (CO_2)



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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)

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Methods – Data Analysis

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

Threshold	Inhalable Dust, mg/m³	Respirable Dust, mg/m³	NH_3*, ppm	CO, ppm	CO_2, ppm
OEL	10	3	25	25	5000
50% OEL	5	1.5	12.5	12.5	2500
10% OEL	1	0.3	2.5	2.5	500
Industry Recommendations	**2.8**	**0.23**	**7**	**-**	**1540**

*NH_3 concentration estimates were also compared to STEL = 35 ppm

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Methods – Data Analysis

- Normality Tests
- Tested whether the new system:
  - ***REDUCED*** dust — YES = ☺
  - ***Increased*** gas concentrations — NO = ☺
  - Caused ***spatial*** or ***shift*** differences — NO = ☺

Today, we will simply focus on these two

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

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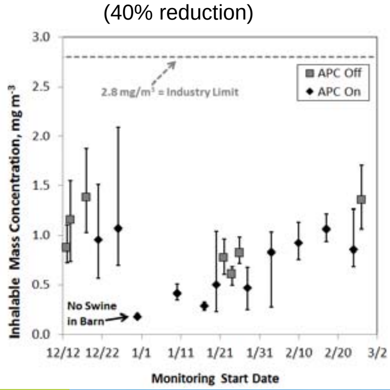
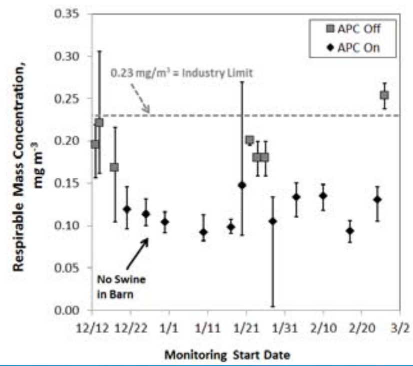
Results: Filtration Unit (Yr. 1)

Year 1: Filtration Unit

- Inhalable dust: 1.01 → 0.68 mg/m^3
  (32% reduction)
- Respirable dust: 0.20 → 0.12 mg/m^3
  (40% reduction)

Dust Reduced?
YES = ☺





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Control device selected to control dust – not a gas control

- H_2S, CO: << OELs throughout study
- CO_2:
- NH_3:

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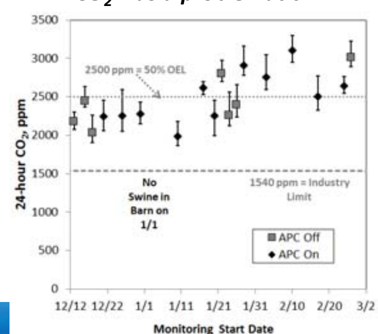
- H_2S, CO: << OELs throughout study
- CO_2: *All days* exceeded 1540 ppm
  - 44% exceeded 50%OEL
  - ***CO_2 unaffected by APC status***
- NH_3:

CO_2 was a problematic…



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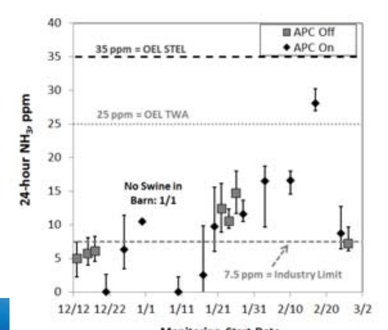
- NH_3: One OEL exceeded
  - 3 "off" days and 8 "on" days > 7 ppm
  - 1.6 ppm mean increase with APC on
    ($p > 0.31$: Wilcoxon; Non-parametric)



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  - 3 “off” days and 8 “on” days > 7 ppm
  - 1.6 ppm mean increase with APC on
    (p > 0.31: Wilcoxon; Non-parametric)

Did gas concentration increased with system on?
NO = ☺

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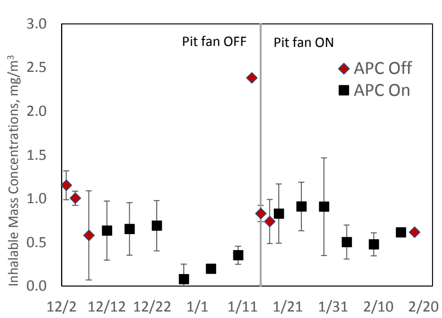
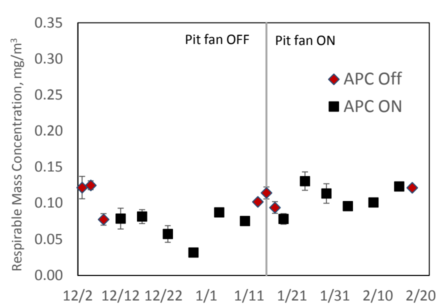
Results: Cyclone/Heater (Yr. 2)

Year 2: Cyclone Unit

- Inhalable dust: 0.85 → 0.59 mg/m^3 (t-test p=0.004)
  (30% reduction)
- Respirable dust: 0.11 → 0.09 mg/m^3 (t-test p=0.002)
  (19% reduction)

Dust Reduced?
YES … *but not really high*





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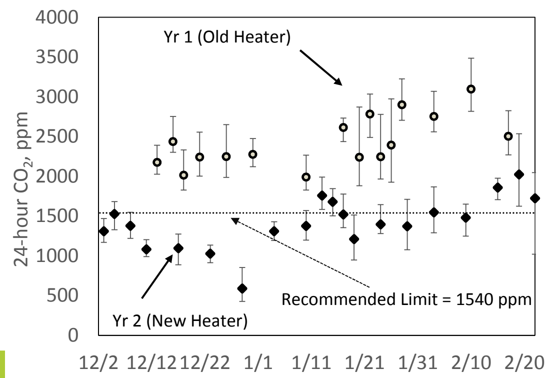
Results: Cyclone/Heater (Yr. 2)

Year 2: New Vented Heaters

- CO_2:
  - 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 CO_2
- 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?

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