Combustion Gas Reduction in a Farrowing Barn

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Background

Swine workers are at risk of developing respiratory illnesses. Health effects are associated with exposures to mixtures of dust, NH_3, and CO_2. Swine barn contaminant concentrations are highest during the wintertime when there is minimal ventilation.

Sources of CO_2 include swine respiration and gases from heaters. Poorly maintained heaters can also generate CO.

Heaters commonly used in swine barns release combustion products, including CO and CO_2, directly into animal and work spaces.

Although effective control options exist for dust, there are limited options available for gases, particularly CO_2. The question is whether using different heaters can effectively reduce the concentrations of this gas to improve the indoor air quality.

Objectives

1. Determine whether wintertime swine barn CO and CO_2 concentrations can be significantly reduced by replacing traditional in-room vented heaters with heaters that vent combustion gases outside
   - Old heater: Guardian 60 (L.B. White Co.)
   - New heater: Effinity 93 (Modine Manufacturing Co.)
2. Assess the temporal and spatial variability of contaminants in order to characterize the effect of colder time periods and heater proximity on gas concentrations.
3. Evaluate CO_2 production factors in order to compare heater performance between the two winter seasons tested.

Methods

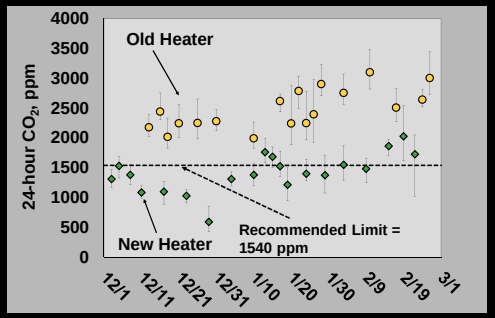
Equipment:
- ToxiRAE Pro CO_2 monitor (Rae Systems, Inc.)
- VRAE multiple gas monitor (Rae Systems, Inc.)

Collection:
- Deployed at 6 locations, breathing zone height, on three aisles, for 24 hours with 1 min. logging intervals
- Sampled over two winter seasons (December - February)
  Season 1 (2013-14) - Old heater
  Season 2 (2014-15) - New heater

Statistical Tests:
- One-way ANOVA: Compare mean combustion gas concentrations by heater type
- Tukey-Kramer: Evaluate differences in concentration across the room and by shift
- Multiple linear regression: Estimate CO_2 from production factors

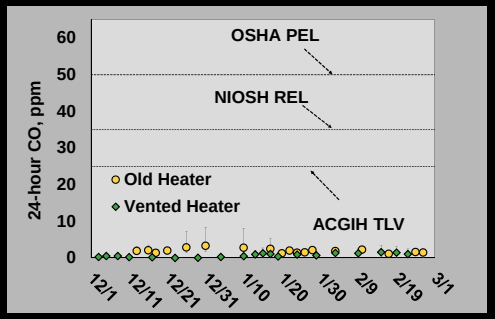
Results

Objective 1: Did heater reduce concentrations?



Error bars represent highest and lowest concentrations on each sample day across all positions

Carbon Dioxide:
- Old heater: 100% over limit
- New heater: 25% over limit
- 44% reduction ($p < 0.001$)



Error bars represent highest and lowest concentrations on each sample day across all positions

Carbon Monoxide:
- Old heater: 100% under limit
- New heater: 100% under limit
- 60% reduction ($p < 0.001$)

Objective 2: Did heaters affect concentrations by shift or location?

No difference by shift ($p > 0.61$)

Old heater was associated with spatial differences, but the new heater was not:
- CO_2 highest by open hallway door (old heater in operation) ($p < 0.001$)
- CO highest by room heater with old heater ($p < 0.001$)
- No difference by position with new heater ($p > 0.22$)

Results, continued

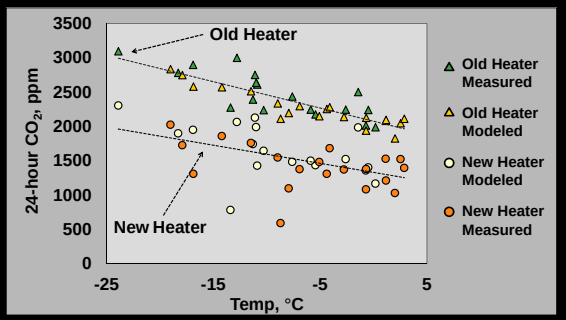
Objective 3: Examine CO_2 from pig vs heater

The following best-fit models were generated, by heater type:

Old: CO_2 (ppm) = 1719 – 36.9 T + 16.8 S + 2.8 P ($R^2 = 0.85$)

New: CO_2 (ppm) = 483 – 22.4 T + 42.7 S + 5.7 P ($R^2 = 0.75$)

where: *T = outdoor temperature (°C)*
S = number of sows
P = number of piglets



These equations were used to estimate concentrations for the year the *other* heater was actually in use (with colder temperatures and more pigs for old heater measurement winter compared to the new heater).

Comparisons between heaters using estimates allowed matching concentration by production factor. From this, CO_2 concentration differences in the room were attributed to:
- Temperature and pig count differences: ~ 200 ppm
- Heater: ~ 800 ppm

Conclusions

CO and CO_2 concentrations were significantly lower with the new heater in operation ($p < 0.001$).

While CO did not pose health risks, CO_2 was consistently over an industry recommended limit with the old heater, but only 25% of the time with the new vented heater.

These findings suggest that the simple replacement of old heaters with new heater technology can substantially improve swine barn conditions and help protect worker health.

Future Research

Future work will assess the longevity of new vented heaters in the swine barn environment.

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