Measurements of odour and hydrogen sulfide emissions from swine barns

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Zhou, X. and Zhang, Q. 2003. *Measurements of odour and hydrogen sulfide emissions from swine barns*. Canadian Biosystems Engineering/Le genie des biosystemes au Canada **45**:6.13-6.18. Odour and hydrogen sulfide (H2S) emissions were measured on ten swine farms in southern Manitoba between May and October in 1999 and 2000. On each selected farm, air samples were taken from barn exhaust fans and manure storage. Odour concentrations of collected samples were determined by using a dynamic-dilution olfactometer. A Jerome™ meter was used to measure H2S levels of air samples from six farms. The average odour concentrations from barn exhaust ranged from 131 to 1842 OU/m³ and odour emission rates from 12 to 39 OU/s per m2 of floor area. No apparent correlations were found between the odour concentration and the general farm characteristics, such as years of operation, type of operation, ventilation system, and manure handling system. The average H2S levels spanned from 148 to 927 ppb on the six farms and H2S emission rates from 6.4 to 25.1 mg/s per m2 of floor area. Outdoor temperature had a significant effect on odour concentrations from barn exhaust, but not on odour emission rates (in a range from 12 to 35°C). The odour concentration measured within 10 mm of the manure surface was the highest in May and the lowest in July in earthen manure storages. Low odour concentrations were measured in an earthen manure storage with straw cover that formed a thick crust on the manure surface. Keywords: swine, odour, hydrogen sulfide, olfactometer, barn, manure storage.

Les émissions d’odeur et de sulfure d’hydrogène (H2S) ont été mesurées sur dix fermes porcines du sud du Manitoba entre mai et octobre en 1999 et 2000. Sur chacune des fermes sélectionnées, des échantillons d’air ont été prélevées à la sortie des ventilateurs et à la structure d’entreposage du lisier. Les concentrations d’odeur des échantillons recueillis ont été déterminées à l’aide d’un olfactomètre à dilution dynamique. Un moniteur Jerome a été utilisé pour mesurer les niveaux de H2S dans les échantillons d’air provenant des six fermes. Les concentrations d’odeur moyennes provenant des sorties d’air variaient de 131 à 1842 OU/m³ et les taux d’émission d’odeur variaient de 12 à 39 OU/s par m² de surface de plancher. Aucune corrélation n’a été trouvée entre la concentration d’odeur et les caractéristiques générales des fermes, comme le nombre d’années de production, le type de production, le système de ventilation et le système de gestion du lisier. Les niveaux moyen de H2S ont variés de 149 à 927 ppb sur les six fermes et les taux d’émissions de H2S de 6,4 à 25,1 mg/s par m², de surface de plancher. La température extérieure avait un effet significatif sur la concentration d’odeur provenant des sorties d’air mais aucun effet sur les taux d’émission d’odeur (pour des températures de 12 à 35°C). La concentration d’odeur mesurée à l’intérieur d’une couche d’air de 10 mm d’épaisseur située au-dessus de la surface du lisier était la plus élevée en mai et la plus faible en juillet pour les structures d’entreposage de lisier en sol. Des concentrations d’odeur faibles ont été mesurées sur les structures d’entreposage en sol recouvertes d’une couche de paille hachée qui formait une croûte épaisse à la surface du lisier. Mots clés: odeur, sulfure d’hydrogène, olfactomètre, porcherie, structure d’entreposage du lisier.

INTRODUCTION

Swine production facilities have increased in size over the years and along with this increase have come the public concerns about odour. Odour from swine operations contains many odorous compounds resulting from the anaerobic decomposition of swine manure. Compounds that pose concerns are ammonia, hydrogen sulfide, volatile fatty acids, p-cresol, indole, skatole, and diacetyl, by either their relatively high concentration or their low detection thresholds (Priest et al. 1994). Many technologies have been developed and attempted for odour management. Some examples are chemical and biological treatment of manure (including manure additives), dietary manipulation, liquid-solid separation, biofiltration, manure storage covers, and dust suppression. However, few of these technologies are universally adopted by the swine producers. A simple approach that is widely practiced for odour management is to maintain adequate setback distances between the swine operations and the residences. To establish science-based criteria for setback distances, air dispersion models are used to predict downwind odour concentrations. The use of air dispersion models relies largely on source emission information (Smith 1993) which is highly variable with farm characteristics, weather conditions, manure handling systems, and time of day. The application of these models is limited by the inadequacy of source emission information.

The research reported in this paper focused on measurements of odour emission from swine production facilities. The objectives were: 1) to quantify odour and hydrogen sulfide (H2S) emissions from typical swine barns in Manitoba, and 2) to determine the effects of building and environmental conditions on odour and H2S levels from barn exhaust and manure storage.

MATERIALS and METHODS

Farm selection

A total of ten swine farms, identified as A to J, were selected for this study. The selection was made to cover farms of different characteristics and was based on farmers’ willingness to participate. All ten farms were located in Southern Manitoba. Farms A, B, C, D, and G were farrow-to-finish operations; E and F were nursery operations; H was a farrow operation; I was a finish operation, and J was a farrow-to-nursery operation. More details of these farms are summarized in Table 1.

Odour concentrations were measured on all ten farms and odour emission rate and H2S measurements were carried out only on six farms (E to J) because of the time constraints.
Table 1. General characteristics of ten selected farms.

<table>
<thead>
<tr>
<th>Farm</th>
<th>Type</th>
<th>Years in operation</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Farrow-to-finish</td>
<td>5</td>
<td>750 sows</td>
</tr>
<tr>
<td>B</td>
<td>Farrow-to-finish</td>
<td>10</td>
<td>350 sows</td>
</tr>
<tr>
<td>C</td>
<td>Farrow-to-finish</td>
<td>35</td>
<td>800 sows</td>
</tr>
<tr>
<td>D</td>
<td>Farrow-to-finish</td>
<td>40</td>
<td>120 sows</td>
</tr>
<tr>
<td>E</td>
<td>Nursery</td>
<td>3</td>
<td>5000 nursery pigs</td>
</tr>
<tr>
<td>F</td>
<td>Nursery</td>
<td>4</td>
<td>10,000 nursery pigs</td>
</tr>
<tr>
<td>G</td>
<td>Farrow-to-finish</td>
<td>4</td>
<td>700 sows</td>
</tr>
<tr>
<td>H</td>
<td>Farrow</td>
<td>2</td>
<td>3000 sows</td>
</tr>
<tr>
<td>I</td>
<td>Finish</td>
<td>4</td>
<td>4000 finish pigs</td>
</tr>
<tr>
<td>J</td>
<td>Farrow-to-finish</td>
<td>2</td>
<td>2500 sows</td>
</tr>
</tbody>
</table>

Specifically, odour measurements were taken from a total of 23 barns on ten farms, including three farrow, five dry-sow, nine nursery, and six finish barns. All 23 barns had negative pressure mechanical ventilation systems, slatted floors, and shallow gutters for handling liquid manure. Among the ten farms, two had manure storage tanks with solid structural covers and the other eight had earthen storages. Because odour emission from tanks with solid structural covers was negligible, odour was not measured for these tanks. Earthen manure storages on farms E and J had straw covers as a means of odour reduction.

Sample collection

Samples were collected three times on each selected farm in a random order between May and October in 1999 and 2000. On each selected farm, odour samples were taken from barn exhaust fans and manure storage by using a vacuum chamber and 10-L Tedlar™ bags (St. Croix Sensory, Inc., Stillwater, MN). Samples were mostly taken between 1300h and 1700h. The amount of time to collect a sample (fill a Tedlar™ bag) was about five minutes. Each sample, therefore, represented the five-minute average odour concentration. For collecting samples from barn exhaust, a sampling probe was placed in the mid stream of airflow from the exhaust fan. At the same time, the size of the exhaust fan and the average air velocity were measured. The airflow rate from each running fan was calculated from the measured air velocity and fan area. The total ventilation rate from the barn was determined as the summation of the airflow rates of all running fans in the building. For manure storages, samples were taken by locating the probe closely (within 10 mm) to the manure surface, in parallel to the wind direction, at the downwind edge of the manure storage. Meanwhile, the wind velocity at the same location was recorded. While samples were being collected, environmental conditions (temperature, relative humidity, wind, and sky cloudiness) were recorded.

Evaluation of odour concentration

Collected samples (in Tedlar™ bags) were transported to the olfactometry laboratory at the University of Manitoba for measurement within 24 hours. A dynamic-dilution olfactometer (St. Croix Sensory, Inc., Stillwater, MN) and six screened assessors were used to determine the odour concentration of each sample. For each sensory session, the rates of both sample and total flow were calibrated before and after testing and the average of the two calibrations was used in calculating dilution ratios. The triangular forced-choice method was used to present samples to the assessors, with a 3-s sniff time. Panel data were retrospectively screened to remove outliers by comparing individual threshold estimates with the panel average. The retrospective screening was carried out according to the European Standard for determining odour concentration by dynamic olfactometry (CEN 1999).

Screening of odour panels was performed on all of the assessors following the European Standard (CEN 1999). Two panel selection criteria were: 1) the geometric mean of the individual threshold estimates expressed in mass concentration of the n-butanol gas had to fall between 20 to 80 ppb, and 2) the antilog of the standard deviation calculated from the logarithms of the individual threshold estimates, expressed in mass concentration of the n-butanol gas, had to be less than 2.3 to ensure the consistency requirement. Ten individual threshold estimates for the 50 ppm n-butanol reference were performed on each assessor in at least three sessions on separate days, with a pause of at least one day between sessions.

For samples taken from farms E, F, G, H, I, and J, a Jerome™ meter (JEROME 631-X, Arizona Instrument Corporation, Phoenix, AZ) was used to measure the H2S levels of the samples right before the samples were tested for odour concentration.

RESULTS and DISCUSSION

Odour emission from barn exhaust

To compare odour levels among the ten farms, the average odour concentration of all barns on each farm was calculated. This average odour concentration is referred to as the farm-average odour concentration in the following discussion. Large variations in odour concentration were observed among the farms and on individual farms (Fig. 1). The farm-average odour concentration was the lowest on farm A (131 OU/m³), and the highest on farm G (1842 OU/m³). The variation in odour concentration was also the least on farm A (79 to 209 OU/m³), and the largest on farm G (245 to 4635 OU/m³). Multiple comparisons indicated that ten farms could be divided into three groups according to their odour concentrations: a relatively low odour concentration group (Farms A, B, D, and I), a medium group (C, E, F, and J), and a high level group (G and H). Farm-average odour concentrations ranged from 131 to 252 OU/m³ in the low level group, 641 to 750 OU/m³ in the medium level group, and 1765 to 1842 OU/m³ in the high level group.
The patterns of variation in hydrogen sulfide (H$_2$S) levels measured on six farms (E to J) were similar to those of odour concentration. Farm I had the lowest H$_2$S level of 148 ppb and farm G the highest of 927 ppb (Fig. 2). These values are comparable to those reported by Jacobson et al. (1999). There was a positive correlation between the odour concentration and H$_2$S level (Fig. 3), with a coefficient of correlation of 0.87.

The odour emission rate from barns was determined as the odour concentration times the airflow (ventilation) rate. This resulted in a unit of OU/s for the odour emission rate (odour concentration OU/m$^3$ × airflow rate m$^3$/s). For easy comparisons, the emission rate is often described in terms of odour units emitted per unit floor area: OU s$^{-1}$ m$^{-2}$. Similarly, the hydrogen sulfide emission rate is expressed as mg s$^{-1}$ m$^2$. Measured odour emission rates ranged from 12 on farm J to 38 OU s$^{-1}$ m$^{-2}$ on farm G (Fig. 4). These rates were slightly higher than those reported by Jacobson et al. (1999) for swine barns in Minnesota (1 to 30 OU s$^{-1}$ m$^2$). A similar pattern was observed for H$_2$S emission (Fig. 5), with the lowest farm-average rate of 6.4 mg s$^{-1}$ m$^2$ on farm J and the highest of 25.1 mg s$^{-1}$ m$^2$ on farm G.

No definite relationship between the general farm characteristics and the measured farm-average odour concentration was observed. For example, farms A and G were similar in characteristics; both were farrow-to-finish operations, with farm A having 50 more sows than G (750 vs 700 sows); the two farms were 5 and 4 years old, respectively; and both had slatted floors and shallow gutters for manure collection. However, the odour concentration on farm A was significantly (P < 0.05) lower than that on farm G. In contrast, farms E and F also had similar characteristics; both were nursery operations, 2 and 4 years old, with wall mounted exhaust fans and the same cleaning schedule, except that F had twice as many pigs as E. But the odour concentrations on these two farms had no statistically significant difference (P > 0.05). The odour concentrations in swine barns are affected by many factors. Data from this study showed that general barn characteristics alone were not sufficient to project odour emission. Large variations in odour level within the same farm and among the farms might be attributed to differences in the day-to-day barn conditions, which varied with the management practice, weather conditions, and many other factors. Further research should be conducted to determine the effects of day-to-day barn conditions on odour emission. The specific barn conditions that should be
examined include: pen (floor) cleanliness; washing frequency; dunging patterns; manure properties; feed ration, climate (temperature and relative humidity), and any measures used for odour control.

Large variations in odour concentration with outdoor temperature were observed in general. To quantify these variations, the measured odour concentration for a barn at a given temperature was expressed (or normalized) as a percentage of the average odour concentration in the barn during the study period. Numerically, 100% in the relative (or normalized) odour concentration means that the measured odour concentration was equal to the average odour concentration for the barn, whereas 200% means that the measured odour concentration was twice as high as the barn-average. This normalization minimized the effect of barn differences on comparing odour concentrations as affected by outdoor temperature. Variations in odour emission and ventilation were expressed in a similar fashion. The odour concentration in the outdoor temperature range of 12 to 15°C was about twice as high as the barn average and was significantly (P < 0.05) higher than those at other temperatures (Fig. 6). There was no significant difference in odour concentration between temperature ranges of 15-18 and 18-21°C. There was a significant (P < 0.05) decrease in odour concentration when the outdoor temperature increased from the 18-21 range to 21-25°C.

No significant (P > 0.05) changes in odour concentration were observed after the outdoor temperature reached above 21°C. Low ventilation rates at low outdoor temperatures contributed to high odour concentrations from building exhaust. As shown in Fig. 6, the ventilation rate increased from 42 to 156%, or by 3.7 times when the outdoor temperature changed from 12 to 35°C.

The change in odour emission rate with outdoor temperature was found not to be significant in this study (P > 0.05) (Fig. 6). At low outdoor temperature, the odour concentration was high and the ventilation rate was low; whereas, at high outdoor temperature, the odour concentration was low and the ventilation rate was high. Since the emission rate was determined as the product of odour concentration and ventilation rate, the rate did not change significantly with outdoor temperature. Numerically, the highest odour emission occurred at outdoor temperature above 35°C, which was 27% higher than the barn average. The lowest emission occurred at the outdoor temperature range of 15-18°C, which was 68% of the barn average.

To compare odour emissions among different types of barns, data were analyzed for three farms (G, H, and J), on which at least two types of barn were measured for odour concentration and emission rate. Analysis of variance was performed with the GLM procedure of SAS/STAT (SAS Institute Inc., Cary, NC) to examine the statistical significance of the differences in odour among different types of barn, with farms being treated as blocks in the analysis. The results indicated that the odour concentration in nursery barns was significantly (P < 0.05) higher than that in dry-sow barns, and there was no significant difference between farrow and nursery barns or between farrow and dry-sow barns (P > 0.05) (Fig. 7). Analysis of variance also showed that the emission rates from farrow and nursery barns were significantly (P < 0.05) higher than that from dry-sow barns, and there was no significant difference between farrow and nursery barns or between farrow and dry-sow barns (P > 0.05) (Fig. 8). Research by Zhu et al. (1999) showed that nursery buildings had the highest odour emission rate compared with farrow and dry-sow buildings.

**Odour from earthen manure storage**

The wind speed plays an important role in odour emission from manure surface in storages. High wind speed would increase the
odour transfer rate from the liquid to the air. In a study using a wind tunnel, Schmidt et al. (1999) found that measured emission rate increased exponentially with the wind speed. The wind speed was not controlled in the current study because no wind tunnel was used to collect odour samples. A two-factor variance analysis was conducted to consider the effect of wind speed on odour concentration while comparing odour levels on different farms. The analysis was performed using the GLM procedure of SAS/STAT (SAS Institute Inc., Cary, NC), with farm and wind speed being the two influencing factors. The results indicated that the differences in odour concentration were significant ($P<0.05$) among the eight farms and the effect of wind speed on odour concentration was also significant ($P<0.05$).

It is interesting to note that the wind speed near the manure surface was within a narrow range (less than 2.0 m/s) on most sampling days (Fig. 9). It should be mentioned that these wind speeds were measured within 10 mm of the manure surface, and therefore, they should be lower than that measured at weather stations because of the berms and shelterbelts surrounding the storages. A subset of odour data was selected for wind speeds less than 2.0 m/s for numerical comparisons of odour concentrations among the eight farms (Fig. 10). The highest farm-average odour concentration was measured on farm G (615 OU/m$^3$), the lowest on farm J (205 OU/m$^3$). The low odour concentration on farm J might be attributed to the straw cover that resulted in a thick crust on the manure surface. In contrast, farm E also used straw as manure cover, but straw accumulated along a side of the storage and no crust was observed. The odour concentration on farm E was 2.7 times that on farm J. This result indicates that straw cover may be effective in odour reduction, but it has to be used properly.

Figure 11 shows the relative odour concentration (the ratio between the measured odour concentration and the average concentration over the study period) from manure storage on different sampling dates. Multiple comparisons (Tukey’s Studentized Range tests, performed with SAS/STAT, SAS Institute Inc., Cary, NC) indicated that odour concentrations measured during May 17-29 were significantly ($P < 0.05$) higher than those measured during July 1-11 and there were no significant differences among other sampling periods ($P > 0.05$). The results agreed with the observation by Jacobson et al. (1997) that odour concentrations from manure storage in spring is significantly higher than that in summer or fall, because as temperature increases in the spring, combined with the build-up of solids from the winter, the biological activity of bacteria increases drastically at the bottom of the storage and a large amount of odourous gases is generated. When these gases move from the bottom to the surface of the storage, it may lead to the turn-over of the manure in the storage and more odorous gases are released.

**CONCLUSIONS**

1. Odour concentrations from swine barns (exhaust fans) varied greatly among the farms and within individual farms. The farm-average odour concentration varied from 131 to 1842 OU/m$^3$ among the ten farms. The greatest difference between the lowest and the highest odour concentrations measured on an individual farm was from 245 to 4635 OU/m$^3$. No apparent correlations were found between the
2. Odour concentrations from barn exhaust fans were higher at the outdoor temperature range of 12 to 15°C than other temperatures and there were no significant changes in odour concentration after the outdoor temperature reached above 21°C. The odour emission rate was not significantly affected by outdoor temperature in the range from 12 to 35°C.

3. The odour concentration in nursery barns was higher than that in dry-sow barns and there was no significant difference between farrow and nursery barns nor between farrow and dry-sow barns. Odour emission rates from farrow and nursery barns were higher than that from dry-sow barns and there was no difference in emission rate between farrow and nursery barns.

4. Odour concentrations measured within 10 mm of the manure surface in earthen manure storages were the highest in May and the lowest in July.

5. There was a positive correlation between the odour concentration and the H₂S concentration.

REFERENCES


