Pit ventilation in pig-housing facilities

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Lavoie, J., Marchand, G. and Gingras, G. 1997. **Pit ventilation in pig-housing facilities**. Can. Agric. Eng. **39**:317-326. Several studies have reported a high frequency of respiratory problems among workers employed at pig-housing facilities. This indicates the need for developing preventive measures such as those based on ventilation. This study was undertaken to determine the effectiveness of pit ventilation systems and evaluate their performance over time. To this end, levels of chemical and biological contaminants usually present in pig barns were compared in facilities using pit and conventional ventilation systems using standard Institut de recherche en santé et en sécurité du travail du Québec (IRSST) methods. Measurements were carried out in adjacent gestating sow stalls in the same building on the same farm. The pen size, medication, and feed administered to the animals and frequency with which manure pits and manure sluices were cleaned was the same in both groups. The pit ventilation system is capable of reducing the concentration of most contaminants emanating from manure sluices, e.g., total bacteria, ammonia, and dust, if ventilation rates are kept high enough. This is reflected in the significantly lower concentrations ($p \leq 0.05$) observed for these contaminants. With the exception of winter concentrations of carbon dioxide, chemical contaminants in the pit-exhaust facility were less than half of applicable exposure limits set by the Québec Regulation Respecting the Quality of the Work Environment (QRWE). However, the concentrations of total bacteria were comparable to those reported elsewhere for conventional facilities and the concentrations of Gram-negative bacteria in the pit ventilation system were 8 to 41 times higher than those recommended. The pit ventilation system was thus unable to ensure a healthy environment.

Plusieurs études ont identifié un pourcentage élevé de problèmes respiratoires chez les travailleurs oeuvrant dans les porcheries. Le développement de mesures préventives s'avère donc nécessaire. L'une d'entre elles est la ventilation. Dans cette étude, l'efficacité de la ventilation par extraction basse (sous le plancher) a été évaluée et les résultats obtenus des mesures des contaminants chimiques et biologiques ont été comparés avec une porcherie possédant un système de ventilation conventionnel. Les deux élevages de truies en gestation étudiées sont situés côte à côte sur la même propriété et ont le même propriétaire, la même médication, les cages de même dimension, la même nutrition et la même fréquence de vidange des rigoles et des fosses à purin. Les objectifs de cette étude sont donc de déterminer l'efficacité de la ventilation par extraction basse pour réduire les contaminants chimiques et biologiques et d'évaluer dans le temps les performances de ce système. Les contaminants chimiques et biologiques habituellement présents dans les porcheries ont été mesurés en utilisant les méthodes standards de l'IRSST. Des différences statistiquement significatives ont été mesurées pour la majorité des contaminants provenant des rigoles à purin dans la porcherie qui possède le système de ventilation par extraction basse. En conclusion, le nouveau système de ventilation fournit en général, une meilleure qualité d'air dans la porcherie. Cependant, les résultats obtenus des mesures de certains contaminants biologiques ne sont pas assez faibles pour maintenir les expositions des travailleurs sous les niveaux recommandés et assurer ainsi la présence d'un environnement sain.

INTRODUCTION

This study was undertaken to determine the effectiveness of pit ventilation systems in reducing the concentration of chemical and biological contaminants in pig-housing facilities and to evaluate their performance over time.

Intensive breeding practices (Avignon and Lafont 1985), first tried with poultry in Europe in the early 1950s, were applied to pig-housing a decade later in the USA. In Québec, swine production is the second-largest agricultural activity and employs approximately 12,000 people (Lavoie et al. 1989).

As modern animal husbandry techniques based on the use of confined or closed spaces developed, it became clear that housing facilities' ambient air contained substances which were potentially dangerous for the health of workers and animals (Crook et al. 1991). Pig-housing facilities are designed to automate pen-cleaning, manure storage, feed distribution, and medication. Unfortunately, this type of facility also exposes workers to high concentrations of microorganisms, organic dusts (dried swine feces, feed debris, etc.), and gases suspected to cause various health problems (Donham and Gustafson 1982; Rylander 1985; Donham 1986a, 1990; Donham et al. 1989; Dosman and Cockcroft 1989; Cormier et al. 1990; Cormier 1991; Zuskin et al. 1992) and there have been numerous reports of facilities in which the exposure limits for carbon monoxide, carbon dioxide, ammonia, and hydrogen sulphide have been equalled or exceeded (Donham and Popendorf 1985; Donham 1986b, 1989; Donham et al. 1989). Potential biological hazards include bacteria, fungi, and bacterial and fungal toxins (Clark et al. 1983; Attwood et al. 1987; Cormier et al. 1990; Reynolds et al. 1994). Epidemiological studies have reported increased respiratory symptoms and modifications of respiratory function among workers in poultry- and pig-housing facilities (Warren and Tse 1974; Stahuljack-Beretic et al. 1977; Petro et al. 1978; Thelin et al. 1978; Katila et al. 1981; Donham et al. 1984; Brouwer et al. 1986; Muller et al. 1986; Rylander 1986; Attwood et al. 1987; Holness et al. 1987; Lenhart et al. 1990; Crook et al. 1991; Reynolds et al. 1994).

Diseases suspected to affect swine production workers include occupational asthma, allergic alveolitis or hypersensitivity pneumonitis, occupational bronchitis, and organic dust toxic syndrome (Donham and Gustafson 1982; Harries and Cronwell 1982; Solal-Celigny et al. 1982; Haglind et al. 1984; Cormier et al. 1990; Millner et al. 1994).

A high prevalence of bronchitis, as well as asthma like

conditions, have been reported among swine production workers (Donham and Gustafson 1982; Donham 1984, 1989, 1990; Donham et al. 1984; Iversen et al. 1988). For example, Donham et al. (1977) reported that 70% of farmers suffered at least one respiratory disorder and that noisy breathing and frequent chest colds were associated with bacterial concentrations of at least 1.4 x 10^5 Colony Forming Units/m^3 of air (CFU/m^3) ($p \leq 0.05$) (Donham 1986a). Several other studies have associated cough, phlegm production, and throat, nose, and eye irritation with work in pig-housing facilities (Donham and Gustafson 1982; Donham 1984, 1986b, 1989, 1990; Donham et al. 1984; Popendorf et al. 1985; Iversen et al. 1988; Zuskin et al. 1992).

Airborne Gram-negative bacteria and components of these bacteria such as enzymes and endotoxins appear to be responsible for the greatest number of health problems in these workplaces (Clark et al. 1983; Donham 1986a, 1986b, 1989; Attwood et al. 1987; Schlenker et al. 1987; Olenchock et al. 1989; Rylander et al. 1989b; Reynolds et al. 1994). Donham (1986a), among others, has suggested that Gram-negative endotoxins may be responsible for most of the respiratory problems observed among these workers. Endotoxins are powerful pyrogens capable of causing local tissue inflammation and symptoms ranging from irritation of mucous membranes to gastro-intestinal and respiratory problems (Pernis et al. 1961; Lundholm and Rylander 1980; Rylander and Snella 1983; Clark 1984, 1987; Malmros 1990; Sigsgaard et al. 1990; Laitinen et al. 1992; Lessard 1992; Malmros et al. 1992; The Danish Working Environment Service Programme 1994; Marchand et al. 1995).

There are no standards, either Québec or international, for exposure to microorganisms and microbial toxins. However, based on the results of studies conducted in water-treatment, composting, and cotton-handling plants (Rylander et al. 1983, 1989a; Malmros 1990; Sigsgaard et al. 1990; Millner et al. 1994; Poulsen et al. 1995), guidelines of total bacteria of 10^4 CFU/m^3 of air and Gram-negative bacteria of 10^3 CFU/m^3 of air have been proposed.

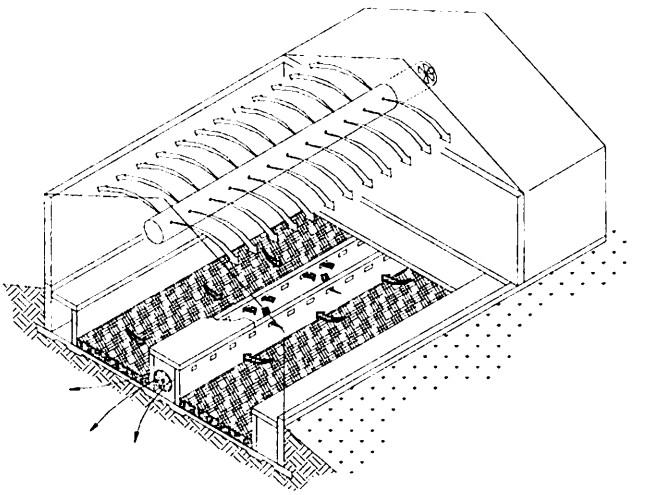
It is thus important to reduce occupational exposure to chemical and biological contaminants present in the environment of pig-housing facilities. Effective ventilation is one of the control measures that has often been suggested (Harry 1978; Barber 1986; Clark 1986; Donham 1986b; Cormier et al. 1990). Some experts have suggested that pit-exhaust ventilation could prove effective in controlling high concentrations of contaminants (Harry 1978; Barber 1986; Clark 1986; Donham 1986b; Crook et al. 1991; Gingras and Lavoie 1991; Pickrell 1991).

The Québec Department of Agriculture, Fisheries and Food has developed a pit ventilation system for use in pig-housing facilities (Fig. 1). In this design, fresh air enters through conduits attached to the ceiling and running the length of the room and facility air is exhausted through capture inlets running the length of the building, just below the floor slats and above the manure sluices. Harry (1978) has suggested that air flow in pig-housing facilities should be designed to prevent redirection of contaminants emanating from manure sluices towards the animals. Because pit-exhaust systems are downdraught, rather than updraught, they avoid resuspending contaminants in facility air. In fact, most contaminants emanating from the manure sluices below the floor slats (total bacteria, Gram-negative bacteria and their endotoxins, hydrogen sulphide, ammonia, excrement particulates, and food debris) are directly exhausted outside the facility. Since workers are no longer in the exhaust path, their exposure is reduced.

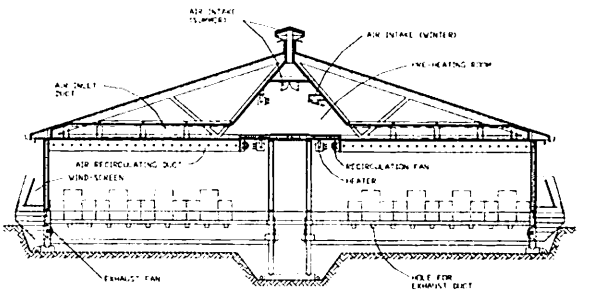
METHODOLOGY

The study was conducted in two farrowing units, one ventilated with a conventional system, the other equipped with a pit ventilation system. Ventilation in the conventional facility was provided by two 508-mm and three 457-mm variable-speed motorized fans (models AZ6 and AZ4, St-Léonard d'Aston, Aston, QC) situated at regular intervals along one wall at 1.5 m above the ground.

In the pit-exhaust facility (Fig. 1), air entered through a



a) Isometric view



b) Transversal view

Fig. 1. Diagram of pit ventilation system for pig-housing facilities.

polyethylene intake duct 450 mm in diameter and 9.75 m long and was distributed through outlets 63.5 mm in diameter located every 450 mm (Champagne and Gingras 1994). Facility air was exhausted through 32 regularly spaced intakes (16 per side) connected to a concrete duct running down the middle of the facility, below the floor slats and above the manure sluices. The duct, measuring 0.548 x 1.83 x 9.75 m (HxWxL), was connected to a variable-speed, 610-mm, six-blade Aston fan (St-Léonard d'Aston, Aston, QC). To ensure uniform air flow distribution, e.g., to make the air exhaust uniform throughout the duct, the exhaust intakes were of different diameters with the largest intake located furthest from the fan. The maximum required flow rate was 1.9 m^3/s.

The volume of the conventional and pit-exhaust facilities were 609 and 248.5 m^3, respectively. The mean animal mass was 180 kg. As shown in Table I, the air volume per animal is practically the same for each facility. By studying facilities that were adjacent to each other, the effect of confounding factors due, for example, to differences in feed, feeding method, pen size, frequency of sluice-cleaning, animal care, medication, and weather was reduced.

Hydrogen sulphide (H_2S), carbon dioxide (CO_2), ammonia (NH_3), total dust, and biological contaminants such as bacteria and fungi were measured simultaneously in the center of the two facilities, 1.5 m above the ground. Gases were measured simultaneously with direct-reading monitors connected to data-collection modules (Model DLX-100, D.E.S. Corporation, QC). Ammonia and carbon dioxide were measured using a multi-gas photoacoustic spectrophotometer (Model 1302, Bruël and Kjaer, Pointe-Claire, QC). Hydrogen sulphide was measured using an electrochemical-cell monitor (Model 4173, Interscan Corp., Chatsworth, CA).

Total dust was collected on polyvinyl chloride filters with a pore size of 0.8 µm (Model Silical, Omega Specialty Instrument Co., Chelmsford, MA), and quantified by gravimetry. High-volume pumps (Model HFS 113A, Gillian Instrument Corp., Wayne, NJ), operating at a flow rate of approximately 2 L/min, verified on-site with a pre-calibrated flowmeter (Model 543, Kurz Instruments, Carmel Valley, CA), were used. The sampling period was approximately one hour.

The detection limits were: ammonia 0.3 ppm, carbon dioxide 3 ppm, hydrogen sulphide 0.4 ppm, and total dust 25 µg. The precision of the carbon dioxide measurements was 2% of the full-scale reading and according to the NIOSH (1977) the total coefficient variation for the dust measurements is less than 7%.

Microorganisms were sampled with Andersen impactors (Andersen Instruments Inc., Atlanta, GA), using standard IRSST methods. Under laboratory conditions, the method has a precision of ± 7% (Jansen et al. 1992). Sampling periods were 15 seconds for total bacteria and 1 minute for fungi. To favour normal distributions, 8 sampling series of almost 30 consecutive samples were taken for each microorganism.

Fungal samples were incubated at room temperature for 7 days in Sabouraud Dextrose Agar (SDA) (Quelab Laboratories, Montréal, QC). Total bacteria samples were incubated at 35°C for 48 hours in Trypticase Soya Agar (TSA) (Quelab Laboratories, Montréal, QC).

Inside and outside temperatures were measured with thermistors (Model YSI-44006, Yellow Spring Instruments Co., Yellow Spring, OH) connected to data-collection modules. The precision of these instruments was ± 0.5°C.

To allow standardized comparison to be made, fresh-air flow rates were calculated using the concentration of carbon dioxide. Previous studies have demonstrated that ventilation rates can be conveniently estimated from these measurements (Commission internationale de génie rural 1984; Feddes et al. 1984). In the present study, the formula proposed for a mean gestation period of 55 days was used.

Measurements were taken in the morning, during, and after hand-feeding of the animals, i.e. the time of day when the animals are the most active. The total duration of sampling in each of the eight sampling series was approximately four hours. To estimate system performance, measurements were taken over two years in all seasons.

Mean contaminant concentrations and air-flow rates were compared using Student's t-test. Distributions that were not initially normal were normalized by logarithmic transformation of the data. The level of statistical significance for all comparisons was set at $p \leq 0.05$.

Table I: Inside and outside temperatures in the two facilities (°C)

		Conventional		Pit-exhaust		Outside
	n	# of animals	T (°C)	# of animals	T (°C)	T (°C)
Autumn 1990	12	79	18	32	18	10
Winter 1991	242	79	18	32	17	-10.5
Spring 1991	339	79	19	32	18	14
Summer 1991	204	79	21	48	20	17
Autumn 1991	232	106	16	48	18	3
Winter 1992	527	106	19	48	17	-5.5
Spring 1992	165	106	23	48	24	22
Summer 1992	201	106	23	48	23	19

* Mean animal mass: 180 kg

** The volume of the conventional and pit-exhaust facilities are, respectively, 609 and 248.5 m^3.

RESULTS AND DISCUSSION

The temperature in the two facilities and for outside air during each of the sampling series is presented in Table I. Table II lists bacterial and fungal concentrations in outside air during each of the sampling series. Contaminant concentrations in the two facilities in the autumn are compared in Table III. Concentrations of hydrogen sulphide are not indicated in the tables as it was never detected.

During the autumn of 1990 (Table III), concentrations of all contaminants

Table II: Concentration* of bacteria and fungi in outside air

	Bacteria (CFU/m^3)	Fungi (CFU/m^3)
Autumn 1990	6 940	275
Winter 1991	51 000	250
Spring 1991	61 590	250
Summer 1991	12 070	1 345
Autumn 1991	12 330	230
Winter 1992	3 000	130
Spring 1992	18 025	825
Summer 1992	1 090	3 010

* Arithmetic mean of two samples

except fungi and carbon dioxide were significantly lower in the pit-exhaust facility than in the conventional facility. As has been described, the pit ventilation system is designed to control the level of contaminants emanating from manure sluices. However, these results indicate that the system was less effective in controlling the levels of fungi, carbon dioxide and, to a lesser extent, total dust. The results of the autumn 1991 sampling series were roughly the same, although the concentration of fungi was significantly lower in the conventional facility.

During the winter of 1991, the mean concentration of bacteria was significantly lower and the mean concentration of ammonia significantly higher in the conventional facility (Table IV). In 1992, the mean concentration of bacteria and dust was significantly higher and the mean concentration of fungi and carbon dioxide significantly lower in the conventional facility.

Table V lists the results of the spring sampling series. In 1991, the only statistically significant difference was for the mean concentration of ammonia in the pit-exhaust facility. In 1992, mean bacteria and fungi concentrations were significantly lower in the conventional facility and ammonia was the only contaminant found in significantly lower concentrations in the pit-exhaust facility. No significant difference was observed for the other contaminants.

During the summer of 1991, the concentration of all contaminants except fungi and dust were significantly lower in the pit-exhaust facility (Table VI) . However, the pattern was reversed in 1992, with significantly lower concentrations of all contaminants except fungi and dust observed in the conventional facility.

The results seem to suggest that the pit system performed less well in 1992. This is supported by the observation that significantly lower contaminant concentrations were observed in the conventional facility in only 10% of 1991 comparisons, but 40% of 1992 comparisons.

The flow rate data are essential for the interpretation of these results. In each of the two facilities, per-animal fresh-air flow rates were calculated using the concentration of carbon dioxide generated by the animals (Table VII).

In the summer of 1991, when per-animal rates were highest in both facilities, the mean concentrations of bacteria, fungi, ammonia, carbon dioxide, and total dust were all significantly lower in the pit-exhaust facility, despite the fact that ventilation rates were significantly lower there (42.0 ± 9.4 L/s vs 63.7 ± 14.1 L/s).

In the spring of 1991 and the winter of 1992, contaminant concentrations were lower, often significantly so, in the pit-exhaust facility, despite significantly lower flow rates there (17.9 ± 1.4 L/s and 3.3 ± 0.09 L/s vs 19.8 ± 22.4 L/s and 5.2 ± 0.9 L/s).

In 1992, the spring concentrations of bacteria and fungi and the summer concentrations of bacteria, ammonia, and carbon dioxide were significantly lower in the conventional facility. This appears to be due to increased dilution by fresh

Table III: Autumn contaminant concentrations

	1990			1991		
	n	Conventional	Pit-exhaust	n	Conventional	Pit-exhaust
Bacteria (CFU/m^3)	29	119 000 (±19 200)	79 800* (±22 000)	29	430 000 (±98 000)	327 000* (±92 800)
Fungi (CFU/m^3)	28	1 760 (±1 880)	2 300 (±1 990)	21	260* (±120)	1 140 (±530)
Ammonia (ppm)	14	8.0 (±1.9)	4.5* (±1.2)	10	11.0 (±1.0)	7* (±0.7)
CO_2 (ppm)	14	1 350* (±200)	1500 (±120)	29	1955 (±170)	1740* (±150)
Total dust (mg/m^3)	14	0.8 (±0.2)	0.5* (±0.2)	26	1.7 (±0.5)	1.0* (±0.4)

* $p \leq 0.05$

Table IV: Winter contaminant concentrations

	1991			1992		
	n	Conventional	Pit-exhaust	n	Conventional	Pit-exhaust
Bacteria (CFU/m^3)	29	190 700* (±43 500)	219 000 (±65 000)	29	343 000 (±114 900)	283 000* (±81 300)
Fungi (CFU/m^3)	30	700 (±330)	780 (±380)	30	460* (±530)	1 820 (±1220)
Ammonia (ppm)	38	7.5 (±1.3)	4.0* (±0.9)	20	11.5 (±4.4)	10.1 (±3.1)
CO_2 (ppm)	27	2750 (±210)	2 800 (±150)	16	2 550* (±430)	3 430 (±860)
Total dust (mg/m^3)	30	0.8 (±0.2)	0.9 (±0.3)	25	2.6 (±1.3)	2.0* (±0.8)

* $p \leq 0.05$

Table V: Spring contaminant concentrations

	1991			1992		
	n	Conventional	Pit-exhaust	n	Conventional	Pit-exhaust
Bacteria (CFU/m^3)	28	100 000 (±38 500)	112 000 (±27 300)	28	188 600* (±67 600)	411 600 (±223 000)
Fungi (CFU/m^3)	29	630 (±410)	780 (±1 045)	27	540* (±200)	1 000 (±410)
Ammonia (ppm)	6	2.5 (±0.3)	1.0* (±0.1)	29	5.5 (±2.2)	4.1* (±0.7)
CO_2 (ppm)	32	950 (±95)	955 (±130)	27	760 (±120)	950 (±210)
Total dust (mg/m^3)	28	0.7 (±0.3)	0.7 (±0.1)	25	0.7 (±0.4)	1.2 (±0.8)

* $p \leq 0.05$

air in the conventional facility, where per-animal flow rates were approximately 25% higher ($p < 0.05$) than in the pit-exhaust facility during the same periods. Outside concentrations were all lower (Table II).

In the winter of 1991, the per-animal ventilation rate in the pit-exhaust facility was 5.7 ± 0.9 L/s and did not differ significantly from that in the conventional facility. The mean concentration of bacteria was significantly lower and the mean concentration of ammonia significantly higher in the conventional facility. Winter ventilation rates were probably too low to affect contaminant concentrations.

As mentioned previously, the pit ventilation system is designed to reduce the concentration of most of the contaminants emanating from manure sluices, e.g. total bacteria, Gram-negative bacteria, hydrogen sulphide, ammonia, and total dust. It also exhausts less air than conventional ventilation systems.

In both facilities, the concentrations of contaminants arising from sources other than manure sluices, such as fungi, were comparable to those reported in the literature for conventional facilities (Donham and Gustafson 1982; Clark et al. 1983; Donham 1986a, 1986b, 1990; Donham et al. 1989; Crook et al. 1991; Crook 1992). Fungal concentrations in this study varied from 2.6×10^2 to 4.9×10^3 CFU/m^3. A Swedish study of the effect of environmental factors in pig-housing facilities on worker health reported a statistical association between fungal concentrations of at least 1.3×10^4 CFU/m^3 and respiratory symptoms (Donham et al. 1989). In other

Table VI: Summer contaminant concentrations

	1991			1992		
	n	Conventional	Pit-exhaust	n	Conventional	Pit-exhaust
Bacteria (CFU/m^3)	28	295 200 (±97 300)	182 900* (±56 600)	24	163 000* (±62 000)	231 000 (±116 000)
Fungi (CFU/m^3)	30	845 (±347)	927 (±347)	27	4 930 (±2 480)	4 390 (±1 560)
Ammonia (ppm)	30	1.4 (±0.5)	0.8* (±0.2)	30	3.0* (±0.8)	4.0 (±1.6)
CO_2 (ppm)	30	620 (±80)	550* (±70)	30	720* (±140)	895 (±195)
Total dust (mg/m^3)	24	0.6 (±0.1)	0.7 (±0.4)	20	0.7 (±0.2)	1.0 (±0.2)

* $p \leq 0.05$

Table VII: Mean per-animal air flow rates (L/s) for each sampling series

	Conventional		Pit-exhaust	
	n	(L/s)	n	(L/s)
Autumn 1990	13	8.0* (±0.9)	13	10.4 (±0.9)
Winter 1991	46	6.1 (±4.2)	46	5.7 (±0.9)
Spring 1991	29	19.8 (±2.4)	30	17.9* (±1.4)
Summer 1991	29	63.7 (±14.1)	30	42.0* (±9.4)
Autumn 1991	27	7.0* (±0.9)	27	9.0 (±1.4)
Winter 1992	26	5.2 (±0.9)	29	3.3* (±0.9)
Spring 1992	27	30.2 (±8.0)	27	21.7* (±7.6)
Summer 1992	30	34.9 (±10.9)	30	23.6* (±8.0)

* $p \leq 0.05$

Table VIII: Exposure limits for chemical contaminants

Contaminant	Quebec	United States (TLV/ACGIH)
CO_2 (ppm)	5 000	5 000
NH_3 (ppm)	25	25
H_2S (ppm)	10	10
Total dust (mg/m^3)	10	10

workplaces, exposure to fungal spores has been related to allergic alveolitis and organic dust toxic syndrome (Eduard et al. 1993). The effects of inhaled fungal spores and propagules may not be limited to allergic reactions (Santé et bien-être social du Canada 1987). The term "pulmonary mycotoxicosis" has been used to designate a group of diseases caused by mycotoxins, endotoxins, and other factors. The extent to which mycotoxins contribute to cause pulmonary mycotoxicosis is unknown, as are the effects of inhaled volatile fungal products on humans (Santé et bien-être social du Canada 1987).

In all eight sampling series, the concentrations of chemical contaminants in the pit-exhaust facility (with the exception of carbon dioxide in the winter) were less than half of applicable exposure limits set by the RQMT (Québec Regulation Concerning the Quality of the Work Environment) and the ACGIH (American Conference of Governmental Industrial Hygienists) (Table VIII) (ACGIH 1994; RQMT 1994). However, Reynolds et al.(1996) reported respiratory problems in swine production workers exposed to 7.5 ppm of ammonia and 2.5 mg/m^3 of total dust. Ammonia concentrations measured during the winter of 1992 (10.1 ppm) and autumn of 1991 (7 ppm) (Tables II and IV) are in this range. The highest dust concentration observed in this study was 2.0 mg/m^3, measured in the winter of 1992 (Table III).

A U.S. study has reported a mean concentration of total bacteria of 1.4 x 10^6 CFU/m^3 in pig-housing facilities (Donham and Gustafson 1982). Crook et al. (1991), in a study of six pig-housing facilities in the United Kingdom, observed total bacteria concentrations of 3.0 x 10^4 to 8.0 x 10^6 CFU/m^3, 2.0 x 10^4 to 6.0 x 10^6 CFU/m^3, and 2.0 x 10^3 to 2.0 x 10^4 CFU/m in samples incubated at 25, 37, and 55°C, respectively. Clark et al. (1983), in their study of six Swedish pig-housing facilities, reported a median concentration of total bacteria of 3 x 10^5 CFU/m^3. A maximum total bacteria concentration of 3.6 x 10^6 CFU/m^3 was reported in Atwood et al.'s (1987) study of 171 Dutch pork-breeding facilities. Donham (1986a) reported a mean total bacteria concentration of 3.0 x 10^6 CFU/m^3 in 30 American facilities. It should be noted that sampling methods may have differed in these studies. On the other hand, the mean concentration of total bacteria reported in the present study is comparable to that reported by a Québec study using the same sampling methods, i.e. 1.7 x 10^5 CFU/m^3 (Cormier et al. 1990). The concentration of total bacteria in this study thus appears to be comparable to those reported elsewhere for conventional facilities.

The mean concentration of Gram-negative bacteria in Donham's study (1986a) of 30 pig-housing facilities was 8.0 x 10^4 CFU/m^3. Clark et al. (1983) reported a mean concentration of 8.8 x 10^4 CFU/m^3 in their study of six facilities. Attwood et al. (1987), in their study of 171 facilities reported a mean Gram-negative bacteria concentration of 1.0 x 10^4 CFU/m^3. According to these authors, the mean concentration of Gram-negative bacteria in pig-housing facilities is approximately equal to 10% of the concentration of total bacteria (Clark et al. 1983; Donham 1986a, 1986b; Attwood et al. 1987). Applying this 10% approximation, the concentration of Gram-negative bacteria in the pit-exhaust facility studied here is 8 to 41 times higher than the recommended level of 10^3 CFU/m^3.

CONCLUSIONS

The pit ventilation system is capable of reducing the concentration of most contaminants emanating from manure sluices, e.g. total bacteria, ammonia, and dust, if ventilation rates are kept high enough. This is reflected in the significantly lower concentrations observed for these contaminants. In fact, when per-animal air flow rates were highest in both facilities, the mean concentrations of chemical and biological contaminants were all significantly lower in the pit-exhaust facility, despite the fact that ventilation rates were significantly lower there. Second, even at significantly lower ventilation rates for the pit ventilation system, the contaminants are also found at significantly lower concentrations in the latter location. Third, winter ventilation rates were probably too low to affect contaminant concentrations.

With the exception of winter concentrations of carbon dioxide, chemical contaminants in the pit-exhaust facility were less than half of applicable exposure limits set by the RQMT and the ACGIH. However, the concentrations of total bacteria were comparable to those reported elsewhere for conventional facilities and the concentration of Gram-negative bacteria in the pit-exhaust facility were 8-41 times higher than the recommended level. The pit ventilation system was thus unable to ensure a healthy environment.

ACKNOWLEDGEMENTS

The authors thank Brigitte Roberge, Claude Létourneau, and Yves Beaudet of the IRSST for their technical expertise, Charles Jobin and Sébastien Cartier of the Québec Department of Agriculture, Fisheries and Food, and France C. Lafontaine for her secretarial work.

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