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Air quality in swine-finishing barns (2000)

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AIR QUALITY IN SWINE-FINISHING BARNS [1]

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Summary

Air quality was assessed in two commercial swine-finishing barns: one naturally ventilated (NV) and one mechanically ventilated (MV). The concentrations of inhalable dust (IDC), respirable dust (RDC), airborne viable particles, carbon dioxide (CO_2), and ammonia (NH_3), as well as the air temperature and relative humidity (RH) inside the barns were monitored for 41 weeks. The two barns did not differ significantly ($P>0.05$) in IDC, RDC, and bioaerosol concentration. Overall mean levels for IDC, RDC, CO_2, and NH_3 were below the threshold limit values specified by the American Conference of Governmental Industrial Hygienists (ACGIH). However, some measurements exceeded the exposure limits suggested by previous researchers, especially during cold days. In general, the air quality in the two types of buildings was acceptable except under certain conditions (e.g., low ventilation rates during cold weather). In such case, workers and producers may need help or further training to ensure adequate air quality. In addition, under these conditions, workers should wear respiratory protective devices to minimize risk of inhalation of dust, gases, and bioaerosols.

(Key Words: Indoor Air Quality, Livestock Buildings, Airborne Contaminants.)

Introduction

In recent years, some livestock operations have become potentially hazardous to the workers and producers because of poor air quality, excessive noise levels, substandard lighting, and physical interaction of workers with animals. A growing body of literature has documented the health problems among workers in some of these operations. A survey of swine confinement workers, for example, reported the following statistics:

- at least 60% of workers surveyed had acute or subacute respiratory symptoms, including dry cough, chest tightness, and wheezing on exposure to the work environment; irritation of the nose, eyes, and throat; and stuffy nose and head.
- at least 25% of workers surveyed had periodic, acute, febrile episodes with fever, headache, muscle aches and pains, chest tightness, and cough.
- at least 25% of workers surveyed experienced chronic bronchitis, occupational (nonallergic) asthma, and noninfectious chronic sinusitis.

In addition, data from the University of Iowa have led to the following suggested exposure limits for swine confinement workers: 2.4 mg/cu m total dust, 0.23 mg/cu m respirable dust, 1500 ppm carbon dioxide (CO_2), and 7 ppm ammonia (NH_3). These limits are con-

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siderably lower than the threshold limit values (TLVs) specified by the American Conference of Governmental Industrial Hygienists (ACGIH) for industrial occupational settings, largely because of the high biological activity of the dust and the additive or synergistic reactions of the combined mixture of dust and gases in livestock buildings. Clearly, air quality in livestock confinement facilities should be controlled to prevent occupational health problems.

The main objective of the study was to assess the air quality in swine growing-finishing houses. The specific objectives were to:

- determine the concentrations of inhalable dust (IDC), respirable dust (RDC), carbon dioxide (CO_2), ammonia (NH_3), and total and respirable viable airborne microorganisms, and
- compare a naturally ventilated barn and a mechanically ventilated barn in terms of the above air quality parameters.

Procedures

The air quality in two barns for growing-finishing pigs was evaluated by measuring the IDC, RDC, airborne viable particles, CO_2, and NH_3. Sampling was done weekly for a 24 to 48 hr period for 41 weeks from July 1999 to May 2000.

The barns, one naturally ventilated (NV) and one mechanically ventilated (MV), were located on the same commercial swine farm in northeast Kansas. The choice of two test barns on a single farm ensured that the overall conditions, including outdoor environmental conditions, breed of pigs, type of feeds and supplements, feeding system, veterinary support, and husbandry practices, were similar (Table 1).

In the NV barn, air sampling was done in a room with 11 pens. In the MV barn, sampling was performed in a room with 10 pens on each side of the alley. The mean stocking densities were 0.68 and 0.65 sq m/head in the NV and MV barns, respectively. The pigs were brought into the barns when they weighed about 25 to 35 kg each and remained in the barns for about 15 to 17 weeks.

The RDC was measured with a respirable dust cyclone, which had a cut-point diameter of 4 mm at 2.2 l/min airflow rate. The IDC was measured with an IOM (Institute for Occupational Medicine) sampler at an airflow rate of 2.0 l/min. Three samplers of each type were installed in each barn. These were located at heights of 1.5 m above the floor over two pens and 1.75 m above the floor along the central alley. Flow meters and critical orifices were used to maintain the sampling airflow rate to within ±5% of the desired rate. Before and after sampling, the samplers including the collection filters were preconditioned in a container with constant humidity and temperature for 24 h before weighing to minimize the effect of humidity on the weights of the filters.

Bioaerosol sampling involved collection of airborne particulates on cellulose nitrate membrane filters and incubation for 72 hr at room temperature on plates with R2A agar as a culture medium. An open-faced filter holder loaded with a 47-mm membrane filter and a respirable dust cyclone with a 37-mm filter were used for sampling total viable particles and respirable viable particles, respectively. Sampling was done at an airflow rate of 2.0 l/min for 3 min. After incubation, the colony-forming units (CFUs) were counted. The colonies on each plate also were categorized based on appearance, i.e., color, surface form, size, and surface texture, and then identified by standard microbiological techniques.

Carbon dioxide concentration, NH_3 concentration, air temperature, and relative humidity (RH) were measured near the dust-sampling location along the alley. In the NV barn, CO_2 and NH_3 concentrations as well as the temperature were recorded every 30 minutes. The CO_2 concentration was monitored with a nondispersive infrared analyzer. The NH_3 concentration was measured with an NH_3 monitor. Temperature was monitored at each sampling point with type T thermocouples. In the MV barn, CO_2 and NH_3

concentrations were measured with detector tubes at the start and the end of each sampling period. The RH was determined in both barns with a direct reading thermo-hygrometer.

Results and Discussion

The ranges of air temperatures and RHs inside the two NV barns are shown in Table 1. The mean air temperature and RH were 21.5°C and 42%, respectively, in the NV barn and 24.2°C and 43%, respectively, in the MV barn. The air temperatures and RHs outside the barns were obtained from the nearest weather station about 20 km away. The outside air temperatures for the duration of the study ranged from –3.9 to 31.9°C with a mean of 13.5° C; the outside relative humidities ranged from negligible (<1%) during extremely cold days to 83 % with a mean of 33 %.

The overall IDC and RDC in the NV barn were 2.19 mg/m^3 and 0.10 mg/m^3, respectively. These were not significantly (P>0.05) different from the corresponding values obtained in the MV barn, which were 2.13 mg/cu m and 0.11 mg/cu m, respectively. Within the NV barn, the combined mean IDC for the two pens (2.15 mg/cu m) was not significantly (P>0.05) different from the mean IDC along the alley (2.26 mg/cu m) (Table 2). Similarly, no significant (P>0.05) difference was observed in the MV barn; mean IDCs were 2.16 mg/cu m and 2.08 mg/cu m for the pens and the alley, respectively.

The RDCs were lower than the TLV of 3.0 mg/cu m for respirable particulates specified by ACGIH; however, they exceeded the recommended exposure limit of 0.23 mg/cu m for RDC for one of 30 measurements in the NV barn and for three of 36 measurements in the MV barn. The IDCs were also lower than the TLV of 10 mg/cu m for total dust specified by ACGIH. They were higher than the recommended exposure limit of 2.4 mg/cu m for nine of 30 measurements in the NV barn and for 11 of 36 measurements in the MV barn. In general, the measured values exceeded the corresponding recommended exposure limits during the period between November and March, when the outside air temperature was about 12°C or less. During this period, both curtains in the NV barn were closed most of the time to conserve heat. In the MV barn, one inlet was closed either partially or totally and most of the time, only one exhaust fan was operated at short intervals. The ventilation rate was lower during this period compared to the warm months (April to October); consequently, the airborne dust concentrations were high.

The measured RDC values (0.10 and 0.11 mg/cu m) were lower than those reported in the literature for growing-finishing swine houses. Mean RDCs of 0.18 and 0.19 mg/cu m in naturally and fan-ventilated barns, respectively, were reported in one study. Another study observed a mean RDC of 0.92 mg/cu m in four finishing barns in Iowa, although their measurements were taken during cold months only. The measured IDCs were also lower or comparable to those in a number of studies. In one study in Iowa, mean total dust concentration was 15.3 mg/cu m (SD = 1.4) in four barns during cold months, whereas a survey of farms in northern Europe showed a mean IDC of 2.19 mg/cu m (range = 1.87 to 2.76 mg/cu m).

The mean concentration of total CFUs inside the NV barn (6.0×10^4 CFU/cu m) was not significantly (P>0.05) different from that in the MV barn (1.7×10^4 CFU/cu m) (Table 3). Both values were significantly (P<0.05) higher than the corresponding mean concentrations outside each barn (NV = 1.7×10^4, MV = 2.0×10^4 CFU/cu m). The two barns also did not show any significant (P>0.05) difference in mean concentrations of the viable respirable particles (NV = 9.8×10^3, MV = 1.0×10^4 CFU/cu m). These values were about 2 to 3 times higher than the corresponding concentrations outside the barns (NV = 4.5×10^3, MV = 3.8×10^3 CFU/cu m). The above values were within the range of published CFU concentrations. A survey of 28 swine confinement units in Iowa showed a mean of 1.4×10^6 CFU/cu m for total viable microorganisms. Another study observed means of 4.2×10^5 CFU/cu m and 1.6×10^5 CFU/cu m for the total and respirable bioaerosol concentrations, respectively.

Preliminary identification of the persistent strains of microorganisms indicated that the viable particles could be various species of the following genera: *Pseudomonas, Staphylococcus, Listeria, Escherichia, Klebsiella, Citrobacter, Lactobacillus, Sarcina*, and *Penicillium*. The relative abundance of these species changed with time. Further identification of the microorganisms is being pursued, particularly for the genera with species known to be potentially pathogenic to humans and animals.

The CO_2 concentrations ranged from 378 to 2095 ppm with a mean of 1106 ppm (SD = 421 ppm) in the NV barn and from 550 to 2225 ppm with a mean of 1417 ppm (SD = 538 ppm) in the MV barn. All measured values were below the TLV of 5000 ppm set by ACGIH. However, they exceeded the 1500 ppm CO_2 maximum level recommended by previous researchers in four out of 21 measurements in the NV barn and 13 out of 26 measurements in the MV barn .

The NH_3 concentrations in the NV barn ranged from negligible (<1 ppm) during extremely windy days to 17.1 ppm during cold days when the side curtains were closed; the overall mean was 6.6 ppm (SD = 4.4 ppm). In the MV barn, they ranged from 5.2 to 24.7 ppm with a mean of 11.9 ppm (SD = 5.9 ppm). The measured NH_3 levels were below the TLV of 25 ppm set by ACGIH; however, they exceeded the recommended NH_3 exposure limit of 7 ppm for humans seven times in the NV barn and 13 times in the MV barn out of 19 measurements in both barns. For both CO_2 and NH_3, the measured values exceeded the proposed exposure limits during approximately the same period that the exposure limit for inhalable dust was exceeded.

The measured CO_2 and NH_3 concentrations were comparable to published values for swine confinement units. One study reported means of 9 ppm for NH_3 (SD = 5.2, range = 3.3 to 25 ppm) and 1740 ppm for CO_2 (SD = 851, range = 900 to 4500 ppm) from 28 swine barns in Iowa. A survey of 15 fattening barns in northern Europe showed CO_2 concentrations ranging from 455 to 2355 ppm with a mean of 1400 ppm (SD = 703). Mean NH_3 concentrations in those ranged from 12.1 to 18.2 ppm with an overall mean of 14.8 ppm.

The observations and the results of this study indicate that for these two specific barns and perhaps in others with similar design features, implementing a combination of measures in relation to manure management, proper ventilation, and controlling feed dust and manure gas might help improve the overall air quality. Because feed is one of the main dust sources, the use of pelleted feeds and/or covered feeder chutes could reduce the generation and concentration of dust. Thorough cleaning and sanitation of all surfaces in the barns and more frequent flushing of the manure pits could reduce the overall dustiness and the levels of gases inside the barns. The ventilation system and its components should be maintained properly to ensure adequate ventilation rates, especially during cold weather. Workers can be protected from exposure to the air contaminants with masks or respirators approved by the National Institute for Occupational Safety and Health.

Table 1. Description of the Two Commercial Swine-Finishing Barns

Features	Naturally Ventilated, NV	Mechanically Ventilated, MV
Overall dimensions, m	12 × 140	9.8 × 54
Breed of pigs	PIC Line 327 × C22 (Pig Improvement Co., Franklin, KY)	PIC Line 327 × C22 (Pig Improvement Co., Franklin, KY)
Number of rooms	5	2
Capacity per room, head	300 – 320	320 - 340
Waste system	Shallow pit, flushed twice weekly	Deep static pit, overflow drained continuously
Type of feed/Feeding system	Ground feed, Automatic self-feeders, Overhead auger delivery	Ground feed, Automatic self-feeders, Overhead auger delivery
Watering system/Location	Suckling waterer, Separate from feeder	Suckling waterer, Integrated with feeder
Environmental control	Automatic curtains, Manual ridge slot adjustment, Misting system	Automatic fan On/Off, Manual inlet slot adjustment, Misting system, Pit ventilation
Room air temperature, °C	14.2 - 33.1	17.8 - 34.3
Room RH, %	22 - 72	27 - 68

Table 2. Mean Concentrations (mg/cu m) of Inhalable and Respirable Dust in Two Swine-Finishing Barns

Dust Fraction	Sampling Location	Naturally Ventilated Barn Mean[a]	SD	Range	Mechanically Ventilated Barn Mean[b]	SD	Range
Inhalable	Pen 1	1.91	1.50	0.15 - 5.86	2.11	1.40	0.22 – 7.20
	Alley	2.26	1.87	0.14 - 7.34	2.08	1.54	0.15 - 7.43
	Pen 2	2.39	1.66	0.41 - 5.81	2.22	1.75	0.08 - 8.37
Respirable	Pen 1	0.10	0.07	0.03 - 0.34	0.11	0.06	0.03 - 0.34
	Alley	0.10	0.07	0.01 - 0.30	0.10	0.06	0.01 - 0.30
	Pen 2	0.10	0.06	0.01 - 0.28	0.12	0.08	0.01 - 0.44

[a]Number of observations = 30.
[b]Number of observations = 36.

Table 3. Mean Concentrations of Viable Particles (CFU/cu m) in Two Swine-Finishing Barns

Location	Sampler Type	Naturally Ventilated Barn Mean[a]	SD	Range	Mechanically Ventilated Barn Mean[a]	SD	Range
Inside	Total	6.0×10^4 (30)	5.6×10^4	1.2×10^2 - 2.4×10^5	6.7×10^4 (36)	3.7×10^4	1.3×10^4 - 1.4×10^5
	Respirable	9.8×10^3 (28)	9.9×10^3	5.0×10^2 - 4.5×10^4	1.0×10^4 (36)	1.1×10^4	1.6×10^3 - 6.4×10^4
Outside	Total	1.7×10^4 (26)	1.5×10^4	3.7×103 - 6.3×10^4	2.0×10^4 (34)	1.8×10^4	3.7×10^3 - 8.0×10^4
	Respirable	4.5×10^3 (26)	4.2×10^3	1.7×10^2 - 1.8×10^4	3.8×10^3 (33)	4.8×10^3	5.0×10^2 - 2.8×10^4

[a]Numbers of observations are shown in parentheses.