MEASUREMENT OF ODOUR EMISSIONS FROM HOG OPERATIONS IN MANITOBA

Final Report Submitted to

Manitoba Livestock Manure Management Initiative Inc.
and
Triple S Hog Manure Management Initiative

by

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EXECUTIVE SUMMARY

Odour emissions were measured on ten (10) hog farms in Manitoba in 1999 and 2000. Five of the ten farms were farrow-to-finish operations (size ranging from 130 to 800 sows), two nursery operations (5,000 and 10,000 hogs), two farrow-nursery operations (2,500 and 3,000 sows), and one grow/finish operation (4,000 hogs). Seven of the ten operations included in this study were less than 5 years old, and the other three were 10, 35 and 40 years old, respectively. On each selected farms, odour samples were taken from (i) barn exhaust, (ii) manure storage, and (iii) downwind (50 m to 3.5 km). A flux hood was used to collect odour samples from land application of manure on three farms. Odour levels (concentrations) of collected samples were determined by using a dynamic-dilution olfactometer with six screened human assessors. A Jerome was used to measure hydrogen sulfide (H$_2$S) levels of odour samples taken from six farms in 2000.

Farm-average odour levels from barn exhaust ranged from 131 to 1842 OU on ten farms. The farms could be divided into three groups according to their odour levels: four in a low odour level group (131 to 252 OU), four in a medium level group (641 to 750 OU), and two in a high level group (1765 to 1842 OU). No apparent correlations were found between the odour level and the general farm characteristics, such as the age and type of operation, ventilation system, and manure handling system. There was a positive correlation between the odour level and hydrogen sulfide (H$_2$S) level. Farm-average H$_2$S levels spanned from 148 to 927 ppb.

The amount of odour emitted from facilities was quantified by the odour emission rate, which was calculated as the product of the odour concentration and the airflow (ventilation) rate. Both odour and H$_2$S emission rates were determined for six farms. Farm-average odour emission rates ranged from 12 to 39 OU*m$^3$/s.m$^2$, and the H$_2$S emission rates from 6 to 25 µg/s.m$^2$.

Odour levels and emission rates measured in this study were similar to those reported for Minnesota livestock facilities by researchers from University of Minnesota. Odour and H$_2$S levels ranged from 20 to 1515 OU and 7 to 1200 ppb, respectively, and odour and H$_2$S emission rates from 1 to 30 OU*m$^3$/s.m$^2$ and 0.1 to 25 µg/s.m$^2$, respectively, in Minnesota.

Outdoor temperature had a significant effect on odour levels from barn exhaust, but not on odour emission rates (in a range from 12 to 39 $^\circ$C). The odour level decreased with outdoor temperature until it reached about 28$^\circ$C. Even though odour levels were low at high temperatures, but high ventilation rates associated with high temperatures resulted in the emission rates comparable or slightly higher than those at low temperatures. The sampling time also affected odour levels from barn exhaust. Odour levels measured between May 17 and June 14 were higher than other sampling periods (from June 19 to September 19). However, the highest odour emission occurred in the period of July 19 – 31.

Three farms on which both odour level and emission were measured from more than one type of barn were selected to compare odour levels and emissions among dry sow, farrow, and nursery barns. It was found that there was no significant correlation between the odour level and the barn type. However, the emission rates from farrow and nursery barns were statistically
higher than that from dry sow barns, and no significant difference in emission rate was found between farrow and nursery barns.

Of the ten farms included in the study, eight had earthen manure storages (lagoons). Odour measurements were taken within 10 mm above the manure surface in lagoons on these eight farms. There were no apparent correlations between the odour level and the general farm characteristics. However, the lowest odour level occurred in a lagoon with straw coverage that formed a thick crust on the manure surface. The wind speed had a significant effect on the odour level near the manure surface in lagoons, i.e., the higher the wind speed, the higher the odour level. The wind speed near the manure surface was less 2.0 m/s on most sampling days (the shelterbelts and berms around the manure storages reduced the wind speed). Under this “low” wind condition, farm-average odour levels ranged from 205 to 615 OU near the manure surface in lagoons.

Injection of manure into soil caused little odour emission from soil. The emission rate measured from the soil with no manure applied was almost the same as that from the manured soil (3.6 vs. 4.0 OU m^3/s.m^2). Air samples collected downwind at the ends (or sides) of the fields on which manure was being applied showed very low odour levels (average odour and H2S levels were 60 OU and 4 ppb, respectively).
INTRODUCTION

The rapid expansion of hog industry in Manitoba has caused the general public to concern about the potential impact of intensive hog operations on the environment. Odour is one of the greatest concerns to the public when considering the siting of new or the expansion of existing hog operations. To some extent, these concerns have become obstacles to the expansion of hog industry in the Province. Should odour be a great concern? There is very little scientific information available as to the level and variability of the odour emissions from hog operations in Manitoba. The goal of this project was to collect baseline information on odour emissions from typical hog operations in the Province. The specific objectives were (1) to measure odour levels and emissions from ten hog farms and (2) to correlate the measured odour levels to the general characteristics of hog operations.

MATERIALS AND METHODS

Site selection

Ten hog farms (A - J) were selected to cover a range of operations and building ages. Four of the ten farms located in the Triple S area, five in other areas of the southern Manitoba, and one in western Manitoba. Of the ten farms, five were farrow to finish operations, two nursery operations, two farrow-nursery operations, and one grow/finish operation. The ages of these farms ranged from 2 to 40 years. Odour measurements were taken from 23 barns on the selected farms, including 3 farrow, 5 dry sow, 9 nursery, and 6 finish barns. The sizes of these barns are summarized in Table 1. Among the ten farms, two had covered manure storage tanks and the other eight had earthen storages (lagoons). Because odour emission from covered tanks was negligible, results on the manure tanks were not included in this report. Similarly, odour was not taken from mortality disposal tanks which were covered with lids.

Five of the ten farms included in this study were characterized by the DGH Engineering in an odour survey study. Characterization of the other five farms was carried out as part of this study. The detailed information on farm characteristics is presented in Appendix I.

Sample collection

Tedlar bags (10 L in capacity) were used to collect odour samples. To collect a sample, a bag was placed in a vacuum chamber and odorous air was drawn into the bag from the odour source by vacuum suction (fig. 1). Each sample was taken in two steps: (i) fill the bag with 2 L of sample air and then evacuate to “coat” the bag, and (ii) draw odorous air into the bag at a rate of 1 to 2 L/minute until the bag was 3/4 full. On each selected farm, odour samples were taken from (i) barn exhaust, (ii) manure storage, and (iii) downwind (fig. 2). For collecting samples from barn exhaust, a sampling probe was placed in the mid stream of airflow from exhaust fans. For lagoon odour, samples were taken by locating the probe closely (within 10 mm) to the manure surface. Downwind samples were taken in distances from 50 m to 3.5 km, or on the property line of the farm. Samples were taken three times on each farm (see Appendix II for a summary of sampling activities). Three sets of data were collected in morning, noon and evening, respectively, on Farm H on three separate days in August to determine the effect of time of day on odour emission.
Because of difficulties in scheduling, odour measurements from land application could not be taken on the selected farms. Instead, samples were collected on three other farms by following a custom manure applicator. The applicator used a manure injection system (Hydro Engineering Corp.), with injector spacing of 508 mm (20 in) and injection depth of 76 to 102 mm (3 to 4 in). The application rate was determined by soil and manure tests, as well as the expected crop yield. A flux hood was constructed to collect odour samples from manured soils (fig.3). The hood covered a soil surface area of 0.3 m² (0.75 x 0.4 m). Fresh air was drawn through a carbon filter, and introduced into the sample collection hood through a 100 mm diameter PVC duct. Airflow rates were measured inside the duct using a hot wire anemometer. Tedlar bags were used to collect odour samples at the outlet of the hood. The odour emission rate from the manured soil was determined from the measured outlet odour concentration and the airflow rate through the hood.

When samples were being collected, weather conditions (temperature, relative humidity, wind, and sky cloudiness) were also recorded and a site map was sketched on a Sampling Information Sheet (Appendix III). A Jerome meter was to measure hydrogen sulfide levels of odour samples collected in the summer and fall of 2000.

**Odour evaluation**

Collected samples (in Tedlar bags) were transported to the olfactometry laboratory at the University of Manitoba for odour concentration (level) evaluation within 24 hours. A dynamic-dilution olfactometer (AC’SCENT, St. Croix Sensory, Inc., Stillwater, MN) and six screened assessors were used to determine the odour concentration (level) of each sample (fig. 4). The olfactometer was capable of providing 14 dilution levels, with dilution ratios between 8 to 66667. The odour concentration measured by the olfactometer was expressed as the dilution-to-detection threshold (DT), or odour unit (OU), which represented the number of dilutions needed to bring the odour down to the level that could be detected by 50% of the population.

Odour evaluations were conducted in the Sensory Laboratory of the Canadian Food Inspection Agency, Winnipeg. The room that housed the olfactometer had a positive ventilation system with carbon-filtered air to eliminate background odours. For each sensory session, flow rates of the olfactometer were calibrated before and after testing and the average of the two calibrations were used in calculating dilution ratios. The triangular forced-choice method was used to present samples to the assessors, with a 3-s sniff time (St. Croix Sensory, 1999). Panel data were retrospectively screened to remove outliers by comparing assessors’ individual threshold estimates with the panel average. The retrospective screening was based on the following criterion (St. Croix Sensory, 1999):

\[
\Delta D = \begin{cases} 
D_{ITE}/DT & D_{ITE} \geq DT \\
-DT/D_{ITE} & D_{ITE} < DT
\end{cases}
\]  

(1)
where
\[ \Delta D = \text{deviation of individual threshold estimate from panel average} \]
\[ D_{ITE} = \text{individual threshold estimate} \]
\[ DT = \text{panel average detection threshold} \]

Any assessor with a \( \Delta D \) greater than 5.0 or lower than –5.0 was eliminated from the test results (CEN, 1999).

Selection of odour assessors

The assessors (panelists) were selected through a two-level sequential screening procedure. At both levels, each participant was presented with three flasks of n-butanol solution or water, one of which was different in odour intensity from the other two. Participants were asked to choose the odd sample (triangle test). In each testing session, participants were presented with six sets of three flasks. For each participant, the number of correct choices was plotted against the number of triangle tests (Meilgaard et al., 1991). This would place the participant in one of three regions: reject, continue testing or accept. For those who fell in the category of continue testing, the tests were repeated on subsequent days until they moved into the accept or reject region. Those participants who moved into the accept region during the first level screening would begin the second level of screening. Participants who were eventually moved to the accept region of the second level screening were selected as assessors.

RESULTS AND DISCUSSION

Odour emission from barns

Odour levels from barn exhaust are summarized in figure 5 for ten farms (A – J). The odour level shown for each farm was the average of all barns on that farm, or farm-average. Large variations in odour level were observed among the farms and on individual farms. The farm-average odour level was the lowest on Farm A (131 OU), and the highest on Farm G (1842 OU). The variation in odour level was also the least on Farm A (79 to 131 OU), and the largest on Farm G (245 to 4635 OU). Multiple comparisons indicated that ten farms could be divided into three groups according to their odour levels: a low odour level group (Farms A, B, D and I), a medium level group (C, E, F and J), and a high level group (G and H). Odour levels ranged from 131 to 252 in the low level group, 641 to 750 OU in the medium level group, and 1765 to 1842 OU in the high level group. In comparison, odour levels from hog barns with mechanical ventilation ranged from 24 to 1515 OU in Minnesota (Jacobson et al. 1999).

No correlations were found between the general farm characteristics (described in Appendix I) and the measured odour level. 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. But the odour level on Farm A was significantly (\( P < 0.05 \)) lower than that on Farm G. Further research is needed to examine the details of day-to-day operations, especially the cleanliness of floors, inside the individual barns to determine the causes of large differences in odour level among farms.
Hydrogen sulfide (H$_2$S) levels were measured on six farms (E – J) when a Jerome meter was purchased in Spring 2000. Among the six farms, Farm I had the lowest H$_2$S level of 148 ppb and Farm G the highest of 927 ppb (fig. 6). H$_2$S concentrations ranged from 9 to 1156 ppb in swine barns in Minnesota as reported by Jacobson et al. (1999). The patterns of variation in H$_2$S level among the farms and on individual farms were similar to those of odour level. The correlation between the H$_2$S concentration and odour level will be further discussed in a different section.

The odour level indicates how strong the odour is, whereas the amount of odour emitted from facilities is measured by the odour emission rate (OU* m$^3$/s), which is calculated as the product of the odour concentration (OU) and the airflow (ventilation) rate (m$^3$/s). Since the odour emission is dependent on the size of operation, the emission rate is generally expressed as a rate per unit area of the barn floor (OU* m$^3$/s.m$^2$). Similarly, the hydrogen sulfide emission rate is expressed as $\mu$g/s.m$^2$. Data collected in this study allowed us to compare the odour and H$_2$S emission rates among six of the ten selected farms. Farm-average odour emission rates ranged from 12 to 39 OU* m$^3$/s.m$^2$ (fig. 7). These rates were slightly higher than those reported by Jacobson et al. (1999) for hog barns in Minnesota (1 to 30 OU* m$^3$/s.m$^2$). The highest odour emission rate occurred on Farm G, where the odour level was also the highest of the ten farms. However, a higher odour level did not necessarily mean a higher odour emission rate. For example, Farm J had a higher odour level than Farm I (693 vs. 252 OU), but the odour emission rate on Farm J was lower than that on Farm I (12 vs. 16 OU* m$^3$/s.m$^2$). The pattern of variation in H$_2$S emission was similar to odour emission (fig. 8). The highest H$_2$S emission occurred on Farm G (25 $\mu$g/s.m$^2$) and the lowest on Farm J (6 $\mu$g/s.m$^2$).

Variations in odour emission could be attributed to many factors. In the following sections, the effects of sampling time, outdoor temperature, barn type, and room size (number of animals in the room) are discussed.

Most odour measurements in this study were taken in the months between May and September in 1999 and 2000. Figure 9 shows the relative odour levels in different sampling periods. The relative odour level was defined as the ratio of odour concentration to the farm-average for that farm. A ratio of 1.0 means that the odour level in a given sampling period was the same as the farm-average. Statistical analysis indicated that the odour ratios were significantly (P < 0.05) greater than 1.0 for periods of May 17 - 24 and June 1- 14, and less than 1.0 for periods of August 2 - 4 and September 9 - 19. Numerically, the odour level were 70% higher than the farm-average between May 17 and June 14, and the lowest odour level measured in the period of August 2 - 4 was 64% of the farm-average.

The pattern of variation in odour emission was different from that of odour concentration. As shown in figure 10, the highest emission occurred in the period of July 19 – 31, which was 57% higher than the farm-average. The emission rate for May 17-24 was not significantly (P > 0.05) higher than the farm-average. The high emission rate in July 19 – 31 was attributed to the high ventilation rate.

Odour measurements were taken three times (morning, noon, and evening) on three days in August from one dry sow barn and one farrow barn on Farm H. It appeared that more odour
was emitted from barns in evening than morning and noon (figs. 11 and 12). The differences in odour level were not statistically significant ($P > 0.05$) among the three sampling times, but the differences in odour emission rate were significant ($P < 0.05$). The effect of time of day on odour emissions should be further studied for different seasons (e.g., spring and summer).

Outdoor temperature had a significant effect on the odour level, but not on the odour emission rate (figs. 13 and 14). The odour level at 12°C was significantly ($P < 0.05$) higher than those at other temperatures, and there were no significant ($P > 0.05$) differences in odour level for temperatures above 28°C. Ventilation rates were usually low at low temperatures and low ventilation rates might have contributed to high odour levels in the barns. Even though odour levels were low at high outdoor temperatures, but high ventilation rates associated with high temperatures resulted in emission rates comparable to or slightly higher than those at low temperatures (fig. 14).

An attempt was made to determine the effect of the number of animals in a room on odour emission. Because of the limited resources, we could not collect enough data to cover a wide range of room sizes for all operations, except for nursery barns which had sizes ranging from 320 to 1250 pigs per room. As indicated by figure 15, the odour level seemed to decrease slightly with the animal number per room, but no clear trend was observed for the emission rate (fig. 16). It should be mentioned that the emission rate shown in figure 16 was expressed as per m² of barn floor area. At the same emission rate per m², a large barn would emit more odour than a small barn.

Table 1 summarizes odour levels and emission rates for all barns included in this study. To compare odour emissions among different types of operation, three farms (G, H and J) on which at least two types of barn were measured for odour levels and emission rates were analyzed. On Farm G, the strongest odour occurred in the farrow barn (2806 OU), the lowest in the dry sow barn (684 OU), and there was no significant ($P > 0.05$) difference between the farrow and nursery barns (fig. 17). The difference in odour level between farrow and dry sow barns on Farm H was not significant ($P > 0.05$), nor were the differences among the three types of barn on Farm J. A factorial analysis of variance performed on data for all three farms indicated that there was no significant ($P > 0.05$) correlation between the odour level and the barn type.

Variance analyses showed that odour emission rates were significantly ($P < 0.05$) different among the three types of barn on Farm G (farrow > nursery > dry sow)(fig. 18). On Farm J, the emission rate from the nursery barn was significantly ($P < 0.05$) higher than those from farrow and dry sow barns, and there was no significant ($P > 0.05$) difference between farrow and dry sow barns. No significant ($P > 0.05$) difference in odour emission was found between the farrow and dry sow barns on Farm H. Analysis of variance performed on data for all three farms indicated 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 ($P > 0.05$) difference between farrow and nursery barns.
Odour emission from earthen manure storages (lagoons)

Factorial analysis of variance was performed to determine the significance of differences in lagoon odour among the eight farms, as well as the effect of wind speed on odour level. Both the differences among the farms and the wind effect were statistically significant (P < 0.05). Multiple comparisons of odour levels among the farms are summarised in Table 2. It appeared that Farm J had the lowest odour level. This farm used straw to cover the lagoons and a thick crust formed on the manure surface. In comparison, Farm E also used straw as lagoon coverage, but straw cumulated along a side of the lagoon and no crust was observed.

The higher the wind speed, the higher the odour level near the manure surface (fig. 19). The coefficient of correlation was 0.72 between the odour level and the wind speed. It should be mentioned that this wind speed was measured within 10 mm above the manure surface, which should be lower than that measured at weather stations because of the berms and shelterbelts surrounding the lagoons. The wind speed near the manure surface was less 2.0 m/s on most sampling days (fig. 20). Therefore, a sub set of data was selected for wind speeds less than 2.0 m/s for numerical comparisons of odour levels among the eight farms. Figure 21 shows the farm-average odour levels measured on eight farms. The highest farm-average odour level was measured on Farm G (615 OU), the lowest on Farm J (205 OU). This range was much less than that from barn exhaust (131 to 1842 OU). Since the total odour emission from a lagoon depends on the odour level and the surface area of manure (under a certain wind condition). If the odour level varies little, the surface area becomes the dominant factor influencing the odour emissions from lagoons.

The H2S level correlated well with the odour level (fig. 22): the highest on Farm G (665 ppb) and the lowest on Farm J (133 ppb). No particular correlations were observed between the odour level and the general farm characteristics described in Appendix I. The wind effect seemed to have masked the variation in odour level with sampling date (fig. 23). The highest odour level was measured in the period of May 17 – 29 and the lowest in July 5 – 11. The wind speeds corresponding to these two sampling periods were also the highest and lowest, respectively. During day, the odour level in evening appeared to be higher than morning and noon, even though the wind in evening was not stronger than other sampling times (fig. 24).

Downwind odour levels

Odour dissipated quickly with the distance downwind (fig. 25). Odour levels over 150 m away from the facilities were close to the background odour level (20 – 60 OU). It should be mentioned that the downwind odour levels reported here were time-averaged odour levels, not instantaneous odour levels, because of the sampling method used in this study. The olfactometer is considered as an industry standard for odour measurement. However, with unstable atmospheric conditions, changing wind speed and direction, obtaining downwind odour samples that are representative to what is actually “felt” by the receptors becomes impractical. When 10 L Tedlar bags were used to collect odour samples for olfactometry measurement, it took 5 to 10 minutes to fill a bag. The collected sample, therefore, reflected the odour level “averaged” over the sampling time. Instantaneous bursts of strong odour may be more of a concern than the average odour strength. Therefore, no conclusions could be drawn from this study with regard to the downwind odour levels from hog operations. Further research should be conducted to develop suitable methods for measuring instantaneous downwind odour levels.
Odour emission from land application of manure

Soil had its own odour, which unfortunately could not be differentiated from manure odour by the olfactometer. The emission rate measured on the soil with no manure applied was almost the same as that on the manured soil (3.6 vs. 4.0 OU*m$^3$/s.*m$^2$)(fig. 26). This indicated that manure injection caused little odour emission from soil. Furthermore, air samples collected downwind at the ends (or sides) of the field on which manure was being applied showed very low odour levels (average odour and H$_2$S levels were 60 OU and 4 ppb, respectively).

Odour and H$_2$S

Hydrogen sulfide (H$_2$S) is a main contributor to manure odour (especially in aged manure) and it has been used by researchers and some regulatory agencies as an odour indicator. The data collected in this study showed that there appeared to be a positive correlation between the odour level and the H$_2$S concentration for both barn exhaust and lagoon odours (figs. 27 and 28). The coefficients of correlation were 0.87 and 0.80 for barn exhaust and lagoon odours, respectively.

CONCLUSIONS

1. Odour levels from barn exhaust varied greatly among the ten farms included in the study. The lowest farm-average odour level was 131 OU, and the highest 1842 OU. Four farms had relatively low odour levels (131 to 252), and four farms had medium odour levels (641 to 750 OU), and two farms had strong odour (1765 to 1842 OU). No correlations were found between the odour level and the general farm characteristics, such as the age and type of operation, ventilation system, and manure handling system.

2. There were large variations in odour level on individual farms. The greatest difference between the lowest and the highest odour levels measured on an individual farm was from 245 to 4635 OU.

3. On six farms included in the study, farm-average odour emission rates ranged from 12 to 39 OU*m$^3$/s.*m$^2$. A higher odour level from barn exhaust did not necessarily mean a higher odour emission rate.

4. Odour levels and emissions from barn exhaust varied with the sampling time. Odour levels measured in the period between May 17 and June 14 were higher than other sampling periods (from June 19 to September 19). However, the highest odour emission occurred in the period of July 19 – 31.

5. Odour levels from barn exhaust were higher at lower outdoor temperatures and temperature had little effect on the odour level when it was above 28°C. The odour emission rate was not significantly affected by outdoor temperature in the range measured in this study (12 – 39 °C).
6. There was no definite correlation between the odour level and the barn type (farrow, dry sow and nursery). The emission rates from farrow and nursery barns were higher than that from dry sow barns and no significant differences in emission rate were observed between farrow and nursery barns.

7. There was no apparent correlation between the room size (number of animals per room) and the odour emission rate (expressed as per m² of barn floor area).

8. Wind speed had a significant effect on the odour level near the manure surface in lagoons: the higher the wind speed, the higher the odour level. Odour levels measured within 10 mm above the manure surface in lagoons ranged from 205 to 615 OU when wind speed was less than 2 m/s. This range among the farms was much less than that from barn exhaust (131 to 1842 OU).

9. No particular correlations were observed between the odour level from lagoons and the general farm characteristics, except that straw coverage reduced odour effectively if used properly.

10. Land application of manure by injection caused little odour emission. The emission rate measured from the manured soil was almost the same as that from the soil with no manure applied.

11. There was a positive correlation between the odour level and the H₂S concentration for both barn exhaust and lagoon odours. Farm-average H₂S levels from barn exhaust varied from 148 to 927 ppb and H₂S emission rates from 6 to 25 µg/s.m².

**RECOMMENDATIONS FOR FURTHER RESEARCH**

A large amount of odour data was collected in this study to compile baseline information on odour levels and emissions from typical hog operations in Manitoba. However, the data were not sufficient for performing detailed statistical analyses to answer some practical questions because there were too many variables that affected odour from hog operations. Furthermore, the olfactometer used in this study was not effective in measuring instantaneous downwind odour levels. Further research is recommended as follows.

1. Conduct detailed odour measurements in barns of the similar type to determine the effects of day-to-day barn conditions on odour emissions. The specific barn characteristics that should be examined include: pen (floor) cleanness; washing frequency; dunging patterns; manure properties; feed ration, and any measures used for odour control (e.g., additives)

2. Develop suitable methods for measuring instantaneous downwind odour levels. A project funded by MLMMI is underway to develop and test a method of using n-butanol scales and odour rangers for odour measurement.
3. Collect more odour data for comprehensive statistical analyses to compare odour levels and emissions among different types of barn, especially grower/finisher barns, and to determine the effect of time of day on odour emissions in different seasons.

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REFERENCES


Table 1. Measured odour levels and emissions from barn exhaust

<table>
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<th>Farm</th>
<th>Barn</th>
<th>No. of Rooms</th>
<th>No. of Animals</th>
<th>Odour Level (OU)</th>
<th>Odour Emission Rate (OU*m³/s.m²)</th>
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<td></td>
<td></td>
<td></td>
<td>Min.</td>
<td>Max.</td>
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Table 2. Multiple comparisons of odour level measured within 10 mm above manure surface in lagoons

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= no significant difference; > significantly higher; < significantly lower, all at a significance level of 0.05