# Monitoring odour occurrence in the vicinity of swine farms by resident observers - Part I: Odour occurrence profiles

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Guo, H., Dehod, W., Feddes, J., Laguë, C. and Edeogu, I. 2005. **Monitoring odour occurrence in the vicinity of swine farms by resident observers, Part I: Odour occurrence profiles**. Canadian Biosystems Engineering/Le génie des biosystèmes au Canada **47**: 6.57 - 6.65. Trained resident odour observers living in the neighbourhood of three production sites of a 5000 sow farrowing-to-finishing swine operation completed an odour monitoring study to determine their odour exposure levels. Fifty residents from 39 families volunteered to be trained as odour observers and monitored swine odours near their residences for one year. Twenty-three families located 1.6 to 6.0 km away from the closest swine sites detected a total of 317 swine odour events during that period of time. Eleven of the families living 2.3 to 6.0 km and all five families living 6.0 to 8.6 km away from the closest swine farms did not detect any swine odour. Most odours (70.3%) were detected during May to October. The majority of odours (54.6%) were detected between 1700 and 0900h. No correlation was found between the distance and number of odour events. The observer's direction from the swine farms was an important factor for odour detection frequency. The time that the observer spent outside and the olfactory sensitivity of the observers might also have affected odour detection frequency and intensity. Annual odour detection frequencies for 20 families ranged between 0.01 and 0.80%. Three families had higher odour occurrence frequencies of 1.19, 1.51, and 3.32%. Odours with intensity 3 or above were reported the most frequently (82.2%). This study proved that using resident odour observers for long term and long distance odour dispersion measurement is practical and effective. However, it also revealed its limitations. Suggestions for improvement are presented. **Keywords:** odour, swine, weather condition, resident, observer**.**

Des résidents entraînés comme observateurs d'odeurs, et habitant dans le voisinage de trois sites de production porcine d'un complexe de 5 000 truies naisseur-finisseur, ont complété une étude de suivi pour déterminer les niveaux d'exposition aux odeurs. Cinquante résidents volontaires provenant de 39 familles ont ainsi été entraînés pour devenir observateur d'odeurs et faire le suivi des odeurs porcines autour de leurs résidences durant une année. Vingt-trois familles situées entre 1,6 et 6,0 km de la porcherie la plus proche ont détecté au total 317 évènements odorants durant cette période. Onze des familles demeurant entre 2,3 et 6,0 km de même que les cinq familles habitant entre 6,0 et 8,6 km de la porcherie la plus proche n'ont pas détecté d'odeurs de porc. La plupart des odeurs (70,3%) ont été détectées entre mai et octobre. La majorité des odeurs (54,6%) ont été détectées entre 1700 et 0900h. Aucune corrélation n'a été obtenue entre la distance séparant les porcheries des résidences et le nombre d'évènements odorants. La localisation des observateurs par rapport aux porcheries était un facteur important pour la fréquence de détection d'odeurs. Le temps passé à l'extérieur par l'observateur ainsi que sa sensitivité olfactive a pu avoir un effet sur la fréquence de détection ainsi que sur l'intensité observée. Les fréquences annuelles de détection d'odeurs pour les 20 familles ont varié entre 0,01 et 0,80%. Trois familles ont eu des fréquences d'évènements d'odeurs élevées de 1,19, 1,51 et 3,32%. Des odeurs d'une intensité de 3 ou plus ont été rapportées le plus fréquemment (82,2%). Cette étude démontre que l'utilisation de résidents comme observateurs d'évènements odorants pour des mesures de dispersion d'odeurs à long terme et sur un grand territoire est pratique et efficace. Cependant, elle présente certaines limitations. **Mots clés**: odeurs, porc, conditions météorologiques, résident, observateur**.**

## INTRODUCTION

The nuisance and health concerns caused by odours from livestock facilities are among the key issues that affect the neighbouring communities and the growth of the livestock industry in Saskatchewan and other Canadian Prairie provinces. Among all the odour control methods, keeping livestock operations an appropriate distance away from established residences may be the most effective, economical, and practical way for ensuring acceptable air quality for the neighbouring residents. Most current setback guidelines are experience-and/or survey-based; the credibility of these guidelines was unconvincing to both the neighbouring residents and the livestock producers (Guo et al. 2004a). Hence, science-based setback distances need to be established.

There are many factors that affect odour dispersion to the neighbouring areas and the resultant impact on the neighbouring residents, including the odour emission rate from the source, the receptor's distance and direction from the source, weather conditions, topography, and the odour sensitivity and tolerance of the neighbours. To generate science-based setback distances, two problems need to be solved first, i.e., a) to determine acceptable odour exposure levels of the surrounding neighbours in terms of frequency, intensity, duration, and offensiveness (FIDO) and b) to predict odour occurrence level (FIDO) in the neighbouring area, which could only be done by odour dispersion models that are validated by field odour dispersion measurement data. The National Center White Papers of the United States (Sweeten et al. 2002) have identified the determination of acceptable odour criteria in terms of FIDO as an urgent research need. To solve any of these problems, field data on odour occurrence as affected by odour sources, weather conditions, and topography are needed.

Compared to extensive odour emission measurements from livestock operations, very limited research work has been done on odour dispersion or plume measurement in the neighbouring areas of livestock operations. There are two methods of measuring odour dispersion. The first method is to measure the odour plume using a panel of trained odour observers. The second method is to monitor odour occurrence at neighbouring residences using trained resident odour observers. For the first method, groups ranging from 5 to 15 trained odour observers are brought leeward of an odour source and the odour intensity of the odour plumes are measured. Several studies have used this method to measure odour plumes (Li et al. 1994; Hartung and Jungbluth 1997; Kaye and Jiang 1999; Zhu et al. 2000; Jacobson et al. 2000; Zhang et al. 2003). Usually, one measurement only takes 10 minutes and the downwind distance from the odour source is less than 1 km and most often less than 0.5 km. Beyond this distance, little odour could be detected. There are two reasons for the inability to detect odour at a greater distance: a) due to the changing wind direction, it is difficult to position the odour observers in the right place on time at such a long distance to catch the odour plume, and b) the measurement takes place mostly during the daytime when unstable or neutral atmospheric stability may not allow odours to travel for a longer distance. Hence, although rather costly, this method is only practical for short distance measurement and the results are obtained under specific weather conditions and topography, which may not be replicated under other conditions. This method is used because the quality of the data is relatively easy to control when compared with the other method using resident observers. However, the setback distances in most setback guidelines are greater than 0.5 km, and livestock odours have been detected up to 6 km away from the odour source (Guo et al. 2004b), so this method will not be helpful for odour dispersion model validation for long distances. Besides, most industrial air dispersion models are intended for long distance predictions up to 50 km rather than 1 km or less (EPA 2004). Ideally, an alternative way for using trained assessors to monitor odours in a certain area over a long period of time would be to arrange odour observers on a grid area to live at the monitoring locations and work full time as assessors (VDI 1993). The high cost would make it impractical.

The second method, using trained voluntary resident odour observers to monitor odour, has it merits and demerits. First, it is very useful for long term odour monitoring at the resident's location considering that the resident is at home for a relatively long period of time. Residents are normally at home and available to observe odours during the stable atmospheric weather conditions from the late afternoon, throughout the night, and to the early morning, and some rural residents may be available to monitor odours at home all the time. Therefore, odour occurrence can be observed under various weather conditions and seasonal and diurnal odour occurrence profiles can be obtained. The cost is relatively low because the assessors are volunteers. There has been very limited research done with this method. Jacobson et al. (2000) and Guo et al. (2001, 2003) monitored odour in a 4.8 x 4.8 km grid of farmland in Minnesota. Nineteen trained resident odour observers monitored odour at their residences from late June to mid-November for five months during their normal daily activities. A total of 264 livestock odour events was documented. This research had some limitations for use in setback distance determination purposes. First, because there were a total of 20 livestock operations within or adjacent to this area, observers perceived odours at the same time from multiple sources including dairy, poultry, and swine operations. Second, the odour monitoring period was only for warm season and spring and winter odours were not monitored. Third, it used a 3-point n-butanol referencing intensity scale, which might be too coarse for the purpose of odour intensity criteria determination. Fourth, because the main objective of that study was to validate an odour dispersion model, odour occurrence profiles at each observer's location, odour occurrence as affected by distance from the odour source(s), the odour emission rates of the source(s), and the frequency of various wind directions, etc. were not analyzed. Finally, it is not likely that adequate odour exposure criteria (FIDO) could be determined based only on one experiment. Nimmermark et al. (2003) also used a similar method and measured odours in five areas of Minnesota.

Odour emission rates and odour dispersion are affected by the differences in livestock facilities and management practices, varying climatic conditions, and topography in different areas. Neighbouring residents in different areas may experience different odour exposure levels even if the scales of the livestock operations are similar. Further research work is needed to obtain odour occurrence profiles in the neighbouring area of livestock operations.

Community odour monitoring by trained local residents was conducted around three swine production sites of a 5000 sow farrowing-to-finishing operation in a rural area in eastern Saskatchewan. The objective was for trained resident odour observers to monitor odour exposure levels occurring in the vicinity of swine production operations. This paper will report the results of Part I of this study on odour occurrence profiles. The impact of weather conditions on odour occurrences will be reported in Part II of this study (Guo et al. 2006).

## MATERIALS and METHODS

### Odour monitoring area and the swine operations

The study area was located in eastern Saskatchewan (103.0°W, 51.8°N). Three separate sites of a 5000 sow farrowing-to-finishing operation were located in this area. The three locations were the farrowing (5000 sows, 3 barns, one 2-cell earthen manure storage basin (EMB)), nursery (19,200 head, 4 barns, one 2-cell EMB), and finishing (11,550 head, 1 barn, one 2-cell EMB) sites. The nursery site was 3.0 km west of the farrowing site and the finishing site was 11.5 km northeast of the farrowing and nursery sites. A total of 147 residences were located within 8.0 km of the three sites, including a small village. Figure 1 outlines this area. The influence of topography on odour dispersion was considered minimal due to the flatness of the experimental area with only sporadic bushes.

There were other small livestock farms in this area. Thirty-four families had cow-calf farms ranging from 4 to 250 cows, among which five large farms had 100 to 150 cows and the largest farm was a 250 head cow-calf operation. There was a 100-milking-cow dairy operation and a small swine farm with up to 100 pigs located south of the village. There were three swine finishing sites 16 km north of the village.

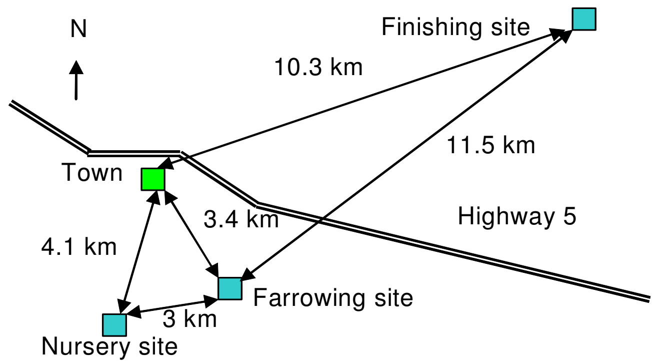



**Fig. 1. Outline of the odour monitoring area.**

### Resident odour observers and data collection

Fifty resident volunteers were trained as odour observers. They were trained to use a 5-point static referencing intensity scale with n-butanol solution in-water to rate the intensity of the swine odours they detected (Procedure B, Static-Scale Method, ASTM E544-99, 1999). The n-butanol concentrations-in-water for intensities 1 to 5 are 250, 750, 2250, 6750, and 20,250 ppm, respectively, corresponding to oral ratings of very faint, faint, moderate, strong, and very strong odours (Guo et al. 2001). They were also trained to use a 5-point oral scale for hedonic tone, i.e., offensiveness, offensiveness 1 being not annoying, 2 somewhat annoying, 3 annoying, 4 very annoying, and 5 extremely annoying.

The odour observers were asked to record odours they detected at or around their residences during their daily activities. The data recorded included odour intensity, offensiveness, occurrence time, duration, character, a general statement about the odour, and their own physical conditions. The study started in December 2001 and was completed in November 2002.

### Meterological data measurement

A weather station was installed near the finishing site. Weather data including wind speed and direction, temperature, relative humidity, and solar radiation were monitored once every minute and the average of every 10 minutes was recorded.

There were missing weather data due to reasons such as power outage or software problems. In case of missing data, the weather data of Yorkton, a city 65 km southeast of this area, was used. This area was flat and the difference in weather due to locations was considered negligible.

### Documenting odour generation and control activities

Acute odour generation or odour control activities, e.g., EMB emptying, draining manure pits, or covering EMB with straw, etc., were documented by the barn managers. Chopped barley straw was blown over the surface of the manure storage cells three times on the nursery site in March, June, and July, twice on the farrowing site in March and June, and once on the finishing site in June. Manure was applied to the nearby crop land of the three sites twice during the study period: between May 28 and June 8, and again between October 4 and 12.

## RESULTS and DISCUSSION

During December, 2001 to November 2002, fifty individuals from 39 families participated in the study. Twenty-three families detected swine odour while the rest did not detect any swine odours. Sixteen families did not detect any swine odours, 11 of them located 2.3 and 6.0 km from the nearest swine sites and five of them were beyond 6.0 km from the nearest swine sites. The distances between the 23 residences where odours were detected and the nearest swine site were between 1.6 and 6.0 km. Of the 23 families, seven owned cow-calf operations and one owned a dairy operation. All the families owned grain farms except one swine barn worker's family and two families who were retired from farming. A total of 322 odour events were reported. By checking the wind direction recorded by the weather station and the manure application record, five odours were assumed not to be from the three swine production sites or manure application fields because the detected locations were either not leeward of the swine sites, out of the area (greater than 18 km away), the locations were uncertain, or the odour characters were unknown. For example, one odour event was reported as an unknown odour at 6.5 km away from the closest swine site in December and was considered invalid. These five odour events were excluded from the study. Therefore, the three swine sites and nearby manure application fields might be the probable sources of a total of 317 odour events. However, some other odours from other livestock operations including the observer's own or neighbour's cow-calf operations, the dairy operation, or the small family swine farm could have been mistakenly considered as swine odours, especially during the manure removal periods with high odour emissions.

Because eight observers' families also owned beef or dairy cattle farms, this raised a concern as to whether exposure to one livestock odour such as cattle odour would reduce the observer's olfactory sensitivity to different odours such as swine odour. In a five-month period of odour monitoring by resident observers, no swine farmers reported swine odours and no cattle or dairy farmers reported cattle or dairy odours, although their residences were just next to or very close to their own livestock operations. However, they could all detect odours from other livestock operations with different animal species which were 0.5 to 4.8 km from their residences (Guo et al. 2001). According to VDI (1993) and CEN (1997), smokers are allowed as odour panellists because no statistically significant differences in odour assessment are found between smokers and nonsmokers. Hence, the individuals involved in cattle production were assumed to be unaffected in their ability to detect swine odours.

### Seasonal odour occurrence profile

Table 1 presents the number of odour events reported during the study on a monthly basis. Figure 2 also shows the seasonal odour occurrence profile and gives the percentages of each month's odour events. Swine odours were observed every month during the whole experimental period. The months with high odour occurrences were May, June, and July; the total number of odour events made up 49.2% of annual events. The least odorous months were March, April, and December; each only had 2.5 to 4.1% of annual odours. During mid-November to late April, the manure storages were frozen, which was probably the main reason for low odour occurrence during this period of

**Table 1. Summary of monthly odour events.**

| Year-Month | All odour Events | Intensity 1 | | Intensity 2 | | Intensity 3 | | Intensity 4 | | Intensity 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Events* | %** | Events | % | Events | % | Events | % | Events | % |
| 2001-12 | 9 | 0 | 0.0 | 0 | 0.0 | 7 | 77.8 | 1 | 11.1 | 1 | 11.1 |
| 2002-01 | 25 | 1 | 4.0 | 5 | 20.0 | 9 | 36.0 | 8 | 32.0 | 2 | 8.0 |
| 2002-02 | 17 | 2 | 11.8 | 0 | 0.0 | 2 | 11.8 | 9 | 52.9 | 4 | 23.5 |
| 2002-03 | 8 | 0 | 0.0 | 1 | 14.3 | 5 | 71.4 | 1 | 14.3 | 0 | 0.0 |
| 2002-04 | 13 | 2 | 15.4 | 1 | 7.7 | 3 | 23.1 | 4 | 30.8 | 3 | 23.1 |
| 2002-05 | 42 | 3 | 7.1 | 6 | 14.3 | 14 | 33.3 | 16 | 38.1 | 3 | 7.1 |
| 2002-06 | 59 | 1 | 1.8 | 6 | 10.7 | 10 | 17.9 | 27 | 48.2 | 12 | 21.4 |
| 2002-07 | 55 | 2 | 3.7 | 3 | 5.6 | 20 | 37.0 | 21 | 38.9 | 8 | 14.8 |
| 2002-08 | 19 | 0 | 0.0 | 5 | 26.3 | 7 | 36.8 | 2 | 10.5 | 5 | 26.3 |
| 2002-09 | 29 | 0 | 0.0 | 4 | 26.7 | 3 | 20.0 | 6 | 40.0 | 2 | 13.3 |
| 2002-10 | 29 | 0 | 0.0 | 0 | 0.0 | 1 | 5.3 | 12 | 63.2 | 6 | 31.6 |
| 2002-11 | 22 | 1 | 4.5 | 10 | 45.5 | 6 | 27.3 | 5 | 22.7 | 0 | 0.0 |
| Total | 317 | 12 | 4.0 | 41 | 13.8 | 87 | 29.2 | 112 | 37.6 | 46 | 15.4 |

* Numbers of odour events reported in these columns were odour events with reported intensities, not including 19 odour events without reported intensities.

**Percentages reported were taken using all odour events with reported intensities.

time. The warm season from May to October had a total of 223 odour events (70.3%), which was more than twice that for the cold season from November to April, which had 94 odour events (29.7%).

The manure storages were covered with barley straw in March to keep them frozen longer into the spring and also to reduce odour emission afterwards. This might be the reason for the rapid increase in odour events in May instead of in April. A total of 47 odour events were reported during the two manure application periods, 38 and 9 in the May-to-June and October manure application periods, respectively. Spring manure application resulted in more odour events than that of fall. Swine odours were detected more frequently during the manure application period than the other times. For instance, during June manure application period, an average of three odour events per day was reported, whereas the rest of June had an average of 1.5 odour events per day.

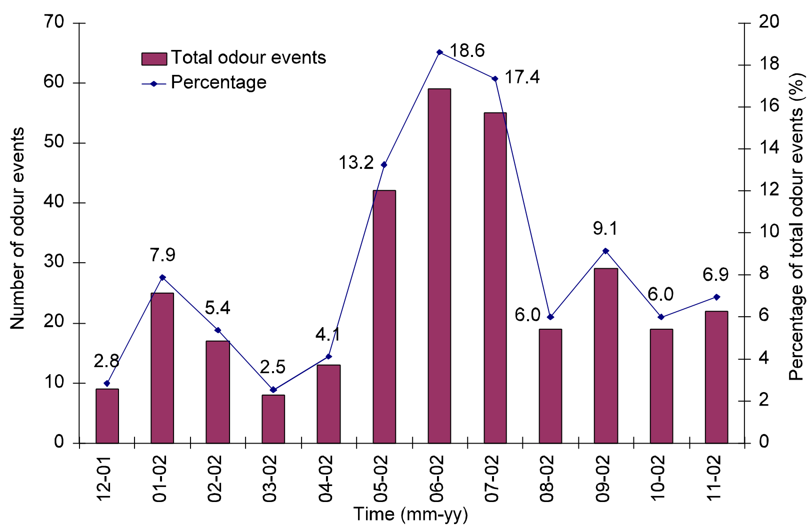
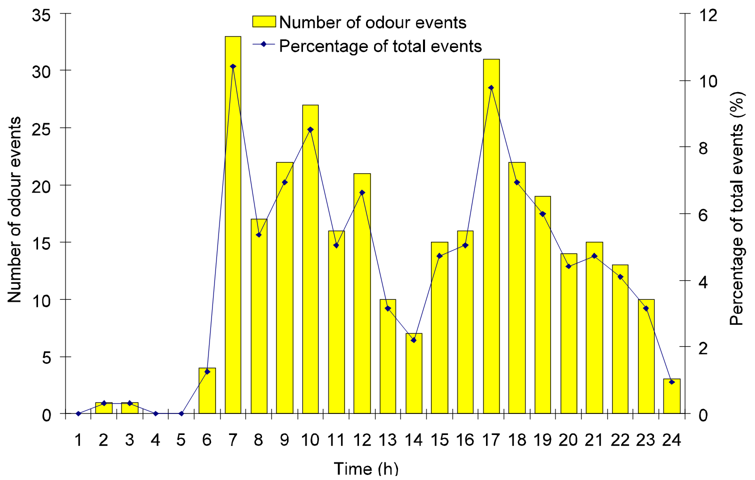



**Fig. 2. Seasonal odour occurrence profile.**

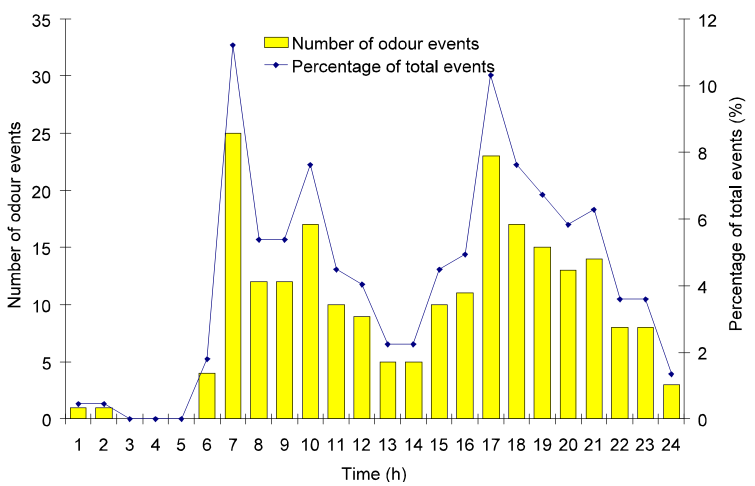
**Diurnal odour occurrence profile**

Figure 3 shows the diurnal distribution of odour events annually, during May-to-October and during November-to-April. As shown in Fig. 3a, most odour events (99.4%) were detected from the early morning (0500h) to the late evening (0000h), times when observers were awake. Only two odour events were detected by one odour observer during 0000 to 0500h when the observer went outside to check the cattle. For all odour events that occurred during the year, 54.6% of the odours were detected before 0900h or after 1700h. The remaining 45.4% were detected between 0900h and 1700h. For air dispersion purposes, daytime refers to 1 h after sunrise and 1 h before sunset. The rest of the time is then referred to as night. Since the daytime length is different for different times of the year, the data were further separated into two periods: the warm season from May to October and the cold season from November to April. From May to October, if we consider daytime from 0900 to 1700h, the majority (59.6%) of the odour occurred during night (Fig. 3b). Similarly, from November to April, 63.8% of odours were detected during night-time from 1600 to 1000h (Fig. 3c).

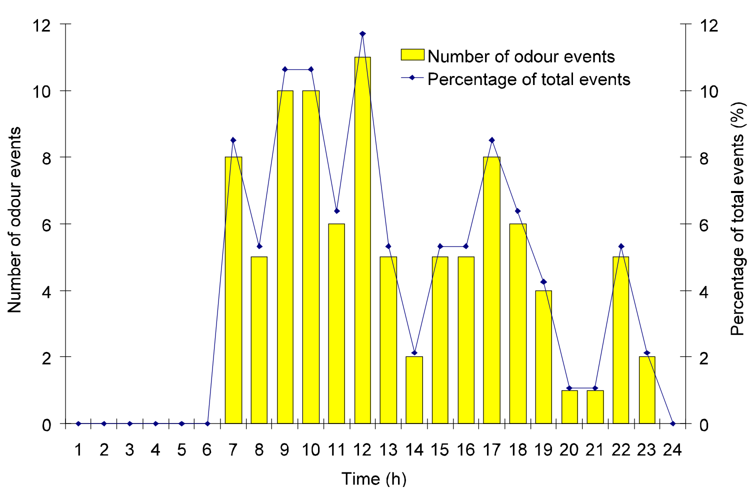
As shown in Fig. 3a, there were two peak hours for odour detection. One was in the early morning during 0600 to 0700h and another in the late afternoon during 1600 to 1700h which accounted for 10.4% and 9.8% of the annual odour events, respectively. There was a low odour detection period during the daytime between 1200 and 1400h with only 5.4% of odour events detected during this period of time. There were two reasons for the observed odour diurnal occurrence profiles, the atmospheric stability and the availability of observers who were outside. Atmospheric stability was the main determining factor for odour dispersion. Stable atmospheric




(a) December 2001 to November 2002




(b) May to October 2002




(c) December 2001 and January to April and November 2002

**Fig. 3. Diurnal odour occurrence profile.**

stability classes that favour odour travel can only occur during the late afternoon, throughout the night, and until the early morning. Observers were most likely to be outside during the two peak odour detection hours during which stable atmospheric conditions were likely to occur, which resulted in high odour detection. However, observers were not outside to detect odours at night. During the daytime, unstable weather was not in favour of odour travel, which explains the low odour detection during 1200 to 1400h. However, this area was fairly windy, which might result in neutral atmospheric stability class, and therefore, odours were detected throughout the daytime. A more detailed analysis on the impact of atmospheric stability on odour dispersion is presented in Part II of the study (Guo et al. 2006).

Figure 3b and 3c show the different diurnal odour detection profiles of the warm season and the cold season. With the majority of the odour events detected in the warm season, the diurnal odour detection profile was similar to the annual one. However, during the cold season odour events were detected the most during the hour before noon from 1100 to 1200h followed by 0800 to 1000h, and then 0600 to 0700 and 1600 to 1700h. There are three possible explanations: a) the stable atmospheric conditions were longer in the cold season due to the short day length, b) the observers who did not own livestock might have gotten up at a later time than they did during the warm season, and c) like most people, the observers might have been outside the most in the afternoon during 1600 to 1700h regardless of the season.

## Odour occurrence at various distances and directions from the odour source

As shown in Fig. 4, there was no correlation between the number of odour events and the distances from the observers' residences to the swine production sites ($P>0.01$). It indicated that the distance between the observer and the swine site was not the only determining factor for odour detection frequencies. The direction of the residence from the odour source was another important determining factor. The annual and May-to-October frequencies of winds from various directions are shown in Fig. 5. The annual prevailing winds came from four directions: northwest (NW), west (W), west-north-west (WNW), and south (S) with frequencies of 11.1, 10.1, 9.5, and 9.9%, respectively. During the warm season, prevailing winds also came from these directions: W (13.1%), WNW (8.6%), NW (8.7%), and S (10.1%) while in cold season they came from W (9.0%) to NW (13.5%) and also S (9.6%).

The locations with high odour events were mostly downwind from these four directions. Observer R1 reported the most odour events and was 2.8 km northeast of the nursery site and 3.8 km northwest of the farrowing site. Winds from S, SSE, and SSW could transport swine odours to this location. Seventy-eight odour events were detected during 62 days in a year at this location. The small family swine farm (about 100

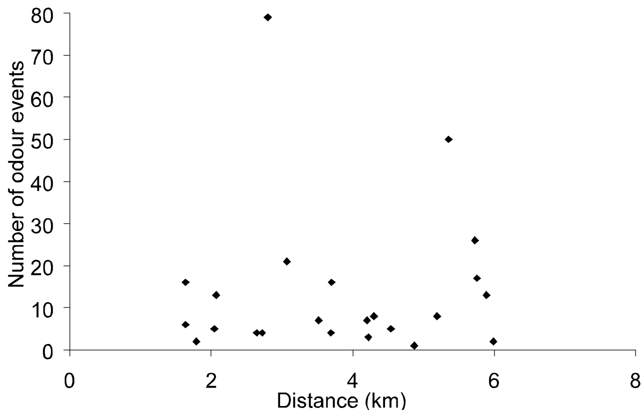



**Fig. 4. Odour occurrence number at various distances.**

pigs) was located southwest across the intersection from the residence of R1. It is possible that some of the odour events detected were from this farm. The 100-cow dairy operation was also located close to the observer's residence.

The second highest odour events were reported by Observer R3 who lived 5.4 km southeast of the finishing site and NW winds could bring odours to this location. There was no other livestock operation in the same direction as the finishing site. A total of 50 odours was detected in 47 days. The residence of Observer R6 was also located 1.6 km southeast of the nursery site and 3.3 km southwest of the farrowing site. Most odours that occurred at this location were brought by the prevailing NW winds. Compared to R3, this observer was much closer to the odour source yet only detected 16 odour events.

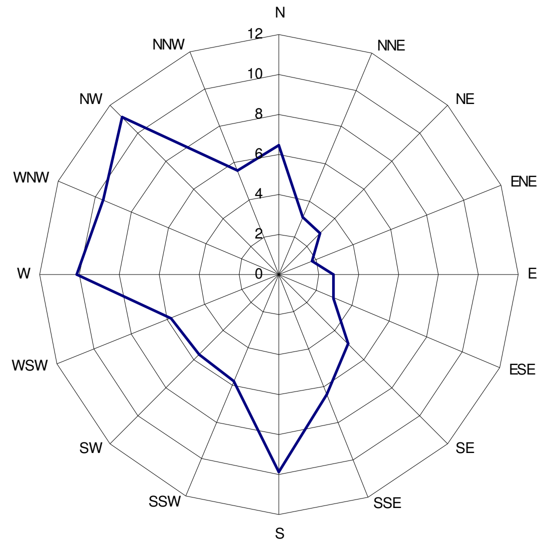
Observer R5 reported 17 odour events and lived 5.8 km south-south-east of the finishing site where NNW winds (annual frequency 5.6%) or NW winds might have brought swine odours to the location.

Observer R4 lived 5.7 km east of the farrowing site and downwind of the west winds and reported 26 odour events. Observer R8 was also located 5.9 km east of the farrowing site and detected 13 odours.

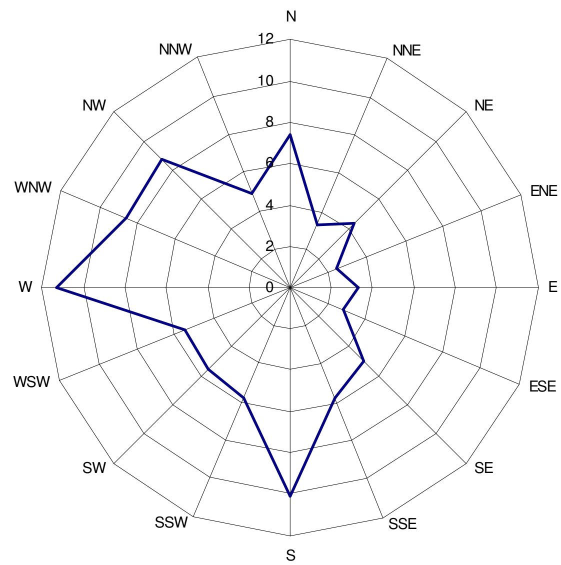
Observer R2 lived 3.1 km and 7.0 km WSW of the nursery and farrowing sites, respectively. The frequencies of ENE and E winds were only 1.8 and 2.7% annually, and 2.4 and 3.3% during May-to-October, respectively. This location was in a direction with the least winds blowing odours from the swine sites to it. Even so, this observer detected 21 odour events. However, observer R7, who also lived 1.6 km west of the nursery, only reported six odour events.

Some other observers also lived closer to the swine sites but detected fewer odours. Observer R10 lived 2.1 km northeast of the finishing site and reported five odour events. R11 was 2.1 km northwest of the finishing site and reported 13 odour events. The swine worker, R12, lived 1.8 km northeast of the farrowing site and reported two odours with intensities 1 and 2; however, the olfactory sensitivity of R12 to swine odours might have been affected by working in a swine barn.

The farthest detection location was 6.0 km away from the farrowing site and Observer R9 detected two odour events. This location was also 6.3 km southwest of the finisher site. This observer raised cattle on his farm. It is notable that of the 16




(a) Annual (calm 5.1%)




(b) May to October (calm 5.3%)

**Fig. 5. Wind rosettes for the study area for 2002.**

families that did not detect any swine odours, the closest family was located 2.3 km north of the nursery site (downwind of prevailing S winds) and northwest of the farrowing site.

Besides distance and directions, some other factors may also have played important roles such as the frequency and duration that the observer stayed outside, which depended on the habits or lifestyle of the residents, and the olfactory sensitivity of the observers to swine odours, which may vary greatly from one observer to another.

Figure 6 shows the reported annual odour durations and frequencies of the 23 families. Twenty locations with distances of 1.6 to 6.0 km had annual odour durations between 1 and 70 h and detection frequencies from 0.01 to 0.80%, which means annual non-odour detection frequencies of 99.20 to 99.99%. Three locations exceeded 1% occurrence frequency, R1 (2.8 km, 79 odour events, 291 h, 3.32%), R3 (5.4 km, 50 odour events, 132 h, 1.51%), and R8 (5.9 km, 13 odour events, 105 h,

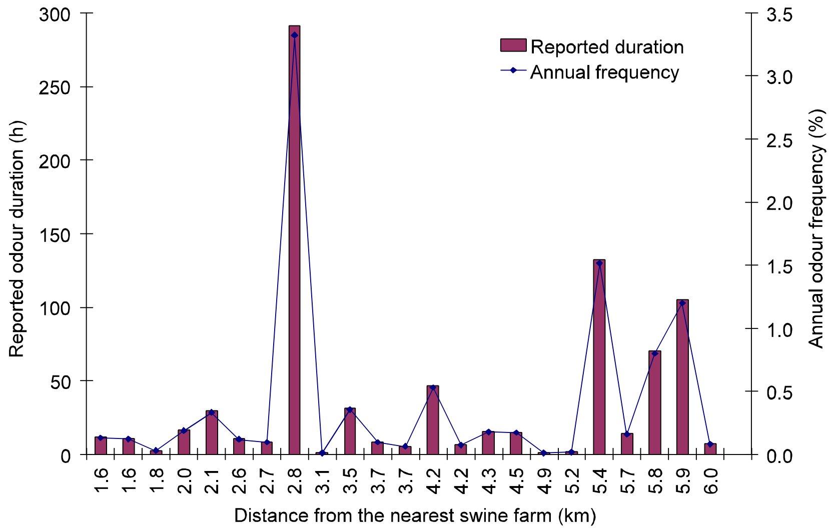



**Fig. 6. Reported annual odour durations and frequencies for each location.**

1.19%). It is should be noted that when the recorded durations were not well defined, estimations were made according to the observers' claims of durations such as durations recorded by observer R1 as "the whole morning", "the whole afternoon", "all day", etc. and the wind direction changes during the claimed time period. As previously discussed, odours from other sources such as the dairy farm and the nearby small swine farm could have been included in the total odours detected by observer R1; therefore, the actual odour occurrence frequency of this location as caused by the farrowing and nursery swine farms might be lower.

### Distribution of odour intensity and offensiveness

A total of 298 odour events were reported with odour intensities. As shown in Table 1, odours with intensity 4 (strong odour) were reported the most and accounted for 37.6% of all odours. Odours with intensity 3 (moderate odour) were the second highest (29.2%) followed by odours with intensity 5 (very strong odour, 15.4%). Odours with intensity 1 (very faint odour) were reported the least (4.0%) while intensity 2 (faint odour) was reported as 13.8% of all odours. This is quite different from the result reported by Guo et al. (2003), where odours with intensity 1 or 2 made up 66.5% of the total 263 odours reported by local resident odour observers.

The distribution of various odour offensive levels was similar to intensity distributions. Odour events with offensiveness 1 to 5 made up 4.7, 18.2, 30.7, 29.4, and 16.9% of all events, respectively. Odour events with offensiveness 3 or above accounted for 77.0% of all events.

Regarding seasonal intensity distributions, odours with intensities 3 or 4 were detected all the year round as presented in Table 1. Odours with intensity 5 were also reported almost every month except March and November. Odours with intensities 1 or 2 were not reported for some months. During the winter time, with the manure storage frozen, total odour emissions from the swine farms were reduced. However, odours with high intensities had been continuously reported. For example, in December 2001, all odours reported were with intensity 3 or above.

To obtain the intensity distribution at various distances from the odour sources, the total number of odour events for various intensities are plotted against the detection distances in Fig. 7. Within 2.5 km from the odour sources, odour events with intensities 1 and 2 were reported more than higher intensities while when distance increased high odour intensities were reported more often.

The above result caused concerns regarding the accuracy of odour intensity ratings by the observers. The percentiles of odour intensities observed by the five odour observers who reported the most odour events are given in Fig. 8. It was found that these observers reported most of the odours as intensity 3 or above. Of the 79 odour events that observer R1 reported, 20.3% consisted of intensity 1 or 2 odours, which was the highest among these five observers. Observer R5 living 5.8 km from a swine site reported 17 odour events: 88% were reported as intensity 4 or 5, 12% as intensity 3, and the observer never reported intensity 1 or 2 odour events. The most distant observer R9 reported two odours with intensity 4 and 5. At such distance from the swine site, very faint or faint odours were most likely to occur. It is obvious that some observers might have over-estimated odour intensities. They were only trained once in using the referencing n-butanol scale and did not calibrate their noses periodically during the experimental period. They might not be able to memorize the strength of the intensities and simply used the oral scale which mainly depends on one's understanding of odour intensity. Besides, when the odour is offensive, it is sometimes difficult to distinguish intensity from hedonic tone.

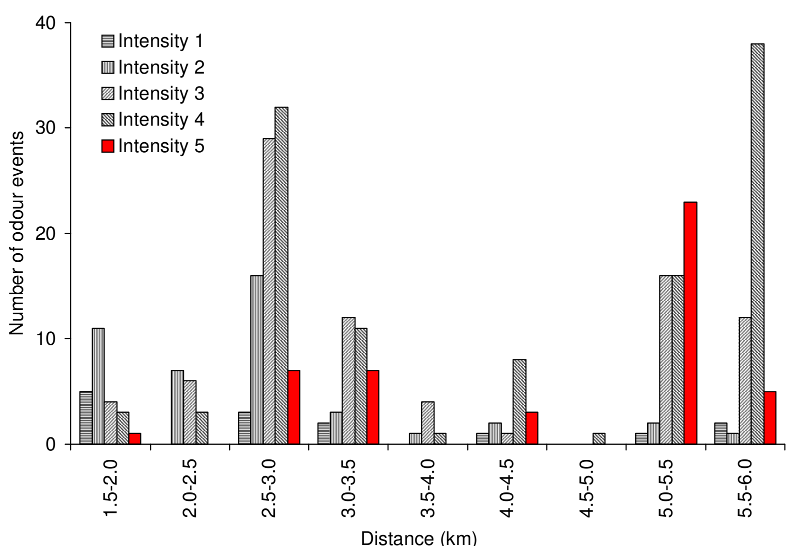



**Fig. 7. Odour events with various intensities at different distances.**

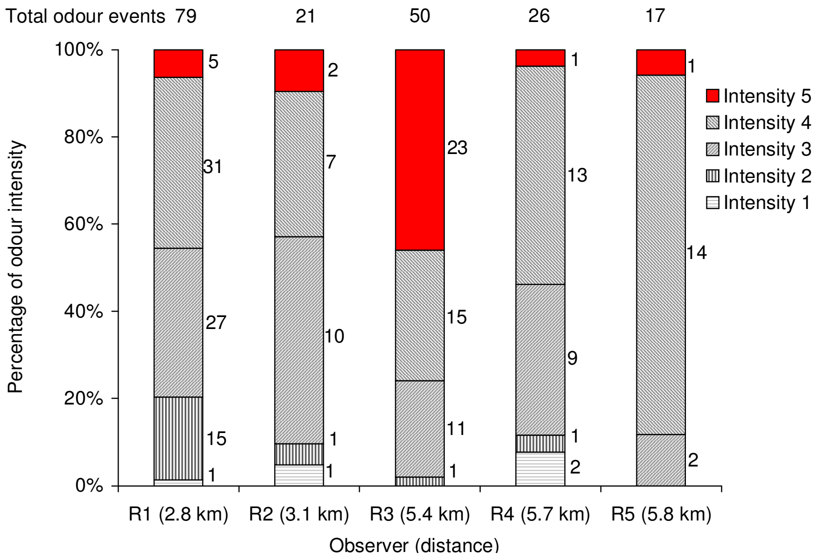



**Fig. 8. Odour intensity distribution of five observers reporting most odours.**

The above results caused three concerns for using the voluntary local residents as odour observers. First, the quality of the data, especially the odour intensity rating, might not be ensured due to the lack of periodic nose calibration using standard n-butanol intensity scale (Guo et al. 2001, 2003, 2004b; Nimmermark et al. 2003) or some observer's reluctance to do so (Guo et al. 2004b). Secondly, some observers might have biased views on intensive swine operations, which may result in biased data. Thirdly, odour monitoring was only done at the volunteers' residence locations, which might not cover all desired locations. Hence, improvement of this method is needed to increase the accuracy and credibility of the data obtained by this method. The possible options include implementing periodic nose calibration, screening the observers for bias for or against the intensive livestock operations, and taking measurements at designated times.

## CONCLUSIONS

Based on the results obtained from this study, the following conclusions can be drawn:

1. Swine odours were detected by observers from 23 families living 1.6 km to 6.0 km from the swine farms. Eleven families 2.3 to 6.0 km and five families 6.0 to 8.6 km away from the swine farms did not detect swine odours.
2. Most swine odours (70.3%) were detected during the warm season from May to October. Manure land application contributed to high odour occurrences in May, June, and October. The majority of odours (54.6%) were detected during 1700 to 0900h from the late afternoon throughout the night until the early morning. During the warm season, there were two peak hours for odour detections: 0600 to 0700h and 1600 to 1700h. However, during the cold season odours were detected the most during 1100 to 1200h.
3. Annual odour detection frequencies for twenty families ranged from 0.01 to 0.80%. Three families had higher odour occurrence frequencies of 1.19% (5.9 km), 1.51% (5.4 km), and 3.32% (2.8 km, near two other livestock farms).
4. Odours with intensity 3 or above were reported the most (82.2%) while very few low intensity odour events were reported. Odours with intensity 5 were reported throughout the year regardless of the season. Similarly, odours with offensiveness 3 or above made up 77.0% of all odours.
5. No correlation was found between the detection distance and number of odour events. In addition to weather conditions and topography, the following factors may affect odour detection frequency and intensity: 1) the distance and direction of the residence from the odour source, 2) the frequency and duration of the periods during which the observer stayed outside, which depended on the habits or lifestyle of the residents, and 3) the olfactory sensitivity of the observers to swine odours, which may vary greatly.
6. Using resident odour observers for long term and long distance odour dispersion measurement has proven to be practical and effective. However, improvement of this method is needed to increase the quality of the data. The possible options include implementing periodic nose calibration, screening the observers for bias for or against the intensive livestock operations, and taking measurements at designated times.

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