TWO AIRSPACE BUILDING DESIGN TO REDUCE ODOUR AND GAS EMISSIONS FROM PIG FARMS

*S.P. Lemay, H.W. Gonyou, J. Feddes, E.M. Barber and R. Coleman

Abstract

By keeping manure storage into the building and creating two independent airspaces within a room (main airspace and an enclosed dunging area [EDA]), it is suggested that the building air quality would be improved. Furthermore the building total emissions would be reduced if the air coming out of the EDA is treated with a biofilter. In-barn trials were completed using 12 experimental pens to determine the EDA usage by the pigs for different configurations. It was concluded that a 0.4 m wide entrance was adequate to allow free movement into and out of the EDA. The use of intermittent water spraying and continuous lighting inside the EDA effectively precluded its use as a lying area. A laboratory study was completed to evaluate the interaction between EDA air extraction rate, door design and contaminant containment. The curtain door at 20 L/s extraction rate was selected as being the most promising design. For the second part of the study, the best EDA configuration is being implemented in full-scale grower-finisher rooms and compared to conventional rooms for odour and gas emissions.

KEYWORDS. Odour control, Gas, Emission, Building design, Biofilter, Swine.

Introduction

Odours emanating from the ventilation system of a hog barn, as well as odours produced from manure storage and handling, are significant contributors to the total farm odour emissions. Odour nuisance can be evaluated by the following quantifiable odour characteristics: 1) frequency; 2) intensity or concentration; 3) duration; and 4) offensiveness (Sweeten, 1997). Bundy (1997) presents the odour sources coming from swine production activities and generating nuisance complaints: buildings were the source of 22% of the complaints; slurry storage was accountable for 17%; slurry spreading, animal feed production and silage clamps generated respectively 52%, 8% and 1% of the total nuisance complaints. Within the building, odours come from the feed and the feeding facilities, the pigs themselves, the floor and others surfaces (pens or building) and, the manure produced by the animals (O’Neill and Phillips, 1991). By its continuous operation, odour emission coming from ventilation exhaust air constitutes a nuisance with high frequency, duration and offensiveness. The odour compounds can be dispersed in the air or attached to dust particles that settle on the surfaces or that are in suspension in the air. Depending on the climatic conditions and the specific location, odour from a building will be diluted and its intensity will decrease as the distance from it increases.

Limiting the contact surface between ambient air and manure will reduce odours. Slatted floors that prevent the hogs from getting dirty and different manure management approaches in the building are other ways to limit odour emissions (Miner, 1995).

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Biofilters, bioscrubbers and dust removal systems are different techniques used to treat the air coming out of ventilation systems of swine buildings. For biofilters, the air, that has been de-dusted, is pushed through organic material (compost, peatmoss, straw or crop residues, wood bark) that is kept moist (by humidified air or direct supply of water) to assure adsorption and absorption of the odorous compounds or organic particles (CIGR, 1994). Pilot-scale biofilters (Turgeon et al. 1997; Buelna et al. 1997; Young et al. 1997a-b) and large scale biofilters (Meszaros 1994; Zeisig and Munchen 1988; Nicolai and Janni 1997; Hartung et al. 1997) have been studied. Low cost biofilters are currently used on many farms in Germany (Zeisig and Munchen 1988; Hartung et al. 1997) and one type has been developed and tested by Nicolai and Janni (1997). The performances obtained with those are interesting for odour control with reductions of 75% of the intensity between the air inlet and outlet of the biofilter. Operation and construction costs of such biofilters have been evaluated to 0.40 CAN$ per piglet produced for a farrowing facility of 700 sows (Nicolai and Janni, 1997).

Pigs develop well defined dunging areas within a few days following birth (Buchenauer et al. 1982; Whatson 1985). There is some debate as to whether pigs are attracted to a dunging area due to its microenvironment, or choose it as it represents the least desirable lying location (Whatson, 1985). Characteristics which have been reported to favour a location for dunging are: proximity to a wall or corner (Petherick, 1982); lower effective temperature due to air velocity and temperature (Randall, 1985); open partitions (Hacker et al., 1994); bright light (Buchenauer et al., 1982) or avoidance of the feeder (Aarnink et al., 1993). Previous studies at Prairie Swine Centre Inc. (PSCI) showed that pigs avoid dunging in the eating and sleeping areas (Gonyou et al., 1995).

In Canada, most pig barns have outside manure storage resulting in two odour sources on a farm basis: the building and the storage facility. By keeping manure storage within the building, the number of continuous odour sources around buildings drops from two to one. By having two separate airspaces (a main airspace and an EDA) in the building, it is suggested that total building gas and odour emissions would be reduced if the air exhausted from the EDA is treated with a biofilter. This building concept is also expected to improve air quality in the main airspace by isolating the dunging area and the manure storage area under the slats in the EDA.

**Objectives**

The objectives of this project are as follows:

- To design and construct an EDA that will be adopted by the pigs as dunging area and that will minimise manure odours/gas transfer to the pig/worker airspace.
- To construct a two-airspace ventilation system in a commercial-scale research room at PSCI and compare it with a conventional room design for odour and gas control.
- To investigate the application of biofilter technology for odour removal from dunging areas and under floor storage facilities and to design and construct two biofilters that can treat the exhaust air from the EDA system.
- To measure odour and gas emissions of a retrofitted feeder barn at University of Alberta with the two-airspace as designed and tested at PSCI that is equipped with a biofilter to treat the exhaust air of the EDA.

The first two objectives are being completed at PSCI (Saskatoon, SK) while the last two ones are realised at the University of Alberta and the Alberta Research Council (Edmonton and Vegreville, AB).
Material and Methods

Laboratory testing of an EDA

A laboratory study has been completed at the Agricultural and Bioresource Engineering Department at the University of Saskatchewan (U of S) to evaluate the interaction between the EDA air extraction rate, its door design and its contaminant containment. Four types of door design have been tested: 1) no door, 2) solid door, 3) flexible plastic strip curtain and 4) air curtain. The evaluation was carried out with four different ventilation rates varying from 25 to 100% of the general minimum ventilation rate on a pen basis: 5, 10, 15 and 20 L/s.

The degree of contaminant containment by the EDA was evaluated by using nitrous oxide (N\textsubscript{2}O) as a tracer gas. The N\textsubscript{2}O concentration was measured at four sampling points around the EDA to characterise the ambient concentration, four sampling points within the EDA, and at two sampling points at the exhaust fan. By measuring the N\textsubscript{2}O injection rate and the exhaust fan ventilation rate, a mass balance was established within the EDA and the amount of N\textsubscript{2}O leaving by the door was calculated for each door type and ventilation rate combination. The door efficiency was calculated for each trial as following:

\[
D.E. = \left( \frac{LR_{\text{WithoutD}} - LR_{\text{WithD}}}{LR_{\text{WithoutD}}} \right) \times 100
\]

where:

- D.E. : Door efficiency (%)
- LR\text{WithoutD} : Air leaking rate without any door (kg/s)
- LR\text{WithD} : Air leaking rate with a particular door (kg/s)

For example, if a specific door does not have any effect on the air leakage from the EDA (LR\text{WithoutD} = LR\text{WithD}), the door efficiency was 0 and if the door completely stops the leakage (LR\text{WithD} = 0), its efficiency was 100%.

Pig behaviour with a basic EDA design

For the two airspace system to be effective in controlling odours, the general living and dunging areas must be distinct and used accordingly. The design of the EDA must be such that it encourages pigs to dung within its confines, and to sleep elsewhere. In terms of managing the pigs’ behaviour, the EDA was designed in a two-step process. In the first step, the size of the EDA and its openings were evaluated to ensure that pigs could use it as it was intended. We examined two features in the first phase: the width of the entry; and, the provision of an entrance ‘hall’ within the EDA that could control the air flow near the entrance. Entrance widths of 40 and 50 cm were used in the first prototypes. Half of the EDAs tested were also equipped with a partition running from the entrance toward the rear of the compartment that divided the EDA into an entrance ‘hall’ and the primary dunging area.

In the second phase, we needed to incorporate features that would ensure that the pigs would sleep outside the EDA, as the EDA is somewhat similar to kennels. Thus we forced the pigs to use the EDA as a drinking area by only providing water within it. Secondly, we installed within the EDA an intermittent sprinkling device similar to those used in hot weather. We also installed a light in the EDA, and placed a grid of metal rods on the floor to make it less comfortable for lying. Our initial design included placement of the feeder outside of the EDA.

In-barn EDA implementation

The EDA concept was retrofitted in an existing growing-finishing room at PSCI in June 1999 as showed in Fig. 1. To limit leaking and undesirable air inlets from the pig/worker space to the EDA, the enclosure was
built to be air tight so air exchanges between the two airspace would occur only through the door. The air extraction system was installed as part of the stage 1 exhaust fan of the room and the set-up allowed control of the flow rate and operating static pressure of the EDA.

Figure 1 Enclosed dunging area implementation in a commercial room at PSCI.

The slatted portion of the pens in both the EDA and control rooms was lowered compared to the existing pen layout to satisfy the EDA design that aims at limiting the manure emission surface. A partition wall was built in the control room to reduce the slatted area in the pen and in both rooms, the unused portion of the slatted floor was covered with plastic to prevent emissions from the manure pit into the room. Nine grower-finisher pigs are housed in each pen with a total floor space of 0.72 m² per pigs including the EDA.

**Design and testing of biofilter material**

Peat moss and ground polystyrene were studied as filter materials for removing odour from an odourous stream of air coming from an existing manure storage. Peat moss is an effective material for removing odours, however, as it becomes compact over time, the high static pressure drop through the medium increases. Low static pressure drop has been measured with the use of ground polystyrene that is a very porous material. However, there is a concern that the biofilm area of the media may be insufficient to achieve an acceptable level of odour removal.

The equipment used was as follows (Fig. 2):

a) **Biofilters:** Two biofilters were each made of acid-resistant fibreglass, with a 1.22 m diameter, 1.83 m height, a 15.24 cm flanged inlet, and a 2.54 cm drain. The total volume of each biofilter was about 2 m³. One was filled with 1 m³ of peat moss and the other with 1 m³ of ground polystyrene. Approximately half of this volume was used for filter materials.

b) **Blower:** Blower had a maximum capacity of 140 L/s per biofilter with an operating flow of 100 L/s per biofilter at 500 Pa plenum pressure.

c) **Heater:** A 12 kW-heater operated by a computer controlled software responding to a temperature sensor located in the biofilter medium.

d) **Water spraying system:** Computer controlled valves to control water flow at rates between 0.5 to 15 L/s.

e) **Source of odorous air:** Source of odorous air was coming from a manure treatment plant of a swine unit.
Preliminary Results and Observations

Laboratory testing of an EDA

Table I presents the results collected with the pilot EDA built at U of S. The EDA ventilation rate was very close to the targeted values of 5, 10, 15 and 20 L/s. All door configurations have been tested without creating any specific air movement in the laboratory airspace. Measurements for the no-door and solid door configurations have been repeated with a 0.5 m/s air draft directed perpendicular to the door.

Without any air draft, the solid door generally improved the gas containment (door efficiency of −4 to 47%). The no door configuration worked surprisingly well compared to the solid door (which had a 5 mm gap on the sides and a 25 mm gap at the bottom) at 20 L/s and very calm air in the laboratory. When the 0.5 m/s air draft was created, the solid door efficiency varied from 5 to 52% which means that the solid door was always improving the gas containment. The curtain door had a better efficiency than the solid door at 20 L/s. This door design was considered to be more realistic of a solid door working in barn conditions. The curtain door was made of 100 mm plastic strips overlapping over each other by 12 mm and covered completely the door opening. The air curtain did not provide a good gas containment (efficiency from −53 to −195%). Even with different air jet angles (−5 to 15° from the vertical) and speeds (2.5 and 5.0 m/s), a lot of inside air was mixed with the jet and evacuated from the EDA. To verify the tracer gas measurements, a video camera and smoke bombs were used to visualise the performance of the air curtain and it showed smoke mixing and leakage through the door with the air curtain.

The following observations were made: 1) the air curtain was not very efficient to contain the tracer gas, 2) a simple and economical design for a solid swinging door would be difficult to make and, 3) a complete open door (no-door) would be vulnerable to air drafts. Consequently, the curtain door constituted the most promising design for the EDA implementation under barn conditions. Because the EDA tracer gas balance analysis could have been affected by the N₂O distribution, the highest ventilation rate of 20 L/s for the EDA design would be the best one to take for maximum air containment.
Table I  Laboratory door efficiencies for different design and ventilation rate combinations.

<table>
<thead>
<tr>
<th>Door type</th>
<th>EDA ventilation rate (L/s)</th>
<th>Outside N₂O concentration (ppm)</th>
<th>Inside N₂O concentration (ppm)</th>
<th>EDA leaking rate (x 10⁻² kg/s)</th>
<th>D.E.† (%)</th>
<th>D.E.‡ (%)</th>
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<tr>
<td>No door</td>
<td>4.3</td>
<td>17.0</td>
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<td></td>
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<td>123.1</td>
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<td>2.96</td>
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<td>Curtain door</td>
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<td>12.4</td>
<td>101.3</td>
<td>2.63</td>
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<td>Air curtain (+10°, 2.5 m/s)</td>
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<td>12.4</td>
<td>63.9</td>
<td>3.64</td>
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<td></td>
<td>15.3</td>
<td>13.4</td>
<td>81.3</td>
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<td>79.5</td>
<td>4.36</td>
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<tr>
<td>Air curtain (+15°, 5.0 m/s)</td>
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<td>13.2</td>
<td>52.2</td>
<td>5.17</td>
<td>-195</td>
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<td>70.6</td>
<td>4.65</td>
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<td>12.8</td>
<td>67.0</td>
<td>5.82</td>
<td>-104</td>
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</table>

* A 0.5 m/s air draft was directed perpendicular to the door.  
† Compared to no door, without any air draft directed perpendicular to the door.  
‡ Compared to no door, with a 0.5 m/s air draft directed perpendicular to the door.  

**Pig behaviour in an EDA**

Video observations over a 24-hour period showed that an entrance width of 40 cm was adequate for pig movement into and out of the EDA, even when pigs were of market weight (105 kg). In addition, the partition within the EDA did not, by itself, restrict the movement of pigs. However, the resulting entrance ‘hall’ was frequently used as a sleeping area. After the addition of sprinklers, lights and metal grids within the EDA, we observed that most visits to the EDA were less than 5 minutes in duration and that the vast majority of lying occurred outside the EDA. However, dunging also occurred outside the EDA to such an extent that further modifications are necessary. Initially the dunging began in one of the two corners furthest from the EDA and feeder. In an attempt to correct this problem the feeders were removed and pigs were floor fed. Although an initial success was obtained, dunging soon began in the corner where the feeder was originally situated.

Three modifications will be incorporated into the next prototype to better control the dunging pattern. Two entrances into the EDA will be installed: one in each corner of the EDA and sleeping area division.
Secondly, the feeder will be placed in one of the front corners of the pen. Finally, the internal partition will be removed to avoid the use of the ‘hall’ for sleeping.

**Biofilter material**

The results indicate that peat moss reduced odours by 59% when applying both water and microorganism nutrients to the media. In another trial, peat moss reduced odours by 33% when no water or microorganism nutrients were applied. When using ground polystyrene as a medium, odours were reduced by 20% with water and microorganism nutrients application. Even though the odour was only reduced by 20%, its character or hedonic tone was changed and qualified as more pleasant. The airflow in the coarse peat moss was significantly reduced over the trial period (90%) and the static pressure increased to approximately 1500 Pa whereas the airflow through the ground polystyrene did not change. Consequently, the biofilter material to be used to treat the exhaust air from the EDA is a mix of ground polystyrene (3 to 10 mm in diameter) and 10-25% peat moss that would keep the pressure drop through the material low. Odour concentration is not likely to be lowered significantly, but the hedonic tone is improved changing the character of the odour. The observations made suggest that a 200 L biofilter will be able to treat the air from the EDA of each pen of grower pigs at a rate of 20 L/s.

**Summary**

In-barn trials were completed using 12 experimental pens to determine the EDA usage by the pigs for different configurations. It was concluded that a 0.4 m access door was sufficient, the EDA will be design with two doors in the second testing phase, and water sprinkling and continuous lighting should be present in the EDA. The curtain door at 20 L/s air extraction rate constituted the most promising design under barn conditions. The biofilter material to be used to treat the exhaust air from the EDA will be a mix of ground polystyrene (3 to 10 mm in diameter) with 10-25% peat moss. The biofilter will have a volume of 200 L to treat an airflow of 20 L/s.

**Acknowledgements**

This project is funded by the Canada Alberta Hog Industry Development Fund. The authors would like to thank Lloyd Zyla and Scott Scherman for the lab tests, Maikel Timmerman, Liliane Chénard, Robert Fengler and Colin Peterson for technical assistance on this project.

**References**


