ENDOTOXIN, AMMONIA, AND TOTAL AND RESPIRABLE DUST IN SWINE CONFINEMENT BUILDINGS: THE EFFECT OF RECIRCULATED AIR AND RESPIRATORY PROTECTIVE MASKS

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Summary

Caretakers and pigs in dusty environments with particles and toxic gases may sustain health consequences. We studied concentrations of ammonia, endotoxin, and total and respirable dust particles in four mechanically ventilated swine nurseries and two grower facilities using an ammonia sampler, filter, and British cyclone. In two of the nursery facilities, we determined the protection offered by respiratory masks that were mounted on glass funnels with filters or British cyclones and sampled for dust. In response to the increasing summer ventilation, large, nonrespirable particle concentrations in swine building atmospheres were reduced more completely by ventilation air movement than smaller respirable particles or ammonia. Total airborne endotoxin concentrations were similar to those eliciting pulmonary reactions. Total airborne endotoxin correlated with total suspended particles rather than respirable particles. Smaller respirable fecal particles enriched in endotoxin apparently stick to larger nonrespirable particles or are agglomerated before they became airborne. Internal recirculated air partially limited the mass concentration of respirable particles in the breathing zone of swine caretakers at lower but not higher ventilation rates. Respiratory protection limited the potential total dust exposures of swine caretakers in such atmospheres (<25%, 2-tie masks; <50%, 1-tie masks of the total suspended particles). Respirable particles were reduced to <55% by 2-tie masks. Properly worn 2-tie masks protect against both large and small respirable particles in swine confinement facilities.

(Key Words: Dust, Respirable Dust, Endotoxin, Recirculated Air, Respiratory Protective Masks.)

Introduction

Energy conservation and optimal rates of pig growth are economically important to the swine industry. Clouds of pollutant gases and particles can be detrimental to producers' and pigs' health but adequate air movement can reduce the caretaker-health-related consequences of inhaling particles, particle-adsorbed endotoxins, and toxic gases. Previous research at Kansas State University and by others has established that the average concentrations of organic dust measured in swine operations exceed allowable dust levels for human exposure.

This study investigated the effects of recirculated air on concentrations of ammonia, endotoxin, and total and respirable dust particles in swine nurseries and grower facilities. We also determined the protection offered by three types of respiratory masks.

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Procedures

Ammonia, endotoxin, and total and respirable particle mass were measured in four mechanically ventilated swine nursery (designated A, B, C, and D) and two grower facilities, using an ammonia sampler, filter, and British cyclone. The fractions of total airborne endotoxin contained in small respirable particles and large non-respirable particles were calculated.

Two nursery facilities (Buildings B and D) with mechanical ventilation were selected to determine the effect of vectorial air velocity (vertical air velocity^2 + horizontal air velocity^2)$^{.5}$ and internal recirculation rate on concentration of ammonia and on total and respirable particle and endotoxin concentrations. Ammonia and dust samples were collected at three levels in each facility—distances of 3.9 to 4.6 ft, 2.5 to 3.0 ft, and .7 to 1.6 ft from the floor. Vertical and horizontal air flow velocities were measured at the ammonia and dust locations using a hot-wire anemometer. A ceiling-mounted (.7 m/s) recirculation fan (Osborne Industries) was installed in Building B to add 9.7% (1,500 CFM) to the measured capacity for air movement (7.3 m/s) (15,500 CFM) measured by the air velocity traversing method.

At the same two nursery facilities (B and D), we determined the protection achieved by wearing respiratory protective masks. To measure this protection, filters or British cyclones were mounted in glass funnels and masks were mounted on these glass funnels and sealed. Stoppers were sealed into the funnels with tubing to draw indoor air samples through the mask using a calibrated battery-powered air pump (BGI Inc, Lexington, MA). Total and respirable dust were determined and compared to samples obtained at the same level and 30 to 50 cm (12 to 20 in.) from the samples taken through the mask. Percent reductions of total and respirable dust were calculated, and averages (means) determined for each type of respiratory protective mask.

Results and Discussion

Increased ventilation in summer relative to that in winter led to marked reductions in total suspended particles and more modest reductions in respirable particles and ammonia. Significantly greater ammonia concentrations and total suspended particulates were noted in grower facilities than in nurseries. We observed higher endotoxin concentrations in small respirable fecal particles relative to those in larger, nonrespirable mixed particles of feed-feces. Greatest variations in winter were between nursery and grower facilities (small vs large pigs), whereas in spring-summer, these differences were attributed to increasing ventilation rates accompanying increasing environmental temperatures. The changes from winter to summer (temporal coefficients of variation [CV]) were twofold to sixfold larger than differences within a building (spatial CVs).

Total airborne endotoxin concentrations in facilities A, B, C, and D are shown in Table 1. No consistent differences occurred between facilities. Total airborne endotoxin concentrations were related with total suspended particles ($P \leq .01$, data not shown) and to the endotoxin in large nonrespirable particles that settle more rapidly in indoor atmospheres, but not to respirable particles. The close correlation between the large particle endotoxin and total airborne endotoxin ($P \leq .01$) and with the total suspended particles fraction ($P \leq .05$; data not shown) suggested a concentration-dependent interaction between small and large particles.

Vertical air velocity was reduced by warming inside the facility. Ammonia was reduced by high vertical and horizontal air velocity rates ($r^2 = .42$, $P \leq .05$) in nurseries during April-June at high ventilation rates.

Direct correlations occurred between increased air circulation and high ammonia (linear; $P \leq .01$; data not shown), respirable dust (logarithmic) ($P \leq .05$), and total dust ($P \leq .05$; data not shown) concentrations.

Increasing ammonia correlating to increasing airflow suggested that ammonia gas has been increasingly scoured from facility manure pits by air entering and leaving the pits. We believe that increased airflow also suspends large and small particles proportional to the air flow.

Table 2 shows total and respirable dust levels with and without fans, as well as the mass differences associated with using air recirculation at 9.7 to 31.9% of the operating facility capacity. Trends toward reduced quantity and relative amount of respirable dust concentrations ($P \leq .05$) were noted 2 to 4 ft from floor, when fans were used. These trends were most prominent at lower air ventilations (4,640 to 9,710 CFM). Reduction was inversely proportionate to facility ventilation and was negatively correlated ($P \leq .05$, $r^2 = .38$; data not shown) to respirable dust quantity and to the fraction of respirable dust ($r^2 = .67$; $P < .05$; data not shown). This suggests that controlled recirculation of air may produce cleaner indoor atmospheres, even in summer. It is important to note that the reductions in dust or ammonia were modest and worked best at lower air recirculation rates.

Table 3 shows the effect of three different types of respiratory protective masks on total and respirable dust. The 2-tie masks reduced total particle concentrations (96%) more than did 1-tie masks (77%). The 2-tie masks also reduced respirable particle concentrations by greater than 50%. The 1-tie masks afforded less protection from the small respirable particles capable of depositing in deep lung than did the 2-tie masks tested in this project. This suggests that 2-tie masks afford significant protection against large non-respirable and smaller respirable particles. Thus, appropriate respiratory protection will afford health advantages to the wearer.

Table 1. Total Suspended Particulates and Airborne Endotoxin Levels and Correlation to the Fraction of Rapidly Settling Endotoxin in Several Nursery-Grower Facilities

			Total airborne endotoxin		
Facility	Date/sample (1991)	Total suspended particulates (mg/m^3)[1]	Specific activity (ng/mg)	Quantity (ng/m^3)[2]	Large particle (%)[1,2,3]
A	Feb 04/A	135	.41	55	95
B	Mar 09/A	215	.79	171	94 ± 2(3)*
	Mar 09/B	175	.25	44	91 ± 8(3)*
	May 04/A	2.6	3.65	9.4	87 ± .4(2)*
C	Mar 11/A	85	1.19	101	86 ± 5(3)*
	Mar 11/B	34	1.25	42	82 ± .2(3)*
	May 28/A	.9	3.80	3.5	50
	May 28/B	2.3	2.90	6.7	81
D	Mar 12/A	32	11.60	373	97 ± 1(3)*
	Mar 14/A	8.8	.70	5.9	58 ± 12(3)*
	Mar 14/B	7.1	6.70	47	93 ± 3(2)*

*(N) = number of samples. [1]Correlation of percent large (rapidly settling) airborne endotoxin particles with total suspended particulates. [2]Correlation of percent large (rapidly settling) airborne endotoxin particles with total airborne endotoxin. [3]Calculated as 1–respirable endotoxin (on cyclone filters)/total airborne endotoxin.

Table 2. **The Effect of Auxiliary Fan Ventilation on Concentrations of Total and Respirable Dust (Summer Conditions)**

	Fans		Total dust			Respirable dust		
Date (1992)	Facility Ventilation[1] (CFM)	Amount Added (%)	Without fan (mg/m³	With Fan (mg/m³)	Reduction (mg/m³)	Without fan[1] (mg/m³)	With fan[1] (mg/m³)	Reduction (mg/m³)
Human breathing zone (.75-1.1 m):								
May 15-16	15,300	9.7	2.23	1.65	.58	.81	.85	-.04
June 23-24	15,300	9.7	.12[2]	1.08	-.96	.04[2]	.03[2]	.01
July 2-3	15,300	9.7	1.41	.37	1.04	≤.00[2]	≤.00[2]	.00
July 16-17	9,710	15.2	1.63	1.40	.23	.53	.07[2]	.46
July 21-22	4,640	31.9	2.02	2.35	-.32	.42	.20	.22
July 21-22	4,640	31.9	ND	ND		.20	<.00[2]	.20
July 30-31	13,900	10.6	1.85	2.34	-.49	≤.00[2]	.32	-.32
July 30-31	13,900	10.6	ND	ND		<.00	<.00	.00
Mean ± Std Error			1.54±.31	1.53±.31	.01±.30	.25±.11	.18±.10	.07±.08
Swine breathing zone								
June 23-24	15,300	9.7	ND	ND	NC[4]	1.88	.97	.91
July 2-3	15,300	9.7	ND	ND	NC	.10[2]	1.05	-.95
July 16-17	9,710	15.2	ND	ND	NC	.03[2]	.15	.12
Mean ± Std Error						.67±.61	.72±.29	-.05±.53

[1]% reduction of respirable dust = 119 - .0073 (CFM). [r^2 = .684; P<.001. Student t statistic]. Absolute reduction of respirable dust (mg/m³) = .42 - .000031 (CFM). [r^2 = .382; P<.01, Student t statistic].
[2]Weights not distinguishable from zero.
[3]ND = not determined.
[4]NC = not calculated.

Table 3. The Effect of Respiratory Protective Masks on Concentrations of Total and Respirable Dust

	Total dust			Respirable dust		
Date/ sample (1992)	Without mask (mg/m³)	With mask (mg/m³)	Reduction (%)	Without mask (mg/m³)	With mask (mg/m³)	Reduction (%)
Mask A (2-Tie):						
Feb 20/A	2.60	.08	96	ND[1]	.00	NC[2]
Feb 20/B	3.61	.11[3]	97	ND	.00[3]	NC
Feb 22/A	3.06	.00[3]	100	.17	.07[3]	60
Feb 22/B	4.25	.00[3]	100	.25	.10[3]	60
Mar 21/A	2.37	.07[3]	95	.15	.08[3]	55
Mar 21/B	4.94	.15	97	.33	.18	47
Apr 11/A	1.60	$\leq$.00[3]	100	.11	$\leq$.00[3]	100
Apr 11/B	3.14	<.00[3]	100	.23	.00[3]	100
Mean $\pm$ Std Error	3.20$\pm$.38	.05$\pm$.02[4]	98$\pm$1[5]	.21$\pm$.03	.07$\pm$.03[4]	67$\pm$14[5]
Mask B (2-Tie):						
Jul 2/A	.37	$\leq$.00[3]	100	$\leq$.00[3]	.04[3]	NC
Jul 3/A	1.41	$\leq$.00[3]	100	$\leq$.00[3]	$\leq$.00[3]	NC
Jul 21/A	2.35	.58	75	.20	$\leq$.00[3]	100
Jul 22/A	2.02	<.00	100	.42	<.00[3]	100
Jul 30/A	2.34	<.00[3]	100	.32	.17	47
Aug 1/A	1.85	<.00	100	<.00[3]	.13[3]	NC
Mean $\pm$ Std Error	1.72$\pm$.30	.10$\pm$.10[4]	94$\pm$6[5]	.31$\pm$.06	.06$\pm$.06[6]	81$\pm$19[5]
Mask C (1-Tie):						
May 15/A	1.65	.77	53	.81	.94	-16
May 16/A	2.23	.75	67	.85	.70	18
Jun 23/A	.57	$\leq$.00[3]	100	.03[3]	$\leq$.00[3]	NC
Jun 24/A	.12[3]	$\leq$.00[3]	NC	.04[3]	.13[3]	NC
Jul 16/A	1.40	$\leq$.00[3]	100	.07[3]	$\leq$.00[3]	NC
Jul 17/A	1.63	.25	85	.53	<.00	100
Mean $\pm$ Std Error	1.60$\pm$.19	.35$\pm$.17[4]	77$\pm$11[5]	.73$\pm$.10	.55$\pm$.28	25$\pm$38[5]

[1]ND = not determined.
[2]NC = not calculated.
[3]Weights not distinguishable from zero.
[4]$P < .05$; Student t statistic.
[5]Calculated as reduction = mean with mask/mean without mask $\times$ 100; calculated as reduction. Std Error = Std Error (with mask)/mean without mask $\times$ 100.
[6]$P \leq .10$; Student t statistic.