# Emission and Dispersion of Odour from Swine Operations

by

**Xiaojing Zhou**

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Department of Biosystems Engineering
University of Manitoba
Winnipeg, Manitoba

# ABSTRACT

Odour emissions and instantaneous downwind odour plumes were measured on two 3000-sow swine farrowing farms located in a flat area of southern Manitoba, one farm (Farm A) with open earthen manure storage (EMS) and another (Farm B) with negative air pressure (NAP) covered EMS. Air (odour) samples were taken in Tedlar bags with a vacuum chamber from exhaust fans of barns and the NAP EMS. A wind tunnel was used to collect air samples from the manure surface in the open EMS. A dynamic dilution olfactometer was used to analyze the collected air samples for odour concentrations, from which odour emissions were determined. The downwind odour plumes were quantified by 15 trained human odour sniffers using an 8-point n-butanol odour intensity scale. For each measurement session, the 15 sniffers were placed in a grid system at 100, 500, and 1000 m downwind from the facility with the assistance of GPS positioning systems. Each sniffer took 60 10-second sniffs within a 10-minute period and repeated three times within one hour. Three commonly used dispersion models (ISCST3, AUSPLUME, and INPUFF-2) were used to predict downwind odour distributions on the two farms. Dispersion predictions were based on the measured odour emission data for each farm and on-site weather data recorded by a portable weather station.

It was found the average odour emission rate from the negative pressure covered earthen manure storage (NAP EMS) was negligible in comparison with the open EMS (0.3 vs 20.3 OU/ s-m$^2$). The total odour emission from Farm A with NAP EMS was 58% of that from farm B with open EMS (174,552 vs. 303,120 OU/s). The open EMS contributed to 57% of total odour emission on Farm B; whereas the NAP EMS contributed to 2% of total odour emission on Farm A. Odour emission rate increased sharply when the outdoor temperature increased from 10°C to 15°C, but the rate changed little when outdoor temperature was above 19°C. Odour emission was lower in the early morning (500 – 700h) and evening (1900 – 2100h) than the mid day. Odour emission from farrowing rooms was 2 to 3 times higher than that from gestation rooms. Specifically, the average odour emission rate of the two farms was 22.9 OU/s-m$^2$ (316 OU/s-AU) from farrowing rooms and 9.6 OU/s-m$^2$ (113 OU/s-AU) from gestation rooms.

Downwind odour intensity measured by trained human sniffers on Farm A with covered manure storage was significantly ($P<0.05$) lower than that on Farm B with open manure storage at 100 and 500 m, but the difference in odour intensity at 1000 m was not significant ($P>0.05$) between the two farms. A reduction in odour emission by covering manure storage resulted in a reduction in separation distance required for odour annoyance-free, but the magnitude (percentage) of reduction in separation distance was considerably less than the reduction in emission rate. Specifically, a 46% difference in odour emission rate between Farms A and B resulted in a 14% difference in the separation distance for odour annoyance-free between the two farms.

When three commonly used dispersion models, namely AUSPLUME, ISCST3, and INPUFF-2, were used to predict downwind odour from the farms, the percentage of agreement between model predictions and field measurements was adequate for downwind distances of 500 and 1000 m, but relatively low for 100 m for all three models. Since the long-distance (>1000 m) predictions are of more practical value, all three models were considered to be adequate in predicting odour downwind from the swine operations.

The peak-to-mean ratios of downwind odour intensity were computed from field odour intensity measurements and analysed against averaging time, downwind distances, and atmosphere stability class. The peak-to-mean ratio of field odour intensity was greater for longer averaging times. The difference in peak-to-mean ratio between 1-minute and 1-hour averaging times was 4.2 times (2.43 vs. 10.13) for stability class B at 1000 m. The peak-to-mean ratio increased with downwind distance. Under the unstable atmospheric condition (stability class B), the 1-hour peak-to-mean ratio increased from 1.86 at 100 m to 10.13 at 1000 m. Higher peak-to-mean ratios occurred under unstable atmosphere conditions. The largest difference in peak-to-mean ratio between stability classes B and E was 2.7 times (10.13 vs. 3.81) for 1-hour averaging time at 1000 m.

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# Chapter 1. INTRODUCTION

## 1.1 Odour from Livestock Operations

The emission of odours from swine operations has been a major environmental concern where swine farms are becoming more intensive in North America. To some extent, this concern has become the obstacle to the expansion and development of the livestock industry. Odour is the sensations and perceptions that occur when a mixture of odourous compounds (odourants) stimulate receptors in the nasal cavity. Numerous odourous compounds are generated from anaerobic decomposition of manure in livestock operations. The effect of odour on humans may be physiological or psychological in nature. The physiological effect is caused by odourants in sufficiently high concentrations – generally at or above their chemical toxicity thresholds, whereas the psychological effect is due to the presence of unpleasant odours from the point of view of the basic emotions involved when odourant concentrations are generally much lower than their toxicity levels (Schiffman 1998). The concentrations of odourous gases in communities downwind from livestock operations are in general considerably lower than their toxicity threshold values and livestock odours are rarely associated with chemical toxicity. In the past decade, much research has been focused on the understanding of livestock odours, from measurement to odour impact, and on developing technologies for managing odour. These technologies include feed additives and dietary manipulation, manure additives, manure storage covers, and biofiltration. However, the application of these technologies in practice may not eliminate odour emission completely, and is prohibited by cost in many cases.

## 1.2 Odour Control by Separation Distance

An economic, yet effective livestock odour management strategy is to maintain separation (setback) distances between facilities and surrounding residential areas. The methods for estimating setback distances are either empirical (experience-based) or dispersion theory-based. In empirical methods, either equations or look-up charts are used to express the setback distances as a function of some key variables describing the livestock operation (type, size, manure storage, etc), the land use, and climatic and topographic conditions. In dispersion-based approaches, the concentration of odour is predicted by atmospheric dispersion models and the setback distance is determined by comparing predicted odour concentrations and occurrence frequencies with a set of criteria for acceptable odour exposure. The majority of the existing setback distance guidelines in Europe, Australia, and North America are experience-based, but the dispersion-based approaches are the choice for the future.

Atmospheric dispersion modelling is based on the diffusion theory of pollutants in the atmosphere for predicting pollutant concentrations at any distances downwind from the emission sources. The effectiveness of dispersion modelling depends on several key components, including: a) the source emission; b) the meteorological data; c) a dispersion model that is appropriate for a specific source type and release scenario; and d) post modelling analysis to assess the impact of the source. Currently, most air dispersion models used for livestock odour applications are adopted from models developed for industrial uses. When using these industrial dispersion models for livestock odours, some restrictions exist. First of all, emissions of odour from animal operations are highly variable, which makes quantifying the odour emission from livestock operations a complex process. Secondly, dispersion models usually calculate average concentrations of time periods from 5 minutes to an hour. This time averaged concentration does not account for the short-time concentration fluctuation caused by the atmospheric turbulence and/or changes in emission. Unlike industrial pollutants which are usually assessed on a time average basis, odour nuisance can arise from a very short period (duration of one breath) detectable exposure, even though the time-average concentration is undetectable.

Therefore, the concentration fluctuation has to be taken into account in odour dispersion modelling. There has been a lack of field data to validate the industrial models for livestock odour applications, because of the great difficulty and cost of such field measurements.

## 1.3 The Scope of Research

The overall goal of this thesis research was to quantify the emission and dispersion of odour from swine operations. Odour associated with livestock operations is from three main sources: (1) building exhaust, (2) manure storage, and (3) land application. A shift to injection-spreading of manure application practice seems to result in more odour complaints traceable to animal production facilities and manure storage units than to the land application of manure (Jacobson et al. 1998). But our understanding of odour emissions from buildings and manure storage is still elusive. In particular, the relative contributions to odour from barns and the manure storage are not well known. This project aimed to quantify these relative odour contributions by comparing odour emissions and dispersion between two similar hog operations with different manure storage systems. This research also attempted to characterize odour plumes downwind of large scale swine operations, in particular the peak-to-mean ratio of odour intensity in the plumes. The specific objectives of this thesis research are described in the following section.

## 1.4 Objectives

(1) To quantify relative contributions to odour emission from swine buildings and manure storage facilities

(2) To assess the effect of covering manure storage on odour emission, and on odour levels downwind from swine operations

(3) To compare and assess existing odour dispersion models and setback models for their use in livestock odour application through comprehensive field odour measurements.

(4) To determine the peak-to-mean ratios of field odour intensity as affected by averaging time, downwind distance, and atmospheric stability.

# Chapter 2. LITERATURE REVIEW

## 2.1 Swine Odour Facts

For most people, pigs stink seems to be a common knowledge. Therefore, odour is always associated with swine production facilities where manure along with feed are the main contributors to malodour release from swine operations (Schaefer 1977). Malodours from swine operations are usually generated from the decomposition of organic matter in the manure and feed. During the accumulation of manure inside barns and in storage, manure can be decomposed aerobically or anaerobically, depending mainly on the availability of oxygen during the degradation process. In a balanced anaerobic decomposition process, anaerobic bacteria decompose carbohydrates, proteins, and fats during an acid fermentation phase to organic acids. Methane-producing micro-organisms break down the organic acids to produce methane and carbon dioxide (Hobson and Shaw 1974). Spoelstra (1980) described a laboratory experiment he did in 1979 in which a mixture of freshly voided faeces and urine was anerobically incubated. The products were mainly volatile fatty acids and carbon dioxide. Only small amounts of methane and other products were formed. He concluded that the main factors contributing to the low rate of methanogenesis in stored pig waste included low natural temperature during storage, overloading of degradable organic materials and high levels of $NH_3$ in the waste. This suggested that the imbalance between the processes of acid formation and methane production is the main cause of the accumulation of volatile compounds in the storage of hog waste.

Research on identifying the gases present in swine odour began in the mid- to late- 1960s. Merkel et al. (1969) published a list of compounds by chromatographic analysis of the airborne components from swine buildings. O’Neill and Phillips

(1992) presented a literature review on the identified odorous substances in livestock wastes and in the air around them. A total of over 168 volatile compounds associated with manure decomposition and animal metabolic activities have been identified by different researchers. These compounds can be grouped into eight categories: carboxylic acid, alcohols, phenolics, aldehydes, nitrogen heterocycles, mercaptans, amines, and sulfides. The most frequently reported odorous compounds which cause the most concern seem to be the volatile fatty acids, hydrogen sulfide, p-cresol, insole, sketole, diacetyl, and ammonia, by virtue either of their relatively high concentrations or of their low detection thresholds. The odorous mixture may vary with the microbial activity in manure, which is highly dependent on many environmental conditions such as temperature, pH, oxygen concentration, and moisture content (Schmidt and Jacobson 1995), as well as the nutrient content of the manure (Hobbs et al. 1996, Zhu et al. 1999a). This leads to the change of both chemical composition and concentration of each composition in odour mixture with the location, the size and type of swine operation, production practices, manure handling practices, season, temperature, humidity, time of day, and wind speed. Therefore, the overall odorous mixture is highly variable.

Identifying the presence of odorants in swine odour is not enough to understand the characteristics of the odour since these odorous compounds are interactive and smell differently than pure compounds when mixed together. The combination of odorous compounds may result in five possible results as addition, reduction, independence, synergism, and averaging (Hill and Barth 1976). Research with mixtures of odorants of known odour intensity proved that it is not possible to predict the odour intensity of a mixture of even two components (Rosen et al. 1962). Efforts have been made to correlate odour intensity and concentration of some major malodour indicators in swine odour. Barth and Polkowski (1974) identified the odorous components in stored dairy manure and found that the volatile organic acids correlated best with odour intensity. A study conducted by Spoelstra (1977) found that indole and skatole could not be indicators of swine odour because the concentrations of these compounds might decline during storage. He also reported that neither ammonia nor hydrogen sulphide was a suitable indicator for swine odour (1980). Williams (1984) found that BOD can be applied as an indicator in odour from both aerobic and post treatment manure storages. Pain and Misselbrook (1990) reported a correlation between odour concentration and $NH_3$ concentration in air, but the relationship is not constant for all farm odours and odour is still detectable at zero ammonia concentration. However, other researchers have found that odour from swine operations cannot be well represented by any single or even a small group of compounds (Hobbs et al. 1999). At present, there is no consistency in the literature regarding the correlation between specific odorant gas emission and the odour sensation.

An odour needs to be assessed both qualitatively and quantitatively. Although analytical techniques have been used to identify individual odorous compounds and their concentrations in an odour, due to the lack of correlation between the concentrations of individual compounds and the human sensation, the human olfactory sense is most commonly used for odour evaluation. Presently the most important parameters to quantify an odour are odour concentration and odour intensity. The quality parameters include odour description and hedonic tone.

The odour concentration is defined as the volume of diluents required to dilute a unit volume of odorous gas until the detection threshold of the odour is obtained (Schmidt 2002) and is presented as “odour unit’ (OU) in North America. In Europe, "odour unit per cubic meter" (OU/m$^3$) is used to describe odour concentration, which is defined as the concentration of odour in one cubic meter of air at the panel's detection threshold of the odour (CEN 2003). Odour concentration can be measured by olfactometers with human assessors. In this method, odorous gas sample is diluted with odourless air at a series of dilution ratios. The mixture is presented to a human panel in an order of ascending concentrations and the detection threshold of each individual panel is obtained. Measurement of odour concentration by using dynamic olfactometry with human assessors has been accepted as the industry standard in the United States and Europe (ASTM 1991, CEN 2003).

Odour intensity is the relative strength of the odour above the detection threshold and is a measure of the human response to an odour (Hamilton and Arogo 1999). For an individual odourous compound, the relationship between its odour intensity and its mass concentration follows a power law (Stevens 1960):

$$I = k\,C^{n} \qquad (2.1)$$

where I is the odour intensity (strength), C is the concentration of odourant, and k and n are constants that are dependant of specific odorous compounds. By measuring the concentration of an odorous compound, the intensity of odour can be calculated. However, as stated before, swine odour is a mixture of over 168 odorous compounds, and odour is not well represented by any individual chemical constituent, therefore, the intensity of swine odour can not be obtained from the measurement of concentration of any odorous compound (Clanton et al. 1999). A common way of measuring odour intensity is comparing the intensity of an odour to the intensities of different but known concentrations of a reference odorant (Zhang et al. 2002a).

Odour Intensity Referencing Scale (OIRS) method serves as a standard method for referencing suprathreshold odour intensity (Schmidt 2002, ASTM 1999).

Panelists are provided a reference odour compound (n-butanol) at a series of different concentrations and asked to compare the intensity of tested odour with the references. Two methods can be used in this standard: dynamic-scale method and static-scale method. The dynamic-scale method involves the use of an olfactometric device with a continuous flow of butanol. The static-scale method utilizes a set of water solutions with different dilutions of standard odorant (butanol). The odour intensity of a sample is expressed in parts per billion of butanol.

Rating or ranking is another commonly used method for odour intensity measurement. Odour samples can be presented to human panelists directly for evaluation and are rated on a numerical scale, with the higher number representing the more intense odour. Zhang et al. (1999) developed a method using the labeled magnitude scale (LMS) (Green et al. 1993) and cloth swatches exposed to swine odour to rank the odour intensity. Odour is drawn through the swatch by using a vacuum pump and adsorbed on the swatch. The swatch is then presented to panelists, and odour intensity can be quantified based on the scale to numerical values.

Odour description describes the characters of the smell, for instance, what the odour smells like or related to any known substances. Descriptors of various odours can be listed on a table or a “descriptor wheel” (St. Croix Sensory 2000, Hamilton and Arogo 1999). Odour description is more commonly used in food, beverage, perfume, and cosmetics industry.

Hedonic tone is a measure of the pleasantness/unpleasantness of an odour (St. Croix Sensory 2000, Hamilton and Arogo 1999). It is subjective to people’s personal preference and experience. Hedonic tone is commonly measured on an arbitrary scale, say, from –5 as most unpleasant to +5 as most pleasant, or from –10 to +10 as the range of classification.

## 2.2 Quantifying Source Emissions of Odour from Swine Operations

Quantifying the amount of odour emitted from a swine operation directly influences the prediction of its impact on the neighboring communities. Odour associated with swine operations is from three main sources: (1) building exhaust, (2) manure storage, and (3) land application. A shift to injection-spreading of manure application practice seems to result in more odour complaints traceable to animal production facilities and manure storage units than to the land application of manure (Jacobson et al. 1998). The following review will focus on emissions from building and manure storage.

### 2.2.1 Odour emissions from animal buildings

The amount of odour emission from buildings is usually quantified by odour emission rate, which is the product of the odour concentration ($OU/m^3$) (OU is often used in North America) from the building exhaust multiplied by the total building ventilation rate ($m^3/s$). This would result in a unit of OU/s ($OU.m^3/s$ in North America). When applying dispersion models, the pollutant concentration is commonly expressed as mass per unit volume ($g/m^3$), and the pollutant emission rate is expressed as mass per second (g/s). Therefore, most researchers presently accept the unit $OU/m^3$ as odour concentration and OU/s as odour emission rate to match the unit in dispersion models. Odour emission rate is also expressed in odour units per unit floor area ($OU/s/m^2$) or per animal unit (OU/s/AU) for comparisons among different facilities.

Measuring the ventilation rate of the building is important in determining the odour emission rate from the building. However, the accurate measurement of building airflow is extremely difficult (Gay et al. 2003). For mechanically ventilated buildings, the ventilation rate can be measured using either fan-wheel anemometers, tracer techniques (Demmers et al. 2000), or static pressure readings and fan curve data provided by manufacturers (Gay et al. 2003). The use of full-size fan-wheel anemometers is accurate and common for measuring airflow of building openings, but it needs a permanent installation that is not suitable for measurement involving a large number of building exhausts. When using static pressure readings and fan curve data, there are many factors that affect airflow measurement, including diurnal animal activity, dust accumulation on fan shutters and blades, loose fan belts, and changes in building static pressure (Bicudo et al. 2002). British Standards Institution suggests a standard method to measure the local air velocity at each of a series of points within the fan opening and then to carry out a numerical integration across the whole openings. The summation of airflow from each opening is determined as the total airflow rate of the building. The tracer gas ($CO_2$ and $SF_6$) mass balance method is commonly used to determine the ventilation rate of naturally ventilated buildings or buildings with a combination of mechanical and natural ventilation system (Heber et al. 2001, Phillips et al. 2001, Guo et al. 2003).

Odour emissions from swine buildings are affected by many factors, including the type and age of operation, building design, outdoor temperature, ventilation rate, manure handling system, barn management, and the use of manure treatment technology (O’Neill and Phillips 1991). A number of previous researchers (Jacobson et al. 1999, Zhu et al. 2000a, Martinec et al. 1998, Schauberger et al. 1999, Zhang et al. 2001, Zhang and Zhou 2003, Gay et al. 2003) reported that large variations in odour emission exist among different types of swine operations, among the same type of operation but different facilities, and even on the same facility over time. For comparison reasons, reported odour emission data are commonly grouped by operation type with manure handling systems and ventilation designs specified.

Jacobson et al. (1999) reported that average odour emission rate from gestation farm and farrowing farm in Minnesota with mechanical ventilation system and pull-plug manure handling system was 3.6 OU/s/ $m^2$ and 0.4 OU/s/ $m^2$ respectively; In the same area Zhu et al.(2000a) reported that measured odour emission rate from gestation rooms and farrowing rooms with mechanical ventilation system and deep pit manure storage ranged from 3 – 20 OU/s/ $m^2$ and 5 – 12 OU/s/$m^2$ ; while Zhang et al. (2001)'s measurements showed that with shallow pit manure storage and mechanical ventilation, odour emission rate ranged from 6 – 18 OU/s/ $m^2$ from gestation rooms and from 7 – 62 OU/s/ $m^2$ from farrowing rooms.

The variation of odour emission reported in the literature can be attributed to a number of factors. Results from different countries or areas are subject mainly to variations of geographic locations, building design, management practice, and climatic conditions, etc. Variations among different farms in the same area are mainly caused by such factors as the type of operation, building design, management practices, and manure handling methods. Within the same farm, variations are more related to the difference in time frames of sampling and differences in change of climatic conditions between sampling days, as well as differences in animal life stage.

The type of operation is the most common factor used to describe the odour emission characteristics of the facilities. Zhang et al. (2003) conducted measurements of odour concentration and odour emission rate from three swine farms which all had gestation, farrowing, and nursery operations. Measurements on different buildings at the same farm were conducted within the same day and repeated three times for each farm between May and September of the year. Odour emission rate from nursery buildings ranged from 11 – 36 OU/s/$m^2$. They reported a general trend of odour concentration and emission as follows: nursery buildings were higher than farrowing, and farrowing higher than gestation. Zhu et al. (1999b) carried out daylong odour measurements on five swine farms and reported the similar result that nursery building had the highest odour emissions. However, these measurements were very limited and not representative of the emissions on an annual basis.

Variations in outdoor temperature and building ventilation rate contribute significantly to the variations in odour emission from animal buildings. Ogink et al. (1997) conducted a study on odour emissions from a number of farrowing and fattening pig housing systems in the Netherlands. They observed a positive effect of ventilation rate on odour emission. Zhang et al. (2003) showed a general trend of lower odour concentration with increased outdoor temperature and ventilation rate in swine barns. Hartung et al. (1998) reported diurnal odour emissions from a maiden sow building and a fatteners building. They observed a decrease of odour concentration in the course of the day between 11:00 am and 7:00 pm, and an increase of odour emission rate at 11:00 am until 1:00 am in the course of the day. Zhu et al. (1999b) conducted 12-h period odour measurement in 5 swine buildings. They reported that odour levels in these facilities generally tended to increase slightly in the afternoon, but the variation during the day was not drastic for most of the buildings. Peak odour levels from some of the animal buildings were observed in their study which might be caused by increased animal activities inside the building at or before the time of sampling. In terms of odour emission rate, they also observed a general trend of increasing odour emission rate starting from 11:00 am for all the swine buildings included in the study, which was attributed to the higher ventilation rate and higher outdoor temperature in the afternoon. Zhang et al. (2003) measured odour emissions from a farrowing and a dry sow building on the same farm in the morning, early afternoon, and evening respectively for 3 days. No particular pattern of odour level change was observed, but significant increases of odour emission rate in the afternoon and evening from both buildings were reported. Wang (2003) and Langenhove and Bruyn (2001) also indicated similar results of no significant changes in odour level during the day in naturally ventilated pig sheds in Australia and mechanically ventilated pig farms in Belgium, respectively.

Ogink et al. (1997) measured odour emission from 8 farrowing and fattening buildings respectively and observed less between-farm and within-farm variations of odour emission from farrowing sites than that from finishing sites. The small between-farm variation for sow system may be related to consistent management practices and layouts of the compartments in the sow system. The large within-farm variation in the finishing systems reflects the effect of weight change of fattening pigs compared to stable weight of pigs in the sow system.

Schauberger et al. (1999) developed a model using outside temperature to predict odour emission from a mechanically ventilated livestock building. The model was based on a steady-state balance of the sensible heat fluxes to calculate the indoor temperature and the related volume flow of the ventilation system. The odour emission rate was quantified as odour flow $E_m$ (OU/s) or specific odour flow (OU/s-LU), which is dependant of the animal type and housing system. In their model calculation, the diurnal variations in odour release were not considered. The data was obtained from a literature review by Martinec et al. (1998) and modified with outdoor temperature accounted as:

$$E_m(T_0) = E_m(0.905 + 0.0095T_0) \tag{2.2}$$

where

$E_m$ = odour emission rate (OU/s)

$T_0$ = outdoor air temperature

Schauberger et al. (2001) further took the diurnal variation of the odour release into account by applying a sinusoidal function with the period of 24 h, proposed by Pedersen and Takai (1997) on the basis of the variation of the animal activity over the time of the day. They assumed that the time course of the energy release and the odour release to be the same. The odour release was calculated as:

$$E(t) = E_m(T_0)\left[1 + 0.2\sin\left(\frac{2\pi}{\tau}(t - 7.25)\right)\right] \tag{2.3}$$

The model of Schauberger et al. (2001) showed significant improvement in considering the variability of odour emission from livestock operations. However, it does not include some other factors which are also critical in determining the production and emission of odour from livestock operations, such as the type of operation, management practices, manure handling system, and odour control measure used in the building. These factors need to be incorporated into modeling odour emissions.

### 2.2.2 Odour emission from manure storage in swine operations

Manure storage is another primary source of odour emission from swine operations. Compared to studies on the odour emission from animal buildings, less information has been reported on the emission of odour from manure storage. The emission rate from manure storage is usually measured using portable wind tunnels (Schmidt et al. 1999, Smith and Watts 1994, Pain et al. 1991). These wind tunnels are open bottom chambers that are placed over the emitting surface. Filtered ambient air is blown or drawn through the tunnel to mix with and transport the emissions away from the emitting surface (Smith and Watts 1994). The odorous air mixture is sampled at the outlet of the tunnel and the odour emission rate is estimated by multiplying the outlet stream odour concentration and the airflow rate through the tunnel. Researchers have found that odour emissions increased as tunnel wind speed increased. The power function relationship between odour emission and tunnel wind speed was established by Schmidt et al. (1999) on the emission measurement over manure storage surface:

$$E_v / E_1 = V^{0.89} \tag{2.4}$$

where

V = given bulk tunnel velocity (m/s)

$E_1$ = emission rate at reference wind speed of 1 m/s

$E_v$ is the emission at velocity V

This result corroborated earlier work by Smith and Watts (1994) on cattle feedlots odour emissions. The research revealed the fact that odour emission rates measured by wind tunnels under controlled wind speeds may not reflect the odour emission rates in the field where the wind speed changes instantaneously. However, before the correlations between the measured emissions under the controlled tunnel velocity and the real emissions at ambient conditions are clear, the wind tunnel is still the most acceptable method for odour emission measurement for manure storage.

## 2.3 Odour Dispersion Modelling

### 2.3.1 Steady state Gaussian plume models

Modelling air dispersion in the atmosphere has been studied since the 1920's and has been widely used for predicting the concentrations of pollutants downwind from industrial sources. The Gaussian plume theory is the basis of air dispersion (diffusion) in the atmosphere and forms the basis of several commercially available atmospheric dispersion models (Boubel et al. 1994). The Gaussian plume idea uses Gaussian or normal distribution to describe the crosswind and vertical distribution of pollutants in the atmosphere. Figure 2.1 shows a schematic representation of a Gaussian plume.

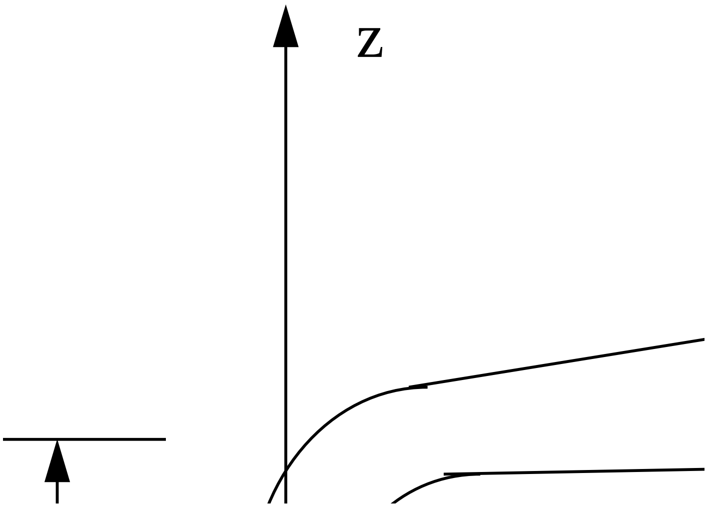


**Figure 2.1.** Schematics of Gaussian plume

Assuming that the material balance or mass conservation is maintained during dispersion, the Gaussian plume equation was derived to predict downwind concentration as follow (de Nevers 1995):

$$C(x,y,z)=\frac{Q}{2\pi\sigma_y\sigma_z U}\exp\left(-\frac{y^2}{2{\sigma_y}^2}\right)\exp\left(-\frac{(z-H)^2}{2{\sigma_z}^2}\right) \tag{2.5}$$

where

C = concentration of pollutant at point (x, y, z), g/m$^3$

y = distance in the across wind direction, m

z = vertical distance from the ground, m

H = height of the plume above ground level, m

Q = source emission rate, g/s

U = wind speed, m/s

$\sigma_y$ = dispersion coefficient, also the standard deviation of the plume distribution in the horizontal direction at a distance x, m

$\sigma_z$ = dispersion coefficient, also the standard deviation of the plume distribution in the vertical direction at a distance x, m

Both dispersion coefficients $\sigma_y$ and $\sigma_z$ are functions of distance x, and they are further discussed in the next section.

The Gaussian plume equation is based on the following assumptions (Turner 1994):

- Continuous emission: the emission of pollutant is taking place continuously and the rate is constant over time.
- Conservation of mass: during the transport of pollutants from source to receptor, the emitted mass from the source is assumed to remain in the atmosphere. No loss of the material through chemical reaction, gravitational settling, or turbulent impaction.
- Steady-state conditions: the meteorological conditions are assumed to remain unchanged over the time period of transport from source to receptor.
- Crosswind and vertical concentration distributions: the time averaged concentration profiles at any distance in the crosswind direction (horizontal and vertical direction) are well represented by a Gaussian, or normal distribution.

The following input parameters are of significance in ensuring good model output.

**Dispersion coefficients, $\sigma_y$ and $\sigma_z$**

The plume size is defined by the two dispersion coefficients $\sigma_y$ and $\sigma_{z,}$ which are dependent upon meteorological conditions and downwind distance x. To specify the numerical value of $\sigma_y$ and $\sigma_z$, Hay and Pasquill (1959) suggested that they are best determined from measurements of the standard deviation of the wind direction. Draxler (1976) calculated plume dispersion directly from fluctuation measurements. In absence of wind fluctuation measurement, Pasquill (1961) provided a scheme for use with routine meteorological data for dispersion from low-level, non-buoyant sources over open, level terrain for steady-state meteorological conditions. The scheme defined the variation and stability of the atmosphere using a series of stability classifications based on wind speed, solar radiation, and cloudiness, which are basically obtainable from routine observations (Table 2.1).

**Table 2.1.** Atmosphere stability classification (Pasquill 1961)

| Surface wind speed (at 10 m) | Day Solar radiation, W/m$^2$ | | | Night | |
|---|---|---|---|---|---|
| m/s | Strong >600 | Moderate 300-600 | Slight <300 | Thinly overcast >4/8 | Clear <3/8 |
| <2 | A | A-B | B | G | G |
| 2-3 | A-B | B | C | E | F |
| 3-5 | B | B-C | D | D | E |
| 5-6 | C | C-D | D | D | D |
| >6 | C | D | D | D | D |

Zannetti (1990) presented a summary table based on the USEPA (2000) meteorological monitoring guidelines to define the stability class of atmosphere from the standard deviations of wind direction fluctuations.

**Table 2.2** Atmosphere Stability Class Based on Standard Deviations of Wind Direction Fluctuations. (Zannetti 1990)

| Pasquill Stability Class | St.Dev of Horizontal wind direction | St.Dev of vertical wind direction |
|---|---|---|
| A | Greater than 22.5 ° | Greater than 11.5 ° |
| B | 17.5 ° to 22.5 ° | 10.0 ° to 11.5 ° |
| C | 12.5 ° to 17.5 ° | 7.8 ° to 10.0 ° |
| D | 7.5 ° to 12.5 ° | 5.0 ° to 7.8 ° |
| E | 3.8 ° to 7.5 ° | 2.4 ° to 5.0 ° |
| F | Less than 3.8 ° | Less than 2.4 ° |

The stability classes are representative of different meteorological turbulence conditions. Stability class A represents strongly unstable daytime conditions, B represents moderately unstable conditions, C represents slightly unstable conditions, D represents neutral (overcast) conditions, E represents slightly stable conditions, and F represents moderately stable conditions (Turner 1994). These stability classifications were developed to allow the use of available meteorological data to determine the dispersion parameters. Many mathematical models have been developed for the calculation of dispersion coefficients based on atmospheric stability classes (Chen et al. 1998). Gifford (1960) used these stability classes to determine the horizontal and vertical dispersion coefficients as the function of the downwind distance from the source, which is called Pasquill-Gifford dispersion parameters.

It should be noted that the dispersion parameter values of Pasquill-Gifford were based on observations from a short release (3 – 10 minutes) (Pasquill 1961, Turner 1994), but is still most widely accepted in air pollution dispersion modelling. For the application of these parameters to modelling agricultural odours, Gassman (1990) indicated that Pasquill's scheme was adaptable as long as the basic assumptions were not violated. Smith (1993) stated that for ground level agricultural odour sources, the preferred method would appear to be the equations used in the Industrial Source Complex Short Term (ISCST) model, based on the empirical Pasquill-Gifford curves.

### Peak to mean concentration ratio

In general, the steady-state Gaussian dispersion theory is associated with assumptions on constant and continuous emission rates, unchanged meteorological conditions during the travel of pollutant from the source to the receptor, and Gaussian distribution of concentration in crosswind directions. Also the calculated downwind concentration represents an average concentration over a period of time. However, large, short period fluctuations in measured concentration levels have been consistently reported and they are considered characteristic feature of the atmospheric dispersion process (Gifford 1960). Since the fluctuations may exceed two orders of magnitude occasionally, these short period concentration peaks may cause significant air pollution effect, and therefore they should be accounted for in air pollution models. In the steady-state Gaussian plume model, the instantaneous concentration fluctuations are smoothed out by time averaging output (Pope and Diosey 2000). In other cases, if the pollutant is released instantaneously and moves as a series of puffs rather than as a continuous stream, the cycling back and forth of the pollutant will also increase the instantaneous concentration. This puff phenomenon and corresponding peak concentrations also are not accounted for in the steady-state Gaussian plume model. Figure 2.2 demonstrates smoke plumes observed instantaneously and averaged over 10 minutes and over 2 hours, whereas Figure 2.3 presents the crosswind concentration profiles showing that the centre line concentration for the instantaneous plume is significantly higher than that for the time-averaged plume. It can be seen that as the averaging time increases, the plume size (width) becomes larger and the peak concentration becomes smaller.

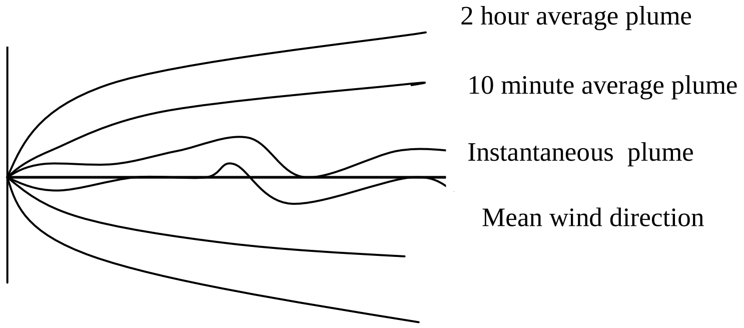


**Figure 2.2.** A smoke plume observed instantaneously and average over 10 minutes and over 2 hours (Slade 1968)

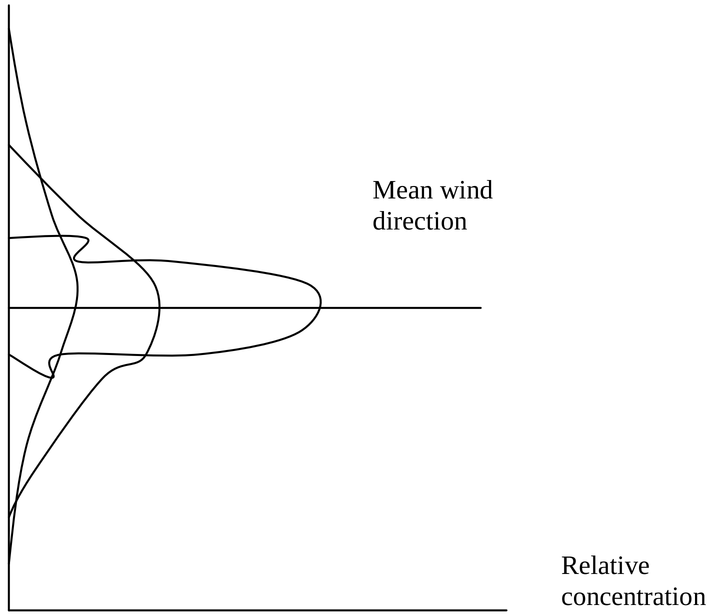


**Figure 2.3** Crosswind concentration distributions for instantaneous, 10 min, and 2 h average

To determine the concentration fluctuation, one strategy is the use of a “peak-to-mean” ratio to modify the mean concentration obtained from the standard dispersion models. Considerable effort has been taken by researchers to determine the peak concentration (Turner 1994). In the book of Turner (1994), he indicated that a one-fifth power law with sampling time for sampling periods from about 3 minutes to about half an hour was reported by Stewart et al. (1958) and the power law was reported applicable for sampling time from 3 seconds to 10 minutes as well by Cramer (1959). Gifford (1960) reported that for a source and receptor located at the same level, the peak-to-average ratio could be expected to be in the range from 1 to about 5. However, when concentrations are observed at levels considerably off the release height, or off the centre line, the peak-to-mean ratios are much higher than those given by the power law. In addition to sampling time, Singer (1961) identified that the stability of the atmosphere and the type of terrain also affected the peak-to-mean ratio. Hino (1968) examined the relationships between ground level concentrations and sampling times and concluded that the concentration was proportional to sampling time to the –0.5 power for sampling times between 10 minutes to 5-6 hours. He referred the –0.2 power law as valid for sampling time less than 10 minutes. Hino’s results on the peak-to-mean ratio are presented in Table 2.3.

**Table 2.3.** Peak to mean ratio of pollutant concentration reported by Hino (1968)

| Sampling Period | Peak to One-Hour ratio (n.u) |
|---|---|
| One hour | 1.0 |
| 30 Minutes | 1.3 |
| 10 Minutes | 2.3 |
| 3 Minutes | 4 |
| 1 Minutes | 4 to 7 |
| 30 Seconds | 4 to 10 |

Smith (1993) used a power function to describe the relationship between mean concentration ($C_m$) over a long time interval ($t_m$) and peak concentration ($C_p$) at a short time interval ($t_p$):

$$\frac{C_p}{C_m} = \left(\frac{t_m}{t_p}\right)^u \tag{2-6}$$

Smith (1993) suggested the following values of the exponent u depending on the stability of the atmosphere (SC): 0.35 at SC=4, 0.52 at SC=3, and 0.65 at SC=2. By using half hour as mean value and 5 s as single breath time, the peak-to-mean factors were obtained as shown in Table 2.4.:

**Table 2.4.** Peak-to-Mean factor under different stability class (Smith 1973)

| Stability Class | Peak-to-Mean factor |
|---|---|
| 2 | 43.25 |
| 3 | 20.12 |
| 4 | 9.36 |
| 5 | 4.36 |
| 6 | 1.00 |
| 7 | 1.00 |

Schauberger et al. (2000) further incorporated the downwind distance into the calculation of peak-to-mean factor using a relationship developed by Mylne and Mason (1991) as follows:

$$\psi = 1 + (\psi_0 - 1)\exp\left(-0.7317\frac{T}{t_l}\right) \qquad (2.7)$$

where

$\psi$ = peak-to-mean factor

$\psi_0$ = peak-to-mean factor calculated from equation 2.6 of Smith (1973)

T = travel time to distance x at the mean wind speed

$t_l = \sigma/\gamma$

$\sigma$ = variance of wind speed averaged over three wind components

$\gamma$ = rate of dissipation of turbulent energy

## Application to agricultural odours

The application of the Gaussian plume dispersion model for the prediction of downwind odour concentration from agricultural sources started from the early 1980's. Several Gaussian plume models (e.g. ISCST3, STINK, AUSPLUME, and ADMS3) which are commercially available have been evaluated for use in livestock odour prediction (Sheridan et al. 2004). Janni (1982) simply evaluated the effects of various meteorological parameters and emission heights on downwind odour concentrations from agricultural sources using an EPA Gaussian air pollution model PTDIS. In his research, steady state conditions, constant wind speed, and open level terrain were assumed. By using a hypothetical source emission rate of 1 g/s and wind speed of 1 m/s, ground-level odour concentrations were estimated for downwind distances between 0.5 and 30 km for the six stability classes. Based on the results, Janni (1982) concluded that the wind speed and stability class, downwind distance, and source emission rate were determinant factors affecting odour dispersion processes and predicted downwind odour concentrations. He further suggested that the wind speed and stability class can be taken advantage of to increase odour dispersion during land application and agitation of manure storage, and proper separation distances can be used to minimize the odour impact on downwind receptors. However, short-term concentration fluctuations were ignored in his research since he thought short-term exposure to odour would not cause offensive complaints. This posed a disagreement with the fact that it is instantaneous odour perception (peak concentration) other than average concentration that causes odour nuisance and complaints.

Carney and Dodd (1989) compared the measured downwind odour concentrations with that predicted by Gaussian plume models. The experiment was carried out on a point source (manure tank), a linear source (linear land manure spread), an area source (land spreading of manure), and a swine building. They collected downwind odour samples and quantified odour concentrations by using an olfactometer. They then used a Gaussian model to predict the odour dispersion. In their model prediction, downwind odour concentration fluctuations were taken into account by taking five times the 3 minute average and the 5 s peak concentrations. They concluded that the Gaussian plume model was a good indicator of odour dispersion from a point source and a linear source. But for area sources, good agreement was found only if an equivalent width of 10 m is used.

Smith (1993) developed a program (STINK) to calculate the odour dispersion from agricultural aerial sources. An aerial source is subdivided into strips that were roughly 2 m wide and perpendicular to the wind direction. Each strip was treated as a line source and the total concentration was calculated by numerical integration of equations for the line source. The program demonstrated the improved prediction of downwind odour concentration over area source emission. It also further demonstrated the importance of wind speed and odour emission rate in determining the odour dispersion. However, concentration fluctuations were not considered in the model and there was no reported field data for model validation.

Mejer and Krause (1985) questioned the applicability of industrial Gaussian plume models for agricultural applications due to the different scales of problems in industry and agriculture, and the uncertainty involved in odour measurement with olfactometers and panellists. They performed tracer gas field experiments for a point source in which odour was replaced with propane gas to facilitate high measurement accuracy, and then compared the model simulation results with the field measured concentrations. They concluded that the Gaussian model generally agrees with the experimental results with reasonable accuracy. They also pointed out that there was a lack of experimental data for the calibration of diffusivity parameters for odour.

Schauberger et al. (2000b) modified a Gaussian plume model for the assessment of odour sensation around livestock buildings. On the basis of calculating the half hour mean concentration along the plume centre line using the Austrian regulatory dispersion model, they assessed the expected maximum concentration in an interval of a breath.

McGahan et al. (2000) used the Australian regulatory dispersion model AUSPLUME to assess the impact of odour from piggeries in Australia on the surrounding communities for siting new operations. The simulation is done on five different size pig operations (500, 2000, 5,000, 10,000 and 25,000 standard pig units). No concentration fluctuation was considered and the model output was used directly for setback determination. Again, there were no field measurements to validate their modelling results.

Various Gaussian plume dispersion models have been studied to predict odour concentrations from agricultural sources and significant differences in model prediction have been shown in different studies (Smith 1993, Curran et al. 2002). There is a general agreement that limited field data are available to validate the models (Guo et al. 2001). One of the challenges in field odour measurement is that it is very hard to evaluate the instantaneous downwind odour by the commonly used olfactometer technique for odour concentration measurement. When collecting a downwind sample into a sample bag for olfactometer analysis, it takes certain amount of time, say 3 – 5 minutes. Therefore the collected sample is a composite sample over the period of sampling time, not representative of the odour that people will experience at downwind locations under instantaneous changes in wind direction and wind speed. A method using human sniffers to quantify the instantaneous odour intensity posses the potential in solving the problem and the detailed procedures are described in German guideline for determining field odour plumes by human sniffers (VDI 1993). Several studies have used human assessors to measure odour plumes from livestock units or to validate dispersion models (Li et al. 1994, Hartung and Jungbluth 1997, Zhu et al. 2000b, Guo et al. 2003).

### 2.3.2 Gaussian puff theory

The Gaussian puff theory was developed to include puff phenomenon or the effects of both plume meandering and spreading process in the dispersion simulation. It assumes that each pollutant emission of duration $t$ injects into the atmosphere with mass $M=Q*\ t$, where $Q$ is the time varying emission rate. The concentration at the receptor contributed by each puff is then calculated and the total concentration in a receptor at time *t* can be computed by summation of the contributions from all existing puffs generated by all sources. Puff models can be used in scenarios. One is to simulate the average concentration of a continuous plume under calm or low-wind conditions. Another application is to simulate the dispersion of instantaneous or semi-instantaneous sources where the release time or the sampling time is short compared with the travel time. In the first scenario, the same dispersion coefficients as those used for the steady-state Gaussian plume models can be used to describe the growth of each puff in the plume. However, when applied to the instantaneous or semi-instantaneous sources, little information is available for determination of the diffusion parameters (Zannetti 1990).

McPhail (1991) and Gassman (1993) indicated that odour moved in the form of a series of puffs rather than a continuous stream. Therefore, puff models might be more appropriate for agricultural odour dispersion. A Gaussian puff model (INPUFF-2) was evaluated for predicting downwind odour from animal production facilities by several researchers. Zhu et al. (2000b) conducted field measurements on 28 farm sites in Minnesota with 7 trained human sniffers to collect data for evaluation and calibration of INPUFF-2 model. The experiment was conducted following a protocol similar to that developed by Hartung and Jungbluth (1997). In the field, positions were marked off at the centreline of downwind direction at distances of 50 to 500 m, and 5 to 20 m apart on the line perpendicular to this centre line so that the plume width could be covered by sniffers. Odour was assessed using an intensity scale of 0 to 5. The weather conditions were recorded at 10-s intervals to match the downwind sniffing frequency. Model predictions were compared with the field measurements using the Wilcoxon Signed Rank Test. The result showed that INPUFF-2 model could well predict downwind odour concentrations from single or multiple animal production sites at distances less than 400 m. However, a source dependent scaling factor had to be used to "modify" the emission rate input. This scaling factor was 35 and 10 for animal building and manure storage emissions, respectively.

Guo et al. (2001) calibrated the same model for long-distance odour estimation up to 4 km. To collect field data, they employed 19 resident-panelists living on a 4.8 x 4.8 km grid of farmland containing 20 livestock/poultry farms to assess downwind odour intensity on a numerical 0 to 3 scale for five months from June to November. Their results revealed that the INPUFF-2 model was capable of predicting downwind odour at low intensity (level 1, faint odour) under stable to slightly unstable weather conditions. However, the model underestimated higher odour intensities of 2 and 3. A number of possible reasons that might contribute to the discrepancies include: a) fluctuations in wind direction and wind speed were ignored when long simulation interval was used in the study; and b) the source emission data for model input were from the average emission rate, not from the real-time on-site measurement in the field.

## 2.4 Assessment of Odour Intensity in the Field

### 2.4.1 Human sniffers

Odour from swine operations is a complex mixture of many different odourous compounds and odour intensity depends on the concentration of each compound and the combination of these compounds as well. A satisfactory method of evaluating odour directly in the field is quantifying the instantaneous odour intensity by using human sniffers. The human sniffing technique has been used by several researchers in their studies of livestock odours. There is a German guideline which describes specific procedures of determining field odour plumes by human sniffers (VDI 1993). Hartung and Jungbluth (1997) followed the German guideline to measure the odour plumes from dairy and cattle barns. Sniffers ranked odour intensity in the field based on a 6-point intensity scale suggested by German VDI Guideline 3882 (VDI 1992). ASTM (1999) describes a standard procedure for measuring odour intensity using n-butanol references. Human panelists can be trained to compare the intensity of livestock odours to different intensities of n-butanol solutions. Zhu et al. (2000b) used seven trained human sniffers to conduct on-site odour intensity measurement. The sniffers were trained to rank odour intensity on a scale of zero to five (0: no odour; 1: very faint; 2: faint; 3: distinctly noticeable; 4: strong; 5: very strong odour). Resident sniffers who received limited training were used by Guo et al. (2001) in monitoring odour occurrences in a livestock production area. They used a relatively simple intensity scale of 0 to 3 (0: no odour; 1: faint odour; 2: moderate to strong odour, and 3: very strong odour). St. Croix Sensory Inc. (Stillwater, MN) developed a method for quantifying odour intensity using n-butanol reference scales. This method requires the human sniffers to be trained and certified as Nasal Rangers. The use of the n-butanol reference scales enables Nasal Rangers to quantify odour intensity instantaneously and obtain immediate results at relatively low cost.

### 2.4.2 Intensity - concentration correlation

Odour intensity and odour concentration are the two most important properties of an odour. Much sensory research has shown that the relationship between the perceived intensity of smell or taste and the physical measure (e.g., odorant concentration) may be described by a power function (see equation 2.1).

Much research has been conducted to correlate the odour intensity to concentration for livestock odours (Sneath 1994, Bundy et al. 1997, Nicolai et al. 2000, Guo et al. 2001, Zhang et al. 2003). Sneath (1994) showed that there was good linear relationship between the odour intensity and the log of odour concentration for poultry and swine odours. Nicolai et al. (2000) and Guo et al. (2001) showed that the Weber-Fechner logarithmic model provided the best mathematical description of the combined building and manure storage odour from swine operations. The Weber-Fechner model has the form of:

$$I = k_1 \log_{10} C + k_2 \tag{2.8}$$

where $k_1$ and $k_2$ are constants.

Using an 8-point scale for odour intensity, Zhang et al. (2003) determined the two constants to be $k_1 = 0.82$ and $k_2 = 0.36$ for swine odour. The above relationship may be used to correlate the odour concentration predicted by dispersion models to the odour intensity assessed by human assessors in the field for the validation of dispersion models.

## 2.5 Setback Guidelines (Models) for Mitigating Livestock Odour

Setback models have been developed and used in some European countries and some states and provinces in North America for minimizing odour impact on the neighboring communities (Schauberger and Piringer 1997, Klarenbeek and Harreveld 1995, OMAFRA 1995, Lim et al. 2000, Jacobson et al. 2005, Guo et al. 2005, Stowell 2008). The methods for estimating setback distances are either empirical (experience-based) or dispersion theory-based. In empirical methods, either equations or look-up charts are used to express the setback distances as a function of some key variables describing the livestock operation (type, size, manure storage, etc), the land use, and climatic and topographic conditions. In dispersion-based approaches, the concentration of odour is predicted by atmospheric dispersion models and the setback distance is determined by comparing predicted odour concentrations and frequency with a set of criteria for acceptable odour exposure. The majority of the existing setback distance models in Europe, Australia, and North America are experience-based.

The Austrian model is one of the early models developed in Europe (Schauberger and Piringer 1997). This empirical model is based on estimation of odour sources using the following parameters: animal number, animal species, housing system, ventilation system, manure handling inside the building, feeding methods, land use, and topography. Williams and Thompson (1986) measured odour emissions from a number of processes and sources. By collating the odour emissions with data on the spatial extent of odour complaints, an empirical formula, i.e., the W-T model was derived to determine the setback distances. They also used dispersion models to calculate the odour concentrations and found the dispersion modelling approach provided reasonably accurate results as compared with the empirical formula.

Researchers at Purdue University developed a setback model (Purdue model) for hog operations (Lim et al. 2000). The Purdue model is an empirical model based on the baseline odour emission data, literature review, and studies of existing setback guidelines, particularly the Austrian and W-T models. Building design and management, and odour abatement factors were introduced to replace the technical factor in the Austrian model. Outdoor manure storage sources were also accounted for in the model.

The Minnesota OFFSET (Odour From Feedlots Setback Estimation Tool) and Nebraska OFT (Odor Footprint Tool) models are among a few dispersion-based guideline tools. The Minnesota OFFSET was developed to estimate the setback distance from animal production sites by researchers at University of Minnesota (Jacobson et al. 2005, Guo et al. 2005). The model was based on extensive odour emission measurements and dispersion modelling using historical weather data from Minnesota. The odour emissions for different animal production facilities were estimated using the averages of over 200 animal buildings and manure storage units across Minnesota. An air dispersion model was evaluated against field odour plume data and used to estimate the odour concentrations downwind from the sources. The setback distances were then determined using the desired odour “annoyance free” frequency. The annoyance free odour intensity level was set at an intensity of 2 (faint odour) on a 0 (no odour) to 5 (very strong odour) intensity scale (ASTM 1999).

The Odor Footprint Tool (OFT) was developed by a group of researchers at University of Nebraska – Lincoln (Stowell et al. 2005). Based on dispersion modelling using AERMOD, the US EPA Air Dispersion Model (Cimorelli et al. 2004), along with meteorological data for the location, the Odor Footprint Tool generates odour roses, directional setback distance curves, and odor footprints (Stowell et al. 2008). Input to the OFT includes livestock facility type and size, location (for weather data), information about odor control technologies implemented, and an acceptable level of risk for odor annoyance (Niemeir et al. 2008).

In Canada, empirical Minimum Distance Separation guidelines (MDS-I and II) along with the Guide to Agricultural Land Use were developed by the Ontario Ministry of Agriculture, Food, and Rural Affairs in 1970’s and are the successors to the 1976 Agricultural Code of Practice. The MDS-I is for Siting Residences from Livestock Operations and MDS-II for Siting Livestock Operations from Residences. The models determine the setback distance according to the animal species, animal numbers, and manure handling systems. The Alberta MDS model is a modified version of the Ontario MDS-II that has been used in Alberta since 2002 (Anonymous 2002). The minimum separation distance is also empirically determined based on animal species, animal numbers, manure handling systems, and land use.

Five setback models were compared by Guo et al. (2004) in order to reveal the differences in setback predictions of various models. The models compared include the Austrian, Ontario MDS-II, Purdue, Minnesota OFFSET, and W-T models. The livestock farms used in this study were swine farms of various sizes. The odour emissions were estimated using the OFFSET method. They reported that setback distances given by different models fell into a wide range of values. The difference might be as much as 10 times between the closest and farthest distance. They suggested that it was critical that the information into the components of the models should be known, especially if these models were used for land use decision-making.

# Chapter 3. MATERIALS AND METHODS

## 3.1 Farm Selection

Two farms (A and B) of 3,000-sow farrowing operation, located in southern Manitoba, were selected for this study. The two farms were similar in layout, each with 17 production rooms, but Farm A had an additional quarantine room at the end of the building (Figs. 3.1 and 3.2). The barns on both farms were mechanically ventilated with wall mounted exhaust fans. Farm A had 90 exhaust fans, including six in the quarantine room and Farm B had 84. Since the quarantine room was normally empty, its contributions to odour emissions were negligible. Both farms were owned by the same company; therefore, the operation and management, including feed rations, were similar between the two farms. Manure on both farms was handled as liquid which was stored in under-floor shallow gutters and then removed to outdoor earthen manure storage (EMS) once every week from gestation/breeding rooms and once every three weeks from farrowing rooms. The major difference between the two farms was that Farm A had a two-cell EMS with negative air pressure covers (NAP); whereas Farm B had an open single cell EMS. The NAP technology was developed by DGH Engineering Inc. (DGH Engineering Inc., St. Andrews, MB). The cover was made of reinforced polyethylene plastic and anchored in a trench along the perimeter of the EMS. A system of perforated pipes and fans drew air from underneath the plastic cover to create a negative pressure under the cover. This negative pressure secured the plastic cover on the manure surface. Although odour emission from the two-cell EMS would be different from the single cell EMS, the NAP cover system virtually eliminated odour emission year round (Small and Danesh 1999). In other words, emissions from the EMS on Farm A would be negligible no matter if the EMS was two cells or a single cell.

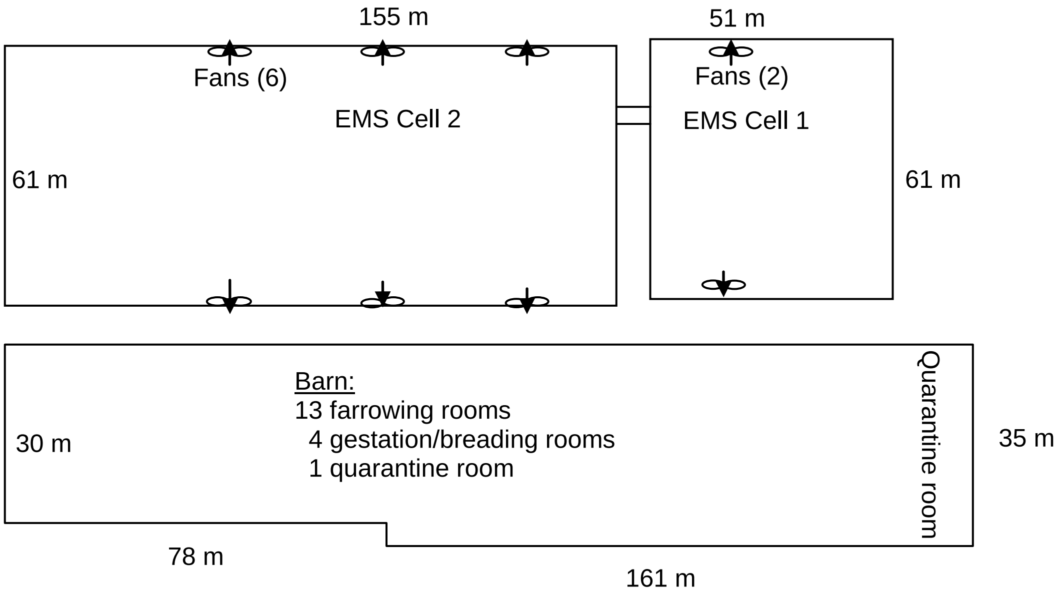


**Figure 3.1.** Layout and dimensions of Farm A selected for study (not to scale)

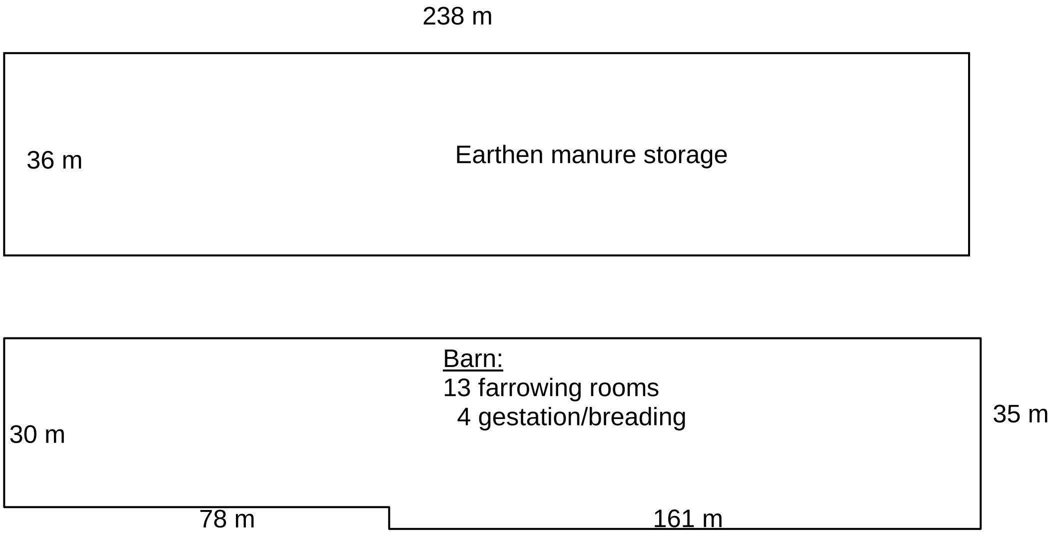


**Figure 3.2.** Layout and dimensions of Farm B selected for study (not to scale)

## 3.2 Air Sampling from Animal Buildings

Because of the large number of exhaust fans (90 and 84 on the two farms, respectively) and the limit of the number of samples that could be handled in the olfactometry lab for odour analysis, taking samples from all exhaust fans was not feasible. A total of eight samples were taken from the building for each sampling date, six from farrowing rooms and two from gestation rooms. Based on the production schedule, at least one room was sampled to represent other rooms at the same production stage. For each room, a composite sample was collected by sampling from two or three exhaust fans in the center of the room. Air samples were collected in 10-L Tedlar bags using a vacuum chamber (AC'SCENT Vacuum chamber, St. Croix Sensory Inc., Stillwater, MN) (Fig. 3.3). When sampling, a bag was placed in the chamber and the inlet of the bag was connected to a Teflon probe which was placed in the mid stream of the airflow from the exhaust fan. Each sample was taken in two steps: (i) fill the bag with 2 L of sample air and then evacuated to "coat" the bag, and (ii) draw odorous air into the bag at a rate of 1 to 2 L/min until the bag was 75% full. For each sampling session, one reference sample was taken upwind from the facility to represent the background odour level. To determine the ventilation rate for each room, air velocity was measured at five points across the radius of each and every running fan in the room with a hot wire anemometer (FloRite 800, Bacharach, Pittsburgh, PA). The airflow rate for each fan was estimated from the average air velocity and fan (duct) diameter. This is a simplified method based on a standard method of AMCA (1999) that recommends four measurement points across one radius for a total of six radii. Due to the large number of fans in the barns, it was unrealistic to measure 24 points for each fan in a relative short time period (2 hours); therefore, the air velocity profile across one radius was considered representative for the duct cross-section. To check the adequacy of this simplified method of measuring airflow rates, the airflow rate data measured in three consecutive sessions were examined. In these three measurement sessions, a total of 39 running fans were measured, and the outdoor temperature was 26, 30 and 29°C, respectively. Because these fans were single-speed fans, the airflow rate of each fan would be the same in all three sessions if other conditions remained the same, such as the pressure difference between inside and outside the building, and wind speed and direction. Therefore, the difference in measured airflow rate of a particular fan between three sessions would be a good indicator of the adequacy of the airflow measurement method. This difference was numerically calculated as: (maximum – minimum) ÷ average. The data (Appendix A) showed that the difference in measured airflow rates between three sessions ranged from 2% to 69%, with an average of 16% and standard deviation of 12%. The large differences tended to occur for small fans (e.g., Fan #86, Appendix A) with low airflow rates, for which a small difference in measured airflow rate represented a significant change percentage-wise. Considering that the differences in flow rate between sessions might also be contributed by other factors (pressure difference, wind, etc) besides the uncertainty associated with the measurement method used, the simplified method used in this study produced reasonable results.

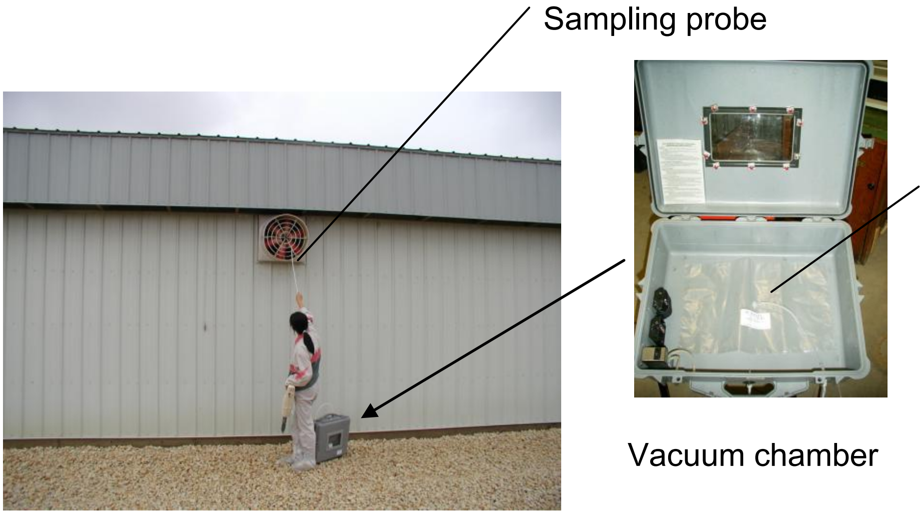


**Figure 3.3.** Sampling odour from building exhaust

Air temperature was also recorded from the hot wire anemometer at exhaust fans to estimate the room temperature. A portable weather station (WatchDog Model 550, Spectrum Technologies, Inc., Plainfield, IL) was set up near the barn to record outdoor temperature, relative humidity, and solar radiation.

### 3.3 Air Sampling from Manure Storage

A floating wind tunnel was used to collect air samples from the manure surface in the open EMS (Fig. 3.4). There are no universally accepted standard devices for sampling odour from manure surfaces. Commonly used methods are wind tunnels and flux hoods. One of the earliest wind tunnels for odour emission measurement was introduced by Lindvall (Lindvall et al. 1974). A research team at

University of New South Wales (UNSW) improved Lindvall's design and developed the UNSW wind tunnel. The team extensively studied the aerodynamic characteristics and performance of the UNSW wind tunnel (Jiang et al. 1995, Bliss et al. 1995, Jiang and Kaye 1996, Wang et al. 2001). After an extensive review of various odour sampling methods, Gostelow et al. (2003) concluded that the UNSW wind tunnel "would appear to be the choice of hood for emission measurement from liquid surfaces". The design and operation of the wind tunnel in this study followed the specifications of the UNSW wind tunnel. The wind tunnel covered a surface area of 0.32 $m^2$ (0.8 m 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 (Fig. 3.4). Airflow rates were measured inside the duct using a hot wire anemometer and were adjusted if necessary to maintain an air velocity of 0.3 m/s. For each sampling session, two odour samples were collected at the outlet of the hood and one reference sample was collected after the carbon filter using a vacuum chamber and Tedlar bags. Manure temperature was measured at 100 mm below the manure surface using a digital thermocouple indicator.

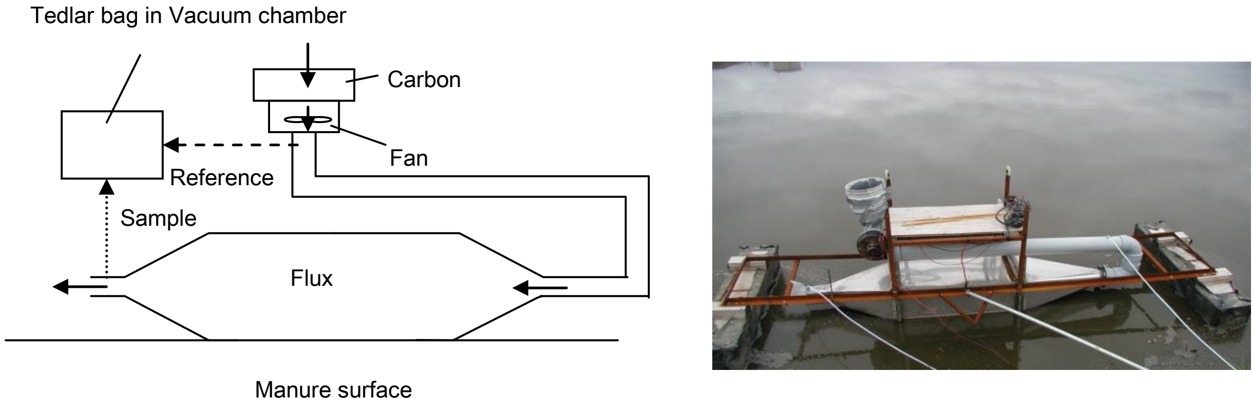


**Figure 3.4**. Sampling odour from manure storage surface

For the NAP EMS on Farm A, one composite sample was taken from the exhaust fans on each of the two cells, and airflow rate from the exhaust fans was measured in the same fashion as for building exhaust fans. It should be noted that manure temperature in the NAP EMS could not be measured because the manure under the cover was not accessible.

### 3.4 Sampling Dates

Air samples were taken on 4 different dates in September and October 2003 on farm A while its two-cell EMS was not covered yet; air samples were taken on 16 different dates from June to September 2004 on the two farms, or eight sampling dates per farm. However, one sampling date on farm B was interrupted by heavy raining and the field data was not complete, the results from that day was excluded from data analysis. On each sampling date, eight samples were taken from the building exhaust and two from manure storage. Of the eight samples from the buildings, six were taken from farrowing rooms and two from gestation rooms on each sampling date. Therefore, a total of 152 samples were taken from building exhaust and 38 from manure storage on the two farms. The majority (57%) of these samples were taken in the afternoon, 31% in the morning, and 22% in the evening. The outdoor temperature ranged from 8 to 32 ℃ on these sampling dates.

### 3.5 Sample Analysis

#### 3.5.1 Selection and training of human assessors

A qualification procedure was performed on all of the panelists by following European Standard (CEN 2003). Two panel selection criteria include: 1) the geometric mean of the individual threshold estimates expressed in mass concentration of the butanol gas has to fall between 20 to 80 ppb to meet the required sensitivity, and 2) the antilog of the standard deviation calculated from the logarithms of the individual threshold estimates, expressed in mass concentration of the butanol gas, has to be less than 2.3 to ensure the consistency requirement. Ten individual threshold estimates for the reference 50 ppm n-butanol were performed on each assessor in at least 3 sessions on separate days with a pause of at least one day between sessions. Those who met both criteria were selected as panel members.

### 3.5.2 Sample evaluation

Collected samples (in Tedlar bags) were evaluated within 24 h for odour concentrations. A single-port olfactometer (AC'SCENT, St. Croix Sensory Inc., Stillwater, MN) with six trained assessors was used for odour concentration measurement. The triangular forced-choice method was used to present samples to the assessors, with a 3-s sniff time. For each olfactometry session, data were retrospectively screened by comparing assessors' individual threshold estimates with the panel average (CEN 2003). Odour concentration was expressed as odour units per unit volume ($OU/m^3$) (CEN 2003).

## 3.6 Calculation of Odour Emission Rates

The odour emission rate from buildings was calculated from the measured odour concentration and ventilation rate (airflow rate of exhaust fans) as follows:

$$Q_{od\text{-}B} = (C_{odour} - C_{od\text{-}BK}) \times V_B/AU \quad (3\text{-}1)$$

where:

$Q_{od\text{-}B}$ = odour emission rate from building exhaust ($OUs^{-1}AU^{-1}$)

$C_{odour}$ = odour concentration of the sample ($OU/m^3$)

$C_{od\text{-}BK}$ = background odour concentration ($OU/m^3$)

$V_B$ = ventilation rate ($m^3/ s$)

AU = animal units

$AU = (N_{pig} \times M_{pig})/500$

$N_{pig}$ = number of pigs

$M_{pig}$ = average mass of pigs (kg).

It was noticed that the background odour ($C_{od\text{-}BK}$) measured upwind was generally much lower (two orders of magnitude) than the odour in building exhaust ($C_{odour}$). Therefore, $C_{od\text{-}BK}$ could be ignored in estimating odour emission rates from buildings.

Odour emission rates from the open manure storage were determined as follows:

$$Q_{od\text{-}S} = (C_{odour} - C_{od\text{-}Ref})\ V_h/A_h \qquad (3\text{-}2)$$

where

$Q_{od\text{-}S}$ = odour emission rate from manure storage (OU $s^{-1}$ $m^{-2}$)

$C_{od\text{-}Ref}$ = odour concentration of the reference sample (OU $m^{-3}$)

$V_h$ = air flow rate through the wind tunnel ($m^3$ $s^{-1}$)

$A_h$ = manure surface area covered by the wind tunnel = 0.4 x 0.75 $m^2$

Odour from the NAP EMS was determined in a similar fashion as for building exhaust:

$$Q_{od\text{-}S} = (C_{odour} - C_{od\text{-}BK}) \times V_c/A_s \qquad (3\text{-}3)$$

where:

$V_c$ = air flow rate through the exhaust fans of NAP EMS ($m^3$ $s^{-1}$)

$A_s$ = total area of manure surface ($m^2$).

### 3.7. Downwind Odour Monitoring Grid

To monitor the odour dispersion plume downwind from a facility, 15 trained human sniffers were hired each time and placed in pre-determined positions. For each sniffing session, a weather station was set up first to determine wind direction. A base point was selected at the edge of the site and its position was marked by the longitude and latitude readings from the GPS. Based on the measured wind direction, sniffers were placed roughly in a three-row grid system (Fig. 3.5) downwind from the base with the assistance of GPS positioning systems (GPS45, Garmin International, Lenexa, KS). Upon reaching the predetermined grid point (Table 3.1), sniffers recorded their exact positions based on the longitude and latitude readings from the GPS, therefore their relative downwind position to the base point can be determined.

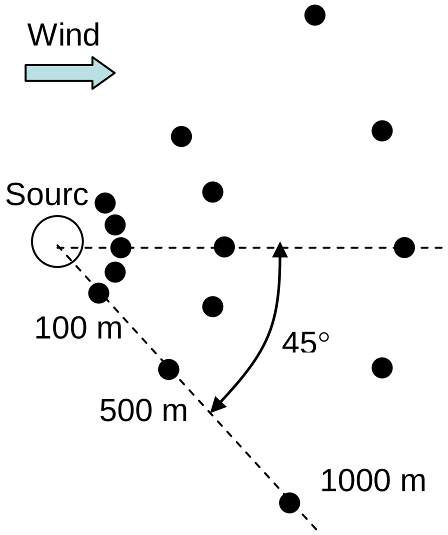


**Figure 3.5.** Field grid (locations) for downwind odour sniffing

**Table 3.1**. Grid locations for field odour sniffing

| Position no. | Distance from source (m) | Angle from wind direction ($^o$) |
|---|---|---|
| 1-1 | 100 | -45 |
| 1-2 | 100 | -30 |
| 1-3 | 100 | 0 |
| 1-4 | 100 | 30 |
| 1-5 | 100 | 45 |
| 2-1 | 500 | -45 |
| 2-2 | 500 | -30 |
| 2-3 | 500 | 0 |
| 2-4 | 500 | 30 |
| 2-5 | 500 | 45 |
| 3-1 | 1000 | -45 |
| 3-2 | 1000 | -30 |
| 3-3 | 1000 | 0 |
| 3-4 | 1000 | 30 |
| 3-5 | 1000 | 45 |

### 3.8. Selection and Training of Field Human Sniffers

Human sniffers were recruited primarily from the students at the University of Manitoba. A preliminary screening test was performed for each participant. The 8-point referencing n-butanol solutions were used for the screening test (Table 3.2).

**Table 3.2.** Standard 8-point n-butanol odour intensity reference scale (ASTM 1999)

| Intensity level | n-butanol in water (ppm) | Annoyance scale |
|---|---|---|
| 0 | 0 | no odour |
| 1 | 120 | not annoying |
| 2 | 240 | a little annoying |
| 3 | 480 | a little annoying |
| 4 | 960 | annoying |
| 5 | 1940 | annoying |
| 6 | 3880 | very annoying |
| 7 | 7750 | very annoying |
| 8 | 15500 | extremely |

This Odour Intensity Reference Scale with n-butanol (in water) was based on the ASTM standards (ASTM 1999). N-butanol solutions were prepared in 45 mL glass bottles with Teflon coated lids. Samples were presented to the participant in a random order and the participant was asked to evaluate the samples and place them in order from the weakest to the strongest odour levels. The inversion (error) value was then calculated and those who scored at 0 or 1 were selected for further training. Over 40 people were pre-screened and 22 were selected finally as field odour sniffers.

The selected sniffers went through a series of six (6) training sessions. The focus of these sessions was to train the sniffers in “memorizing” the odour reference scale which they would be using in the field. The following procedure was performed during each of the 6 training sessions. First, each sniffer was provided with a set of eight (8) n-butanol samples, as described in Table 3.2, and he/she sniffed the samples from #1 to # 8 several times. In between each sniffing, the sniffer wore a carbon filtered mask for 10 – 20 s to “rinse” his/her nose. Second, each sniffer was given 3 to 6 coded samples of known intensity (but unknown to the sniffer). He/she evaluated one sample at a time, assigned a scale (1 to 8) to this sample, and recorded the scale on a ballot. Those who correctly rated the sample were asked to check with the standard solution bottle of n-butanol and sniff the sample again to reinforce the rating. Sniffers who incorrectly rated the sample had to sniff both the standard and the coded sample to “feel” the difference. After this training of matching coded samples to the eight standard concentrations, two or three samples of hog odour simulant (York et al. 2002) were presented to sniffers for assessment. Sniffers assessed one sample at a time and assigned a scale to this sample of simulated hog odour. Group consensus had to be reached for each of the samples. The results were collected after each training session to evaluate the performance of sniffers over the entire training period. Each sniffer was allowed to be one level off for the wrong identification; otherwise further training had to be conducted.

### 3.9. Field Downwind Odour Measurement Protocol

The sniffers “calibrated” their noses using the standard reference n-butanol samples in each session before leaving for the field. They sniffed the samples from #1 to #8 and scaled their intensities on a labelled magnitude scale (Green et al. 1993) sheet to enhance their memory of the scale (Fig.3.6).

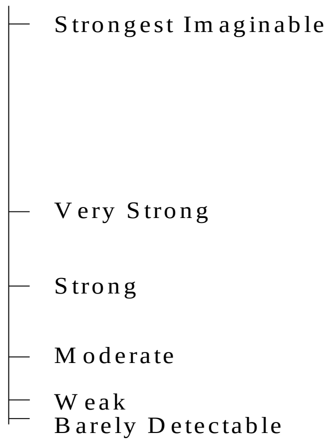
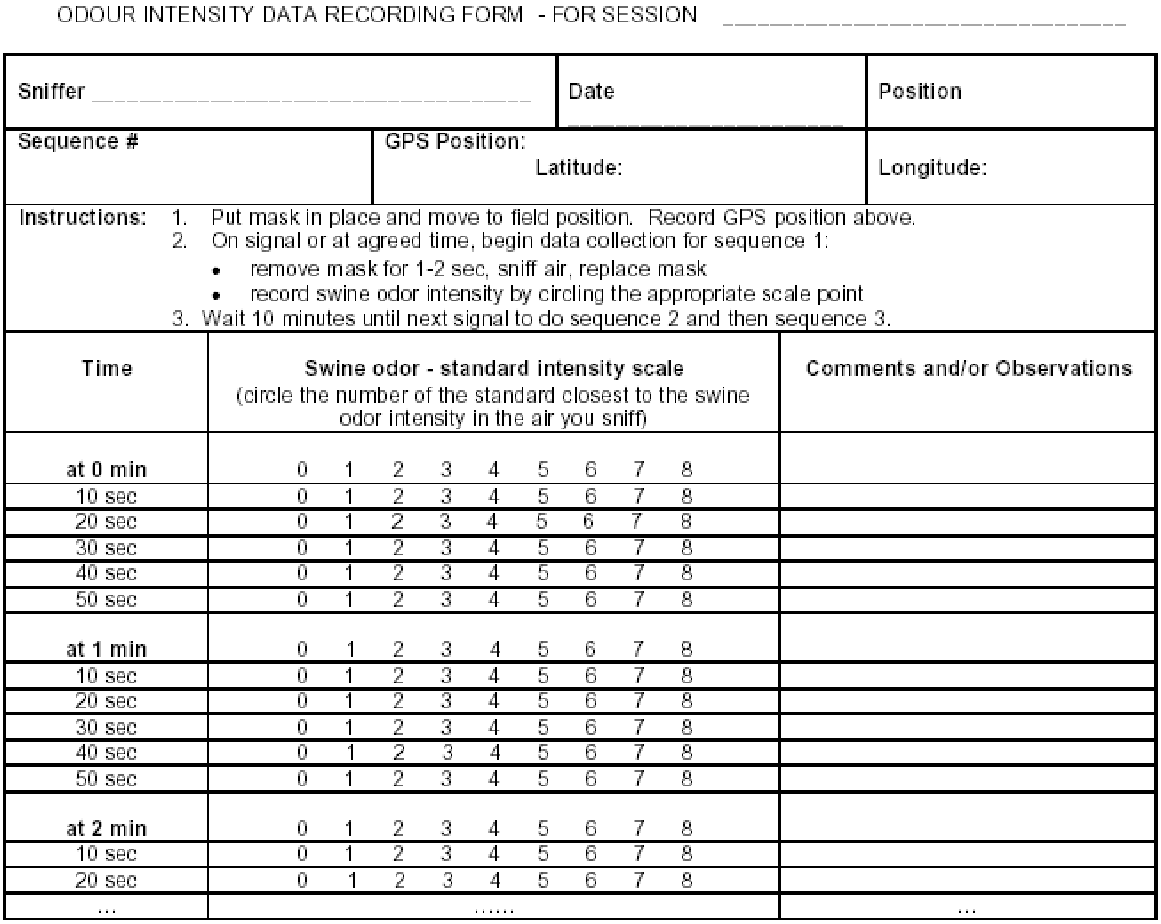


**Figure 3. 6.** Labelled magnitude scale (Green et al. 1993)

Every sniffer was carrying a two-way radio system to allow him/her to receive instructions from a central coordinator. Sniffing was timed by the coordinator, i.e., the coordinator informed all sniffers when to start and then broadcast every 10 s to remind the sniffers to conduct sniffing. The duration of a single measurement session was 10 min. To prevent the nose from being “saturated”, each sniffer wore a carbon filtered mask. They only removed the masks briefly every 10-s to sniff odour. For every sniffing, the sniffer recorded the odour intensity and odour description on a field data recording sheet. A sample data recording sheet is shown in Fig. 3.7 and details are given in Appendix A. At the end of each 10-min duration, 60 observations were recorded by every sniffer. A total of 3 measurement sessions were carried out within one hour, with a 10-min break between sessions.



ODOUR INTENSITY DATA RECORDING FORM - FOR SESSION ______________________________

| | | |
|---|---|---|
| **Sniffer** ________________________________ | **Date** ____________________ | **Position** |
| **Sequence #** | **GPS Position:**<br>**Latitude:** | **Longitude:** |

**Instructions:**
1. Put mask in place and move to field position. Record GPS position above.
2. On signal or at agreed time, begin data collection for sequence 1:
    - remove mask for 1-2 sec, sniff air, replace mask
    - record swine odor intensity by circling the appropriate scale point
3. Wait 10 minutes until next signal to do sequence 2 and then sequence 3.

| Time | **Swine odor - standard intensity scale**<br>(circle the number of the standard closest to the swine odor intensity in the air you sniff) | Comments and/or Observations |
|---|---|---|
| **at 0 min** | 0 1 2 3 4 5 6 7 8 | |
| 10 sec | 0 1 2 3 4 5 6 7 8 | |
| 20 sec | 0 1 2 3 4 5 6 7 8 | |
| 30 sec | 0 1 2 3 4 5 6 7 8 | |
| 40 sec | 0 1 2 3 4 5 6 7 8 | |
| 50 sec | 0 1 2 3 4 5 6 7 8 | |
| **at 1 min** | 0 1 2 3 4 5 6 7 8 | |
| 10 sec | 0 1 2 3 4 5 6 7 8 | |
| 20 sec | 0 1 2 3 4 5 6 7 8 | |
| 30 sec | 0 1 2 3 4 5 6 7 8 | |
| 40 sec | 0 1 2 3 4 5 6 7 8 | |
| 50 sec | 0 1 2 3 4 5 6 7 8 | |
| **at 2 min** | 0 1 2 3 4 5 6 7 8 | |
| 10 sec | 0 1 2 3 4 5 6 7 8 | |
| 20 sec | 0 1 2 3 4 5 6 7 8 | |
| … | …… | … |

**Figure 3. 7.** Data recording sheet for field odour sniffing

## 3.10. Meteorological Condition Monitoring

For each field sniffing session, a portable weather station (WatchDog Model 550, Spectrum Technologies, Inc., Plainfield, IL) was set up first on the open area of the farm site to determine the wind direction. The weather station was placed 2 m above the ground level to collect on-site weather information during the entire field sniffing session. Solar radiation, temperature, relative humidity, and wind speed and direction were recorded every minute. The measured weather data were used as the model input in dispersion models to predict the downwind odour concentrations for that specific session.

## 3.11. Field Measurement Schedule

A total of 40 1 h measurement sessions were carried out on the two farms in 2003 and 2004. Two sessions were conducted in one day at two time periods (early morning-noon, noon-afternoon, or afternoon-early evening). The selected measurement dates covered a range of meteorological conditions. Among those sessions, 24 sessions were on farm A, with 8 sessions in 2003 and 16 sessions in 2004, to compare the effect of NAP cover to the control of odour and GHG emissions on the same farm. Sixteen (16) sessions were conducted respectively on farm A and B in 2004 for comparison between the two farms.

## 3.12. Dispersion Modelling

### 3.12.1 Preparation of input data for dispersion models

Since source emission data were collected during the same time when field sniffing was being conducted, the measured odour emission rate from the building and manure storage for the day served as steady source emission input for all the sniffing sessions on that day. For ISCST3 model, The RURAL condition was assumed to calculate 1-h average concentration values. A Cartesian grid receptor network with FLAT Terrain was used.

The primary input information and assumptions for AUSPLUME odour dispersion simulation include ground source emission with no plume rise, no stack downwash and penetration of inversion layer, and rural land conditions. Input information for INPUFF-2 was similar to those for ISCST3 and AUSPLUME including the location of two farms and the sniffers and odour source emission information (emission rate, source height, source area, emission temperature, and velocity).

Hourly weather data were prepared by taking the average of the minute readings from the on-site weather station (WatchDog Model 550, Spectrum Technologies Inc., Plainfield, IL) for ISCST3 and AUSPLUME. Atmospheric stability of each hour was classified using the Pasquill (1961) stability categories based on hourly average solar radiation and wind speed values. One-minute weather data measured by the on-site weather station was used directly in INPUFF-2.

### 3.12.2 Processing the output data from models

Comparison of model prediction and field measured odour intensity was conducted to evaluate the adequacy of dispersion models for livestock odour application. At each measurement grid point, it was considered to be in agreement between the measured and simulated data if the simulated value was within the 95% confidence interval (CI).

## 3.13 Odour Intensity Peak-to-Mean Ratio

For each field measurement session, downwind odour peak-to-mean ratios were calculated for 1 min, 10 min and 1 h average sniffing time period at each sniffing location. The ratio was first calculated using accumulated 10 second peak intensity divided by accumulated average intensity over the averaging time, and then the accumulated peak-to-mean ratios were averaged again over the entire sniffing session.

# Chapter 4. RESULTS AND DISCUSSION

## 4.1 Odour Emissions

### 4.1.1 Odour emission from building exhaust

Large variations in odour level (concentration) at the building exhaust were observed on the two farms (from 300 to 3000 OU/m$^3$). The average odour level at the building exhaust on the two farms ranged from 799 to 1026 OU/m$^3$ (Table 4.1). These average values are comparable to those reported in the literature. For example, Zhang et al. (2003) reported that average odour levels ranged from 131 to 1842 OU/m$^3$ in 10 hog barns in southern Manitoba. Jacobson et al. (1999) reported odour levels from hog barns with mechanical ventilation in a range from 24 to 1515 OU/m$^3$ in Minnesota.

**Table 4.1.** Measured odour concentrations and emission rates from barn exhaust

| | Farrowing | | Gestation | |
|---|---|---|---|---|
| | Farm A | Farm B | Farm A | Farm B |
| **Odour concentration (OU/m$^3$)** | **1026** | **899** | **927** | **799** |
| Standard deviation | 487 | 505 | 314 | 396 |
| **Odour emission (OU/s-m$^2$)** | **22.7** | **23.0** | **11.6** | **7.6** |
| Standard deviation | 15.2 | 14.4 | 6.0 | 3.4 |
| **Odour emission (OU/s-AU)** | **314** | **317** | **136** | **90** |
| Standard deviation | 214 | 198 | 71 | 40 |

The statistical analysis tool in Microsoft Excel was used to perform t-tests to compare the average odour concentrations in both farrowing and gestation rooms between the two farms (see Appendix C for details). The results indicated that there were no statistically significant ($P>0.05$) differences in odour concentration in either farrowing or gestation rooms between the two farms (Tables C.1 and C.2).

The odour emission rate is commonly expressed as odour unit per second per unit area of the building floor (OU/s-m$^2$) or per animal unit (AU) (OU/s-AU). The mean odour emission rate from farrowing and gestation rooms were 22.7 and 11.6

$OU/s\text{-}m^2$ respectively on Farm A, and the corresponding values were 23.0 and 7.6 $OU/s\text{-}m^2$ on Farm B. There was no statistically significant ($P>0.05$) difference in emission rate between the farrowing rooms of the two facilities (Table C.3); however, the emission rate from gestation rooms on Farm A was significantly higher than that on Farm B ($P<0.05$) (Table C.4). The emission rate from farrowing rooms was 2.0 times higher than that from the gestation rooms on Farm A, and 3.2 times on Farm B. The differences in odour emission between the farrowing and gestation rooms were statistically significant ($P<0.05$) for both farms (Tables C.5 and C.6). The higher odour emission from the farrowing rooms was attributed to the fact that lactating pigs produce more manure with higher BOD than gestating pigs (ASABE 2005). Furthermore, manure was removed every three weeks in the farrowing rooms, but weekly in the gestation rooms. The longer manure removal cycle would also lead to more odour emission from the farrowing rooms. Measured emission rates in this study were within the range reported by other researchers. For example, Zhang et al. (2002b) reviewed odour emission data published in the literature and summarized that odour emission from hog farrowing buildings varied from 0.4 to 62 $OU/s\text{-}m^2$, and the published odour emission from gestation buildings ranged from 3 to 20 $OU/s\text{-}m^2$.

Large variations in measured odour emission might be attributed to many factors, including sampling date and time, and outdoor temperature. The Minitab statistical analysis software (Minitab Inc., State college, PA) was used to conduct Tukey multiple comparisons of odour emission rates among different conditions. The results indicated that odour emission was significantly ($P<0.05$) lower in September than June, July, and August for farrowing rooms, and odour emission from gestation rooms was significantly ($P < 0.05$) higher in July than September (Fig. 4.1) (see Tables C.7 and C.8 in Appendix C for details of statistical analysis). Low odour emission in September was mainly attributed to the low outdoor temperature, which resulted in low ventilation in the building. The average outdoor temperature in September was 12°C; whereas the average outdoor temperature was 22°C, 23°C, and 17°C in June, July, and August, respectively. Rising temperature might affect odour emission in several ways. First of all, the ventilation rate would increase to maintain desirable indoor temperature for the animals as the outdoor temperature rose. As the odour emission rate is calculated as the product of the ventilation rate and the odour concentration, a higher ventilation rate means a higher emission rate. Furthermore, a higher ventilation rate would increase air speed over manure surfaces which may result in increased mass transfer coefficients and odour release. Secondly, higher temperature would promote biological activities in the manure, which in turn would increase the production of odour compounds.

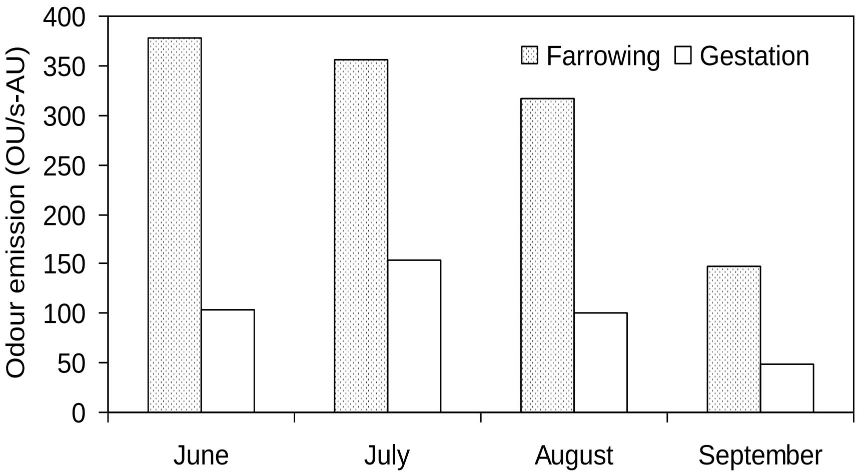


**Figure 4.1.** Average odour emission rates in four summer months.

It should also be noted that higher ventilation rate would bring more fresh air into the building, and therefore lower the odour concentration in the building. The net increase in odour emission caused by the outdoor temperature rise was attributed to the combined effect of increasing ventilation rate and decreasing odour concentration.

Although the odour concentration in September was slightly higher than that in other months, it did not compensate the effect of decreasing ventilation rate on the emission rate.

The effects of outdoor temperature on both odour level and odour emission rate from farrowing rooms were shown in Fig. 4.2. The odour emission rate increased with outdoor temperature. The rate of increase was higher in the lower temperature range than in the high temperature. The odour concentration in the temperature range of 10-14°C was slightly higher than that in other temperature ranges. The odour emission rate at the 10-14°C range was significantly ($P<0.05$) lower than that for other temperature ranges and there was no significant ($P>0.05$) change in odour emission rate when outdoor temperature was above the 15 - 19$^{o}$C range (Fig. 4.2) (see Tables C.9 and C.10 in Appendix C for details of statistical analysis).

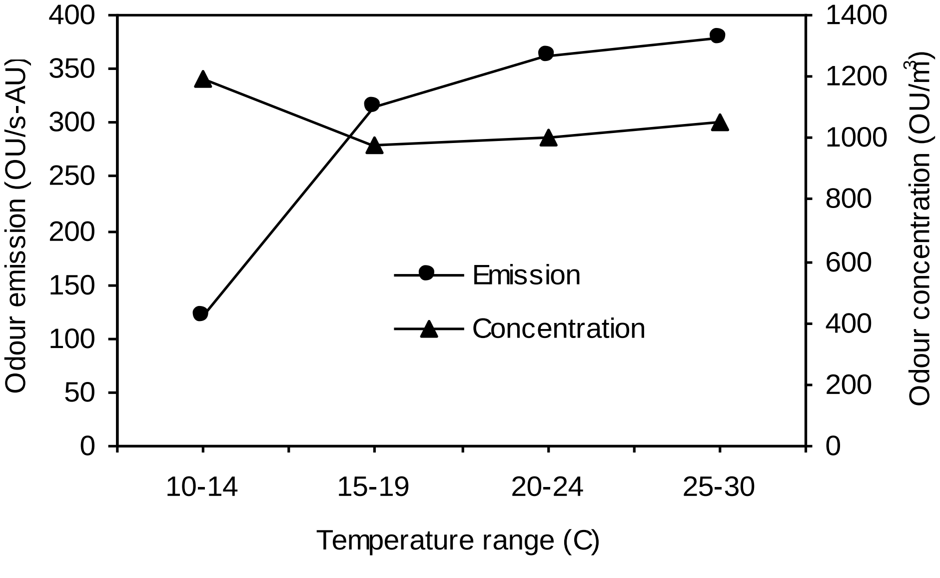


**Figure 4.2.** Effect of outdoor temperature on odour concentration and odour emission rate from farrowing buildings

The variation in odour emission grossly followed that of outdoor temperature during the day (Fig. 4.3). It should be mentioned that each data point in Fig.4.3 represents the average emission rate over a sampling session of about two hours. Odour emission was lower in the early morning (500 – 700h) and evening (1900 – 2100h) than other times of the day. Again these lower rates were attributed to lower ventilation at lower outdoor temperature. The relatively low ventilation during the night removed less odour generated inside the building to the outside, causing higher odour concentration in the building. In other words, odour was accumulated inside the building during the night. As the outdoor temperature started to increase in the morning, the ventilation rate ramped up. This increasing ventilation in the morning, coupled with relatively high odour concentration accumulated over the night, resulted in the highest emission rate in the morning (700 – 900h).

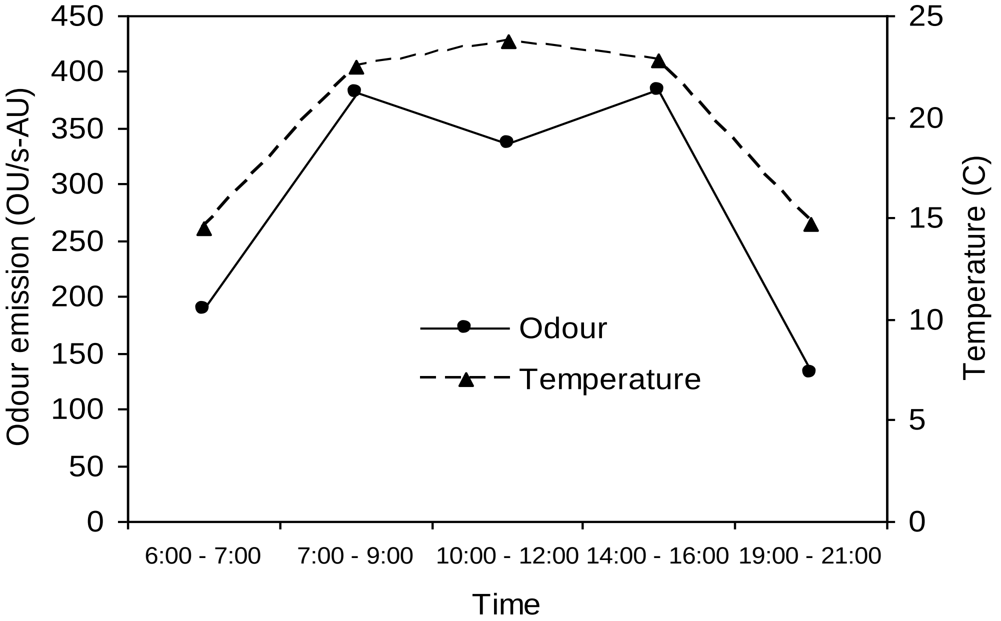


**Figure 4.3.** Variation of odour concentration and temperature during the day.

### 4.1.2 Odour emission from manure storage

The flux hood did not provide reliable measurements of odour emission from the open EMS on Farm B. The problem was that the odour concentration measured at the reference point was sometimes higher than that at the exhaust. This was probably due to the failure of the carbon filter in removing odour at the air intake. A total of 16 samples were collected from the open EMS on Farm B in eight sessions. Seven of the 16 samples had odour concentrations less than their corresponding reference samples. Those seven samples (four sessions) were excluded from the analysis because they would have produced negative emission rates. The average measured emission rate for the remaining sessions was 22.4 OU/s-m$^2$ for the open EMS on Farm B. This value seems to be high in comparison with data reported in the literature. The reported odour emission rates from EMS for hog operations ranged from 3.1 to 17.6 OU/s-m$^2$ (Zhang et al. 2002b). But these reported data were not specifically for farrowing facilities.

The NAP EMS on farm A was installed in 2004, therefore, data collected on Farm A in 2003 was from its uncovered EMS. The odour concentration in the NAP EMS on Farm A in 2004 was much higher than that in the open EMS on Farm B (Table 4.2). However, because only a small amount of air was exhausted from the NAP, the odour emission rate, determined as the product of the odour concentration and the airflow rate, was much lower from NAP EMS in comparison with the open EMS. The emission rate from the primary cell of the NAP EMS ranged from 0.2 to 2.0 OU/s-m$^2$, with an average of 0.7 OU/s-m$^2$, which is only 3% of that of the open EMS on Farm B (Table 4.2). The emission rate from the secondary cell of the NAP EMS (0.2 OU/s-m$^2$) was less than 1% of that from the open EMS. The total manure surface area in the primary cell was about 40% of that in the secondary cell. Based on the area ratio between the primary and secondary cells, the weighted average emission rate from the entire NAP EMS was calculated as 0.3 OU/s-m$^2$, which is negligible in comparison with the emission rate of the open EMS (22.4 OU/s-m$^2$).

**Table 4.2.** Measured odour concentrations and emission rates from manure storage

| | NAP EMS on Farm A | | Open EMS on Farm B |
|---|---|---|---|
| | Primary cell | Secondary cell | |
| **Odour concentration (OU/m$^3$)** | **4646** | **1991** | **769** |
| Standard deviation | 3646 | 1568 | 356 |
| **Odour emission (OU/s-m$^2$)** | **0.7** | **0.2** | **22.4** |
| Standard deviation | 0.6 | 0.1 | 25.1 |

### 4.1.3 Total odour emission (building plus manure storage)

The total odour emission was determined as the sum of building emission and EMS emission as follows:

$$Q_{od\text{-}T} = Q_{od\text{-}B} \times AU + (Q_{od\text{-}S} \times A_S)_{\text{primary cell}} + (Q_{od\text{-}S} \times A_S)_{\text{secondary cell}} \qquad (4.1)$$

where

$Q_{od\text{-}T}$ = total (combined) odour emission rate (OU/s)
$Q_{od\text{-}B}$ = odour emission rate from building exhaust (OU/s-AU)
AU = animal units
$Q_{od\text{-}S}$ = odour emission rate from manure storage (OU/s-m$^2$)
$A_s$ = total area of manure surface (m$^2$)

Data collected on Farm A in 2003 when the NAP was not installed are included in comparison (shown as Farm A 03) (Fig. 4.4). The total odour emission on Farm A and Farm B was almost identical when the EMS on Farm A was not covered (Farm A 03= 324,648 OU/s and Farm B = 321,190 OU/s). When the EMS was covered with NAP on Farm A, the total odour emission was reduced to 174,476 OU/s, which is 54% of that without NAP (Farm A 03). In other words, the NAP resulted in a 46% reduction in total odour emission rate on Farm A. The total odour emission from Farm A with NCP EMS was 54% of that from Farm B with open EMS (17,4476 vs. 32,1190 OU/s). The open EMS contributed 60% to the total odour emission on Farm B; whereas the NAP EMS contributed only 2% to the total emission on Farm A (Table 4.3). In other words, covering the EMS with NAP on Farm B would reduce the total odour emission by about 58%.

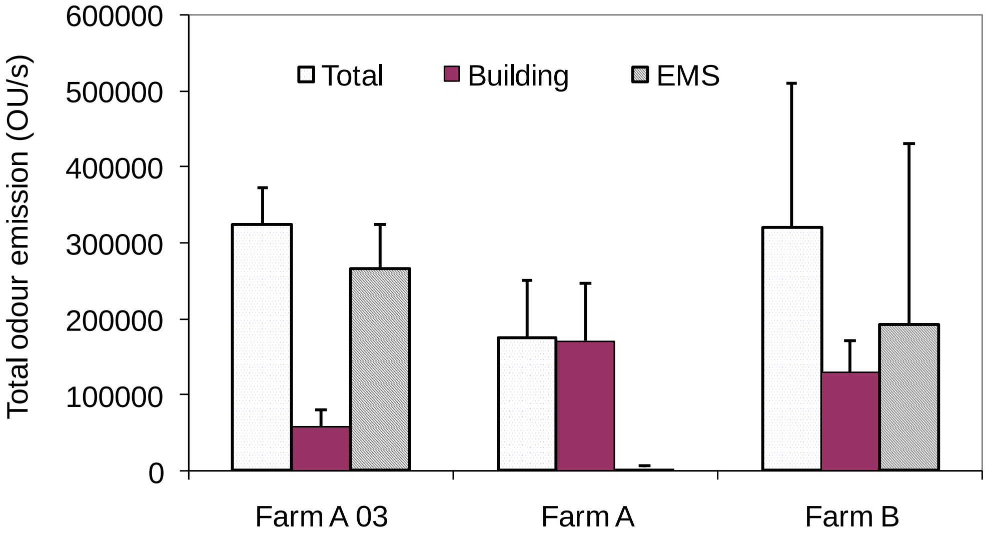


**Figure 4.4.** Comparison of total odour emissions (bars represent standard deviations)**.**

**Table 4.3.** Total odour emission and relative contributions of building and manure storage

| | Farm A (covered EMS) | | | Farm B (open EMS) | | |
|---|---|---|---|---|---|---|
| | Total | Building | EMS | Total | Building | EMS |
| Emission (OU/s) | **17,4476** | **17,0707** | **3,770** | **32,1190** | **12,9267** | **19,1923** |
| % contribution | -- | 98% | 2% | -- | 40% | 60% |

## 4.2 Field Odour Intensity and Occurrence Frequency

### 4.2.1 Bias test

It was hypothesized that odour intensity measured by human sniffers was not biased by seeing the odour source. A field sniffing session was conducted to measure odour both upwind and downwind from a hog facility to test the hypothesis. In the test, the physical locations of all sniffers remained unchanged, but the wind direction changed by 180°. The sniffers would report odour when they were downwind from the facility. If the sniffers were not biased, they would not report odour when they were upwind from the facility. Figure 4.5 shows that 94% of time the sniffers reported intensity level 0 (no odour), and 4% level 1, and 1% level 2, when they were upwind from the odour source. In contrast, the percentages of time that sniffers reported odour intensity levels 4 (annoying), 5 (annoying) and 6 (very annoying) were 14%, 17% and 17 %, respectively. Furthermore, the average odour intensity reported by the sniffers 100 m away from the facility was 2.9 downwind and close to zero (0.1) upwind (Fig. 4.6). The results clearly confirmed that the odour measurements by human sniffers were not biased by seeing the odour source.

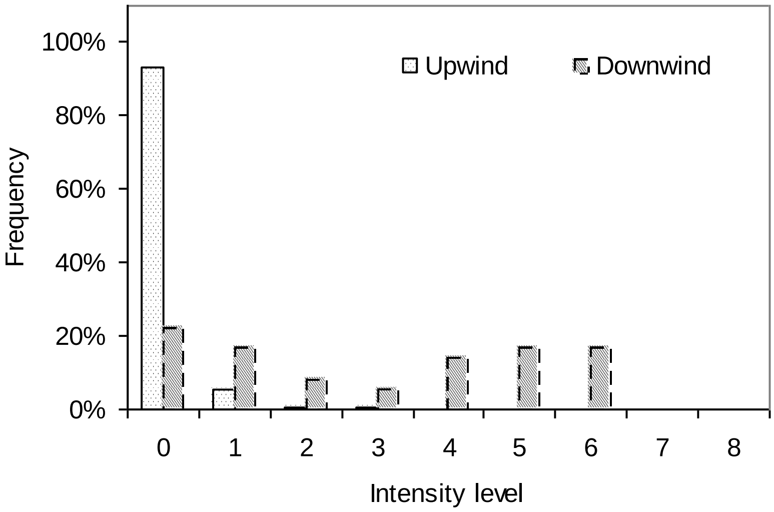


**Figure.4.5** Frequencies of odour intensities reported by sniffers in the field.

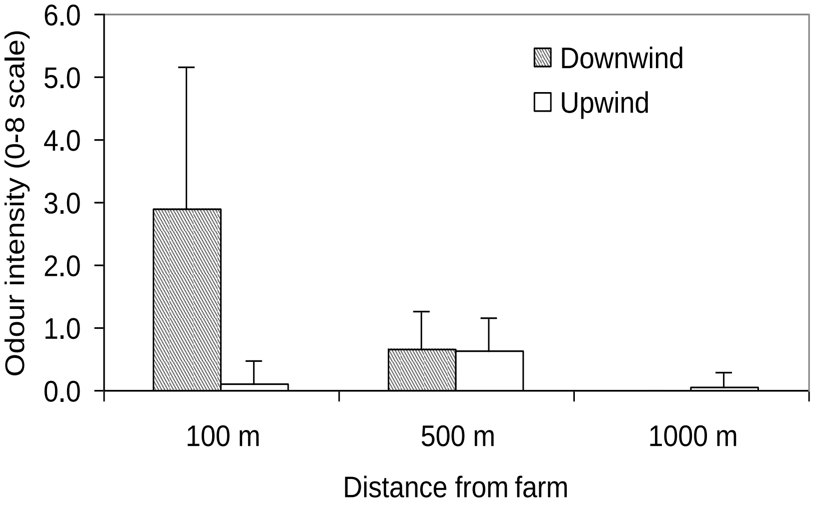


**Figure 4.6. C**omparison of downwind and upwind odour intensities reported by sniffers in the field.

### 4.2.2 Comparison of intensity and frequency between two farms

Comparisons of measured odour occurrence frequencies between the two farms are shown in Table 4.4. Because downwind odour intensity is dependent on the atmospheric stability, comparison should be conducted for the same stability class. In this study, most measurements were taken under the atmospheric stability class B; therefore, data for class B were selected for comparison. Furthermore, the odour emission rate was temperature dependent; therefore, data for ambient temperature between 15 and 30°C were selected for comparison. Odour Free Frequency (OFF) at 1000 m, defined as the percentage of time when the intensity was zero, was 89% and 64% for Farm A and Farm B, respectively (Table 4.4). Odour free frequencies for the two farms were about the same (2% vs. 3%) at 100 m. The strongest odour measured on both farms were level 7, however, the occurrence frequency of intensity 7 on Farm A was much lower than that on Farm B (4% vs. 34%) (Table 4.4).

**Table 4.4.** Frequency of odour occurrence at distances 100, 500, and 1000 m directly downwind from the farm operations.

| | Farm A | | | Farm B | | |
|---|---|---|---|---|---|---|
| Intensity level | 100 m | 500 m | 1000 m | 100 m | 500 m | 1000 m |
| 0 | 3% | 36% | 89% | 2% | 17% | 64% |
| 1 | 8% | 35% | 10% | 14% | 35% | 32% |
| 2 | 7% | 20% | 1% | 12% | 23% | 3% |
| 3 | 12% | 8% | 0% | 7% | 20% | 1% |
| 4 | 26% | 2% | 0% | 5% | 3% | 0% |
| 5 | 23% | 0% | 0% | 8% | 1% | 0% |
| 6 | 16% | 0% | 0% | 18% | 0% | 0% |
| 7 | 4% | 0% | 0% | 34% | 0% | 0% |
| 8 | 0% | 0% | 0% | 0% | 0% | 0% |

The maximum values of the sessional (ten-minute) average are compared to further examine the difference in odour impacts between the two farms. The variation of odour intensity with the distance could be represented by a log function (Fig. 4.7). The regression equations predicted lower odour intensity on Farm A than Farm B in general. T-tests indicated that the measured odour intensity on Farm A was significantly (P<0.05) lower than that on Farm B at 100 and 500 m, but the difference in odour intensity at 1000 m was not significant (P>0.05) between the two farms. In other words, the odour impact downwind from Farm A was less than that from Farm B, but the difference became less significant with increasing distance.

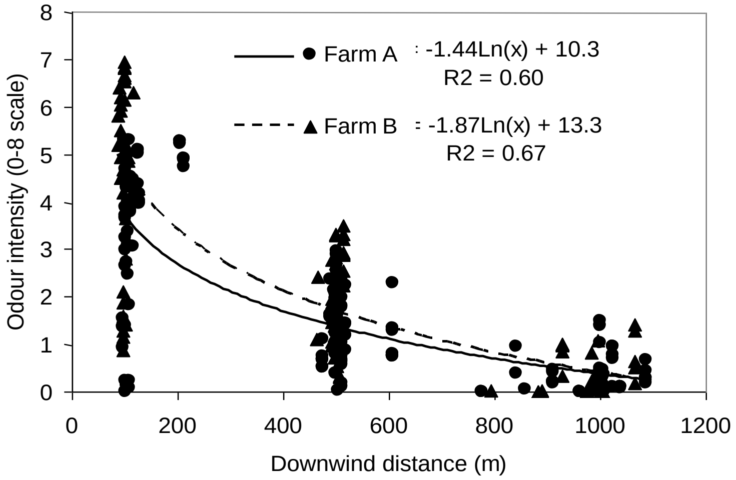


**Figure 4.7.** Comparison of measured odour intensity between the two farms.

## 4.3 Dispersion Modelling

### 4.3.1 Relationship between odour concentration and intensity

Dispersion models predict odour concentration in OU/m$^3$, whereas odour intensity expressed in the 0-8 scale was measured in the field. To compare dispersion models with the field data, it is necessary to convert the measured odour intensity to odour concentration. Much research has been conducted to correlate the intensity to concentration for livestock odours (Bundy et al. 1997, Nicolai et al. 2000, Guo et al. 2001). Nicolai et al. (2000) and Guo et al. (2001) showed that the Weber-Fechner logarithmic model provided the best mathematical description of odour from hog operations. The model has the form of:

$$I = k_1 + k_2 \ln(C) \tag{4.2}$$

where

I = odour intensity

C = concentration of stimulus (OU/m$^3$)

$k_1$ and $k_2$ = constants

To evaluate two constants $k_1$ and $k_2$, odour samples collected in Tedlar bags were evaluated for odour intensity by trained sniffers after testing for odour concentration on the olfactometer. Then measured intensity and concentration were plotted in a semi-log scale to determine $k_1$ (intercept) and $k_2$ (slope). Sixteen odour samples were collected in Tedlar bags from the two farms and presented to the trained human panel for odour intensity and odour concentration measurement in the olfactometer lab at the University of Manitoba. Two of the original source samples were diluted 5 to 200 times to make more diluted subsamples. The human panel used for evaluation of odour intensity and odour concentration in the lab was the same as that used for field sniffing. The results were plotted in Fig. 4.8, and the constants were determined as: $k_1 = 0.78$ and $k_2 = 1.43$.

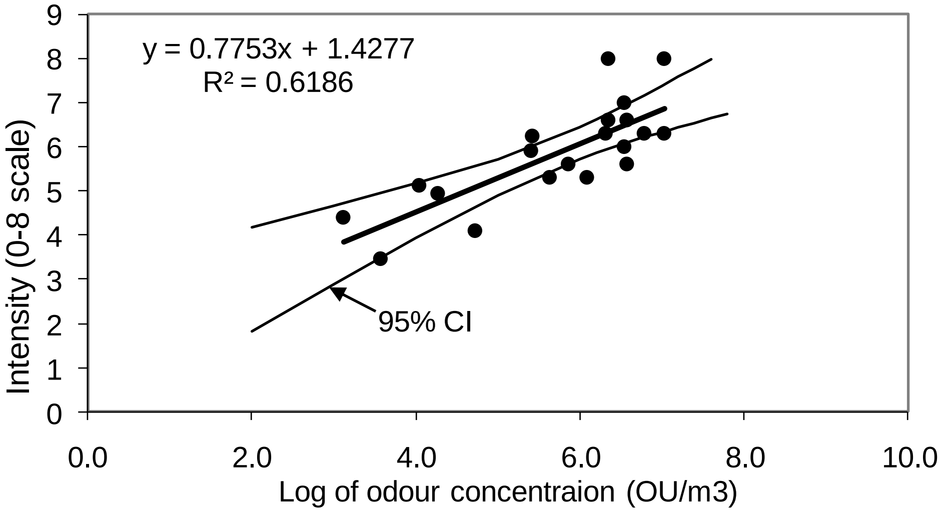


**Figure 4.8.** Relationship between odour intensity and odour concentration.

### 4.3.2 Comparisons between model predictions and field measurements

Odour concentrations predicted by three dispersion models (AUSPLUME, ISCST3, and INPUFF) are summarized in Appendix D. It should be noted that the receptor grid used in the dispersion simulations matched the field measurement grid shown in Fig. 3.5, so that model predictions could be compared to the field odour data reported by human assessors for the 15 measurement locations. Equation (4.3) was then used to convert odour concentrations predicted by the three dispersion models to odour intensities. AUSPLUME and ISCST3 predicted one-hour odour concentrations, while the field odour intensity was measured in sessions of ten-minutes, with three sessions per hour. Therefore, the measured odour intensities for every three ten-minute sessions within one hour were averaged as the one-hour average for comparison with the two dispersion models. INPUFF-2 predicted ten-minute average odour concentrations. Therefore, the predicted values were directly compared with the ten-minute odour intensity values measured in the field. A total of 420 data points were compared between the model predictions and field measurements for AUSPLUME and ISCST3, and 1422 data points for INPUFF-2 (see Appendix E for details).

The field odour intensity reported by human assessors varied considerably within a one hour or a ten minute period (see Section 4.4 for details). The mean values and the 95% CI (confidence interval) of field odour intensity were calculated for one hour and a ten minute period. The following criterion was used to assess the agreement between the dispersion model prediction and the field data: *If a model predicted value was within the 95% CI of the measured odour intensity value, this prediction was considered to **agree** with the measurement*. The detailed comparisons are presented in Appendix E, and the percentage of agreement between the predicted and measured intensity values at three downwind distances are summarized in Table 4.5.

**Table 4.5.** Summary of comparisons between predictions by dispersion models and field measurements

| Downwind distance | % agreement | | | | | |
|---|---|---|---|---|---|---|
| | AUSPLUME | | ISCST3 | | INPUFF-2 | |
| | Farm A | Farm B | Farm A | Farm B | Farm A | Farm B |
| 100 m | 68% | 69% | 64% | 63% | 61% | 47% |
| 500 m | 99% | 89% | 99% | 88% | 98% | 90% |
| 1000 m | 100% | 98% | 100% | 97% | 100% | 98% |
| **Overall** | **89%** | **85%** | **88%** | **83%** | **86%** | **78%** |

The percentage of agreement was relatively low for downwind distance of 100 m for all three models (Table 4.5). The lowest agreement was 47% for INPUFF-2 and the highest 68% for AUSPLUME. Three models predicted odour reasonably well at 500 and 1000 m, with the percentage agreement ranging from 88% to 100%. In particular, the agreement between model predictions and field measurements was almost 100% for three models at 1000 m. This observation agrees with that reported by Guo et al. (2001) when they compared INPUFF-2 with the field data. They showed that INPUFF–2 could successfully simulate the low odour intensity (level 1 in 0-3 scale), but underestimated both (high) intensities 2 and 3. Since long-distance (>1000 m) predictions are of more practical value in assessing the odour impact, all three models are considered to be adequate in predicting odour impact because the agreement for all three models was above 97% for 1000 m.

### 4.3.3 Odour Impact Distance

The most commonly used method of mitigating livestock odours is to maintain appropriate separation (setback) distances between the livestock operations and the surrounding residences/communities. It is critical to know how far odour travels when determining the setback distances. The variation of odour intensity with downwind distance is discussed in this section.

The 15 sniffers were located in three cross-sections transverse to the wind direction and each cross-section had five measurement locations. The distances of three cross-sections were about 100, 500, and 1000 m to the odour source. At each of the three distances, there was one sniffer located at or close to the centerline of an odour plume and this sniffer reported the highest average intensity of all the 5 sniffers. This maximum odour intensity of each cross-section was used to develop a relationship between the odour intensity and the distance (directly downwind). Equation 4.2 indicates that the odour intensity was linearly related to the logarithmic value of the odour concentration. Since the odour concentration decreases with the downwind distance by dilution, a similar relationship was assumed between the intensity and the distance as following:

$$I = k_3 + k_4 \ln(D) \qquad (4.3)$$

where

I = maximum odour intensity reported at downwind distance D (0-8 intensity scale)

D = distance directly downwind from the odour source (m)

$k_3$ and $k_4$ = empirical constants

The two constants $k_3$ and $k_4$ were determined by plotting the measured odour intensity against downwind distance (Figs. 4.9 and 4.10). The regression equations for the two farms were obtained as follows:

$$I = 10.34 - 1.44\ln(D) \quad \text{for Farm A} \qquad (4.4a)$$

$$I = 13.31 - 1.87\ln(D) \quad \text{for Farm B} \qquad (4.4b)$$

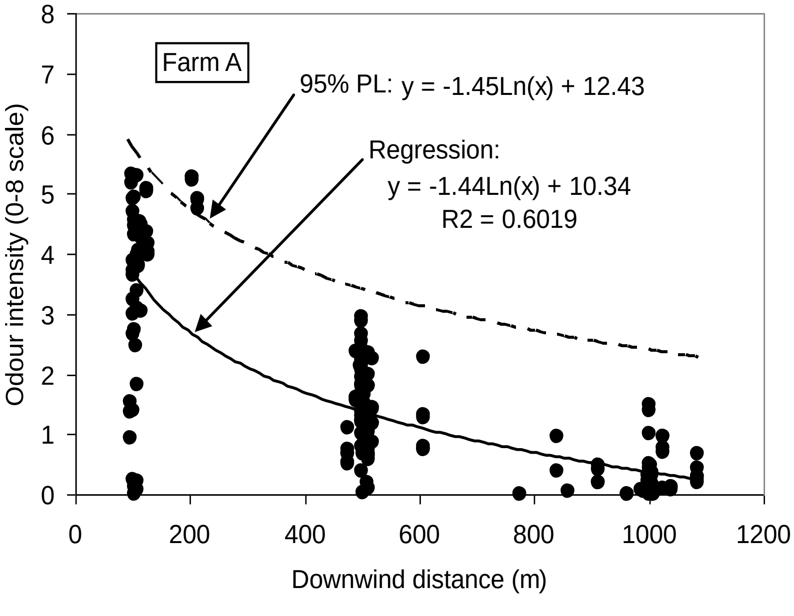


**Figure 4.9.** Variation of odour intensity with downwind distance on Farm A.

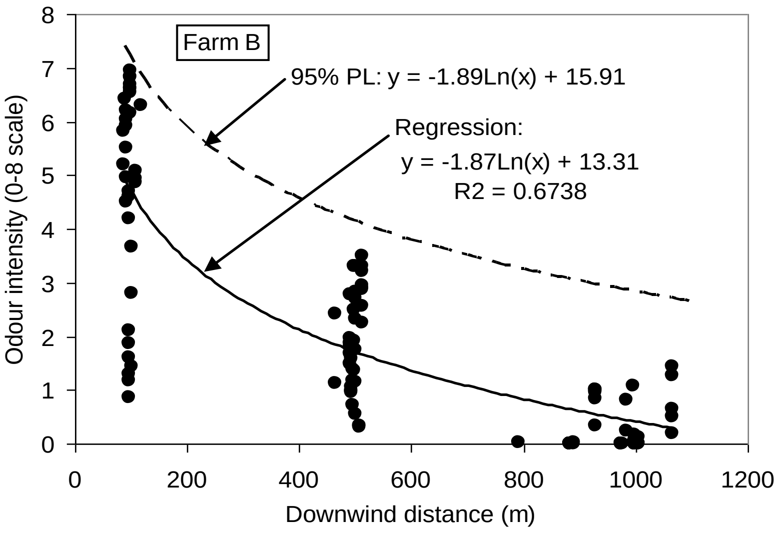


**Figure 4.10.** Variation of odour intensity with downwind distance on Farm B.

However, the regression equation represents the relationship between the mean odour intensity and the distance. If the regression equation were to be used to predict the odour intensity at a given downwind distance, there would be a 50% probability for the measured odour intensity to be higher than the predicted values. In other words, if the setback distance was determined based on the regression equation, there would be a 50% probability that the odour level would exceed the acceptable level. A 50% probability is obviously not acceptable in defining the setback distance. The prediction limit (PL) (or prediction interval) was proposed to be used to predict the odour intensity at given distances. For example, the upper 95% PL (Figs. 4.9 and 4.10) defines an intensity limit at a given distance that the probability for the intensity of “future” odour events to be higher than this limit is 5%. In other words, if the intensity determined by the upper 95% PL is used to define the annoyance-free odour level, the probability of annoyance-free would be 95%. A statistical analysis package MINITAB (Minitab Inc., State College, PA) was used to determine the odour intensity prediction limits for the two farms at various confidence levels and the results are summarized in Table 4.6. The predicted results are graphically illustrated in figures 4.11 and 4.12 for Farm A and B, respectively.

**Table 4.6.** Equation constants for the prediction limits

| | 90%PL | | 92.5%PL | | 95%PL | | 97.5%PL | | 99%PL | |
|---|---|---|---|---|---|---|---|---|---|---|
| Farm | A | B | A | B | A | B | A | B | A | B |
| $k_3$ | 12.1 | 15.4 | 12.2 | 15.6 | 12.4 | 15.8 | 12.7 | 16.2 | 13.1 | 16.6 |
| $k_4$ | -1.4 | -1.9 | -1.4 | -1.9 | -1.4 | -1.9 | -1.4 | -1.9 | -1.4 | -1.9 |

Intensity (I) is predicted as a function of distance (D) by equation $I = k_3 + k_4 \ln(D)$

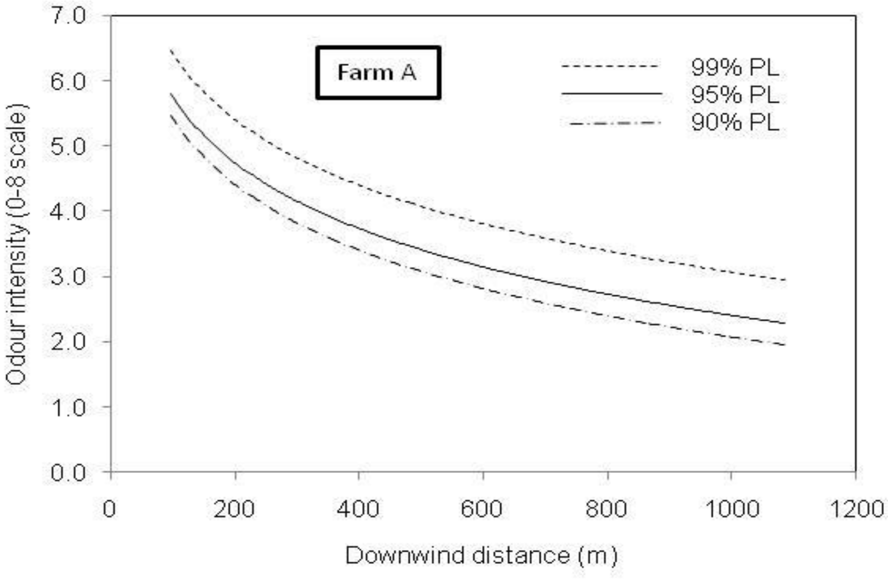


**Figure 4.11.** Prediction limits for odour intensity on Farm A.

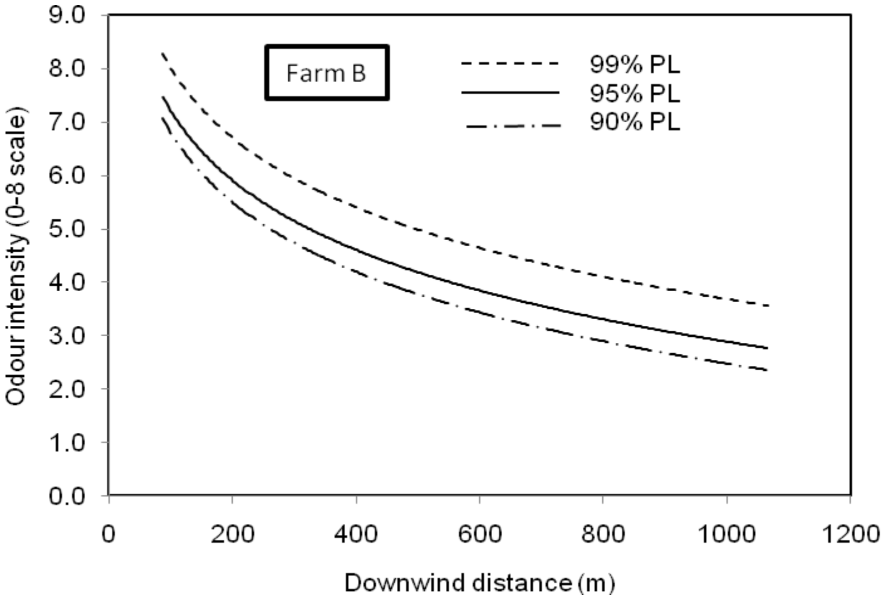


**Figure 4.12.** Prediction limits for odour intensity on Farm B.

It was observed that while the slope $k_4$ in equation 4.3 remained the same for different confidence levels, the difference in the intercept $k_3$ became larger as the confidence level became higher. For example, $k_3$ increased from 12.1 to 12.2 when the confidence level changed from 90 to 92.5%, whereas it increased from 12.7 to 13.1 when the confidence level changed from 97.5 to 99% for Farm A. In other words, predicted odour intensity increased with the confidence level in a nonlinear fashion. This indicates that the predicted setback distance would increase nonlinearly with the odour-annoyance free frequency.

The predicted odour intensity for Farm A was lower than that for Farm B (fig.4. 13), apparently due to the lower odour emission on Farm A which had covered manure storage. But it is interesting to note that the difference in predicted odour intensity between the farms decreased with the distance. For example, the difference was 1.6 at 100 m and decreased to 0.6 at 1000 m.

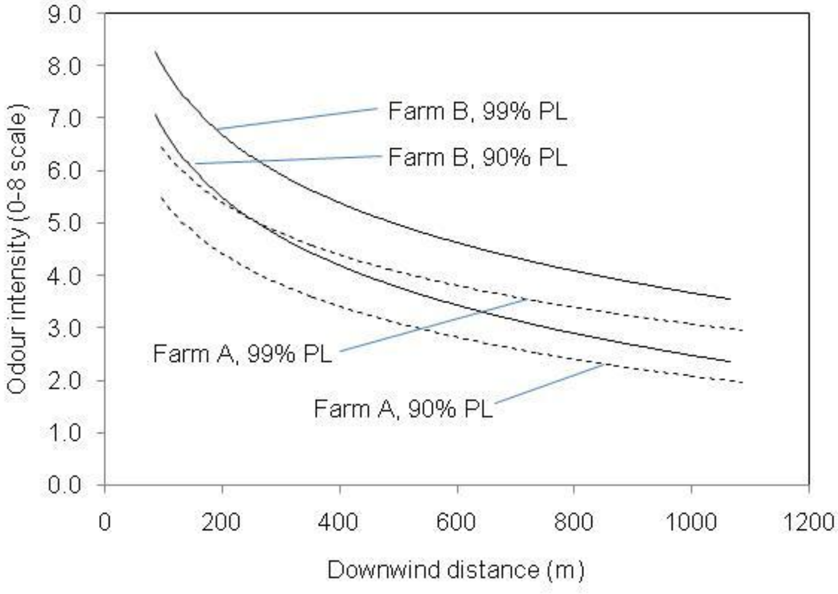


**Figure 4.13.** Comparison of prediction limits for odour intensity between Farm A and Farm B.

Constants in Table 4.6 may be used in equation 4.3 to determine the odour impact distances if the acceptable odour intensity level is prescribed. Odour intensity level 2 in the 0-8 scale is considered to be *little annoying* (Table 3.2). Therefore substituting I = 2 into equation 4.3 yields the separation distance for *odour annoyance free* (Table 4.7).

**Table 4.7.** Setback distances (m) determined by prediction limit equations at confidence levels of 90% to 99% for odour intensity level 2 in 0-8 scale.

| | **90%PL** | **92.5%PL** | **95%PL** | **97.5%PL** | **99%PL** |
|---|---|---|---|---|---|
| Farm A | 1060 | 1170 | 1333 | 1638 | 2094 |
| Farm B | 1290 | 1414 | 1598 | 1938 | 2441 |

It is apparent that the odour impact distance for Farm B was greater than that for Farm A because of the manure storage cover on Farm A. It is interesting to note that the total odour emission from Farm A was 54% of that from Farm B (Table 4.3), but the separation distance (99% PL) for odour annoyance-free for Farm A was 86% of that for Farm B. This means that a reduction in odour emission resulted in a reduction in separation distance, but the magnitude (percentage) of reduction in separation distance was considerably less than the reduction in emission rate.

The measured odour impact distances were compared with four setback models that are used in North America, namely, Minnesota OFFSET, Purdue Model, Alberta MDS, and Ontario MDS II. Detailed calculations of these four models can be found in Guo et al. (2006). The shortest setback distances calculated by all models except the Purdue model were shorter than that determined by the 90% PL (Table 4.8). The maximum distance by the Ontario model was considerably (about 50%) lower than the 99% PL of the measured data, whereas the maximum distances by the Purdue and Alberta models were reasonably close to the 99% PL. The 98.6% annoyance-free distance by Minnesota model was close to the 99% PL.

**Table 4.8.** Comparison of Setback distances (m) determined by the four models

| | i) Minnesota OFFSET | | | | | | Purdue | | Alberta | | Ontario | | Measured | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | W1 99.95% | W2 99.1% | W3 98.6% | W4 97.5% | W5 95.0% | W6 90.8% | Max* | Min* | Max | Min | Max | Min | 99%PL | 90%PL |
| Farm A | 5061 | 3185 | 2042 | 1638 | 1173 | 894 | 2126 | 1063 | 1873 | 702 | 1114 | 557 | 2094 | 1060 |
| Farm B | 5244 | 3305 | 2120 | 1705 | 1222 | 933 | 2841 | 1420 | 2345 | 879 | 1114 | 557 | 2441 | 1290 |

W1-W6: weather classes, along with % annoyance-free; * Mean of 16 directions;

It is interesting to note that covering EMS had little (<5%) effect on the required setback distances in the Minnesota and Ontario models. The maximum setback distances calculated by the Purdue model for Farm A (covered EMS) were 75% of for Farm B (open EMS), or a 25% reduction in separation distance by covering EMS. The Alberta model predicted a 20% reduction, and the 99% PL from the measured data resulted in a 14% reduction.

### 4.4 Peak-to-Mean (P-M) Ratio for Downwind Odour Intensity

#### 4.4.1 Typical pattern of field measured odour intensity

There were 5 sniffers located at each of the three downwind distances（100, 500, and 1000 m）at cross-sections transverse to the wind direction but only one sniffer located at or close to the centerline of an odour plume would report the highest intensity of all the 5 sniffers. A typical field measurement session of 10 min by a human assessor located 1000 m directly downwind from the odour source is presented in Fig. 4.14. Within the first 4 min, an intensity value of 2 was recorded most of the time, but two bursts (10 s interval) of 3 were noted. From 4 to 10 min, the intensity stayed mostly at level 1 and dipped to 0 several times. The mean value during the 10 min period was 1.3, which means that the peak to mean ratio for the period was 2.3. In the following sections, the P-M ratios for various time intervals are discussed.

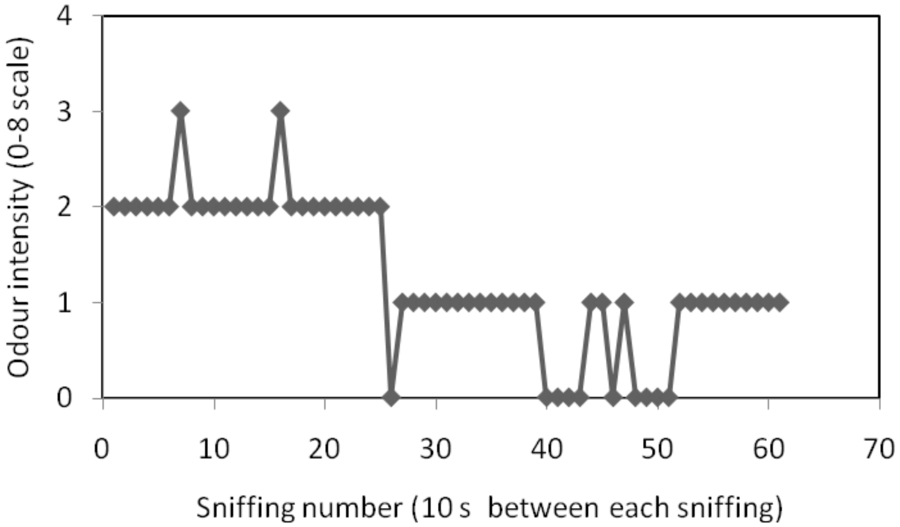


**Figure 4.14**. Instantaneous field odour intensity within a 10-min period, measured by a human assessor located 1000 m directly downwind from odour source.

### 4.4.2 P-M ratio vs. downwind distance

Figures 4.15, 4.16 and 4.17 show respectively 1-min, 10-min, and 1-h P-M ratios at different downwind distances under different stability classes. From these figures, two important observations were made: (1) the P-M ratio increased with downwind distance; and (2) the rate of increase was dependent on the averaging time and weather stability classes. For example, under stability class B, the 1-min P-M ratio was 1.36 at 100 m and increased to 2.43 at 1,000 m, whereas, under stability class E, the 1-min P-M ratio was 1.18 at 100 m and 1.64 at 1,000 m. The effect of both distance and stability class on the P-M ratio became more pronounced as the averaging time increased from 1 min to 10 min, and to 1 h. For example, under stability class B, the 1-h P-M ratio increased from 1.86 at 100 m to 10.13 at 1,000 m, and from 1.46 to 3.81 under stability class E.

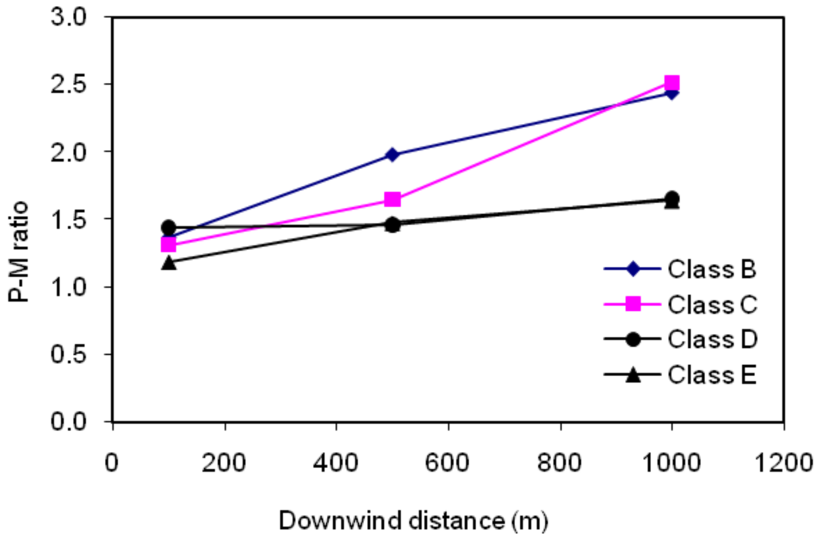


**Figure 4.15.** One-minute peak-to-mean ratio at different downwind distances and atmosphere stability classes

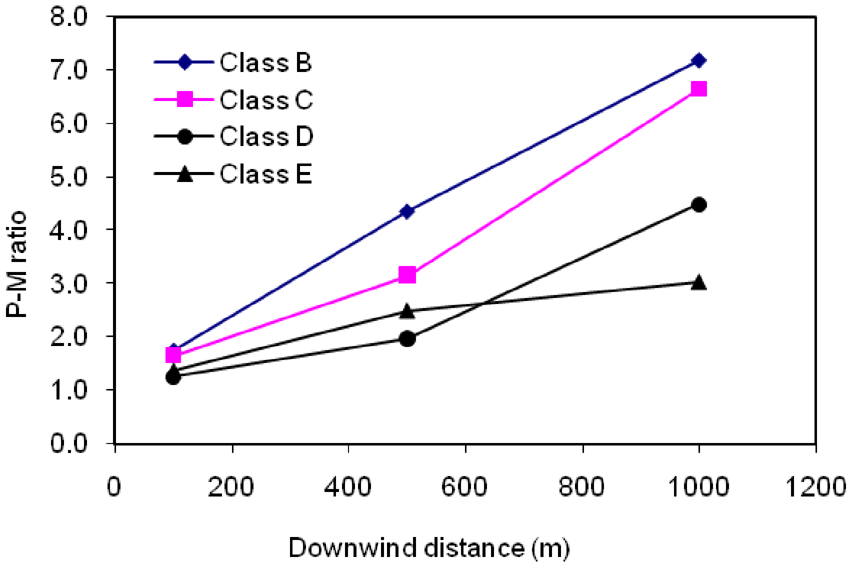


**Figure 4.16.** Ten-minute peak-to-mean ratio at different downwind distances and atmosphere stability classes

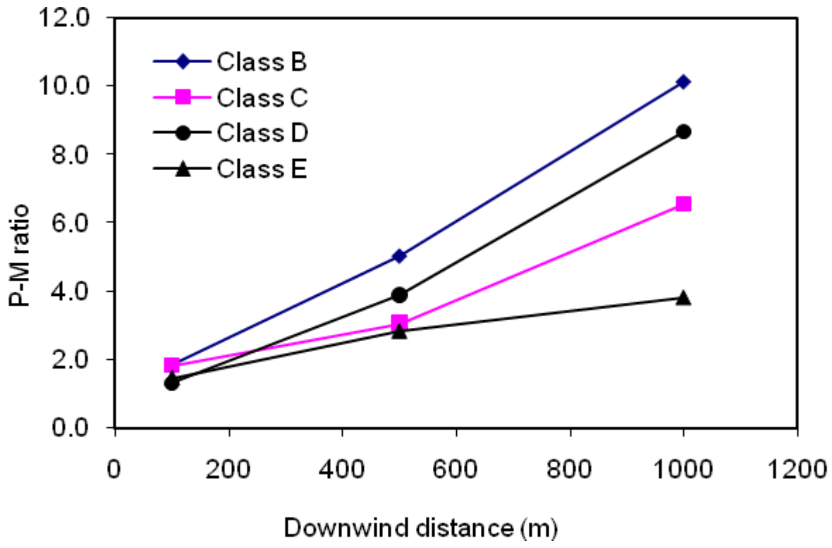


**Figure 4.17.** One-hour peak-to-mean ratio at different downwind distances and atmosphere stability classes

The more turbulent (unstable) the atmosphere is, the higher the P-M ratio. For example, the 1-h P-M ratio at 1,000 m was 10.13 for stability class B, and only 3.81 for class E. This observation agrees with previous findings that under unstable weather conditions higher peak downwind odour concentration can be experienced (Smith 1973).

It is apparent that the longer the averaging time, the greater the P-M ratio, and the difference was greater at greater distances and under more turbulent (unstable) atmospheric conditions. For example, at 1,000 m downwind distance and under stability class B, the 1-h P-M ratio was 4.2 times the 1-min value (10.13 vs. 2.43).

Most dispersion models predict 1-h downwind odour concentration, and therefore, the following equation was proposed to correlate the 1-h P-M ratio to downwind distance under different stability classes:

$$R_{PM\text{-}1h} = a\, e^{bx} \tag{4. 5}$$

where

$R_{PM\text{-}1h}$ = 1-hour peak to mean odour intensity ratio x = downwind distance (m)

a, b = constants

Regression analyses were performed to determine the two constants a and b, as functions of atmospheric stability class (Table 4.9):

**Table 4.9.** Empirical constants for regression equation correlating P-M odour ratio to downwind distance

| Stability Class | B | C | D | E |
|---|---|---|---|---|
| a | 1.43 | 1.55 | 1.10 | 1.40 |
| b | 0.0018 | 0.0012 | 0.0018 | 0.0011 |

### 4.4.3 P-M ratio vs. averaging time

The P-M ratio generally increased with the averaging time and this trend was more pronounced at greater distances and under more turbulent atmospheric conditions (Figs. 4.18, 4.19 and 4.20). The power function of time ratio has been used in the literature (e.g., Smith 1993) to "scale" concentration to different averaging time as follows:

$$C = C_0 \, (T_0/T)^{q} \qquad \text{or} \qquad C/ C_0 = (T_0/T)^{q} \qquad (4.6)$$

where

$C$ = pollutant concentration of T hour averaging

$C_0$ = pollutant concentration of $T_0$ hour averaging

$T_0$ = reference time (e.g., 1 h commonly used in dispersion modelling)

$T$ = time period

$q$ = constant

In this study, field sniffing used a 10 s interval. That is, a peak odour event may be assumed to be an average measurement of 10 s. Following equation 4.7, the 1-min, 10-min, and 1-h P-M ratio may be expressed as:

$$R_T = C_0/C = (T/\ T_0)^{\ q} \qquad (4.7)$$

where

$R_T$ = P-M ratio of averaging time T

T = averaging time (1, 10 or 60 minutes)

$T_0$ = sniffing time (10 s)

A typical plot of $R_T$ vs. $(T/\ T_0)$ is shown in Fig. 4.21. The constant q was determined by regression analysis and the values are summarized in Table 4.10.

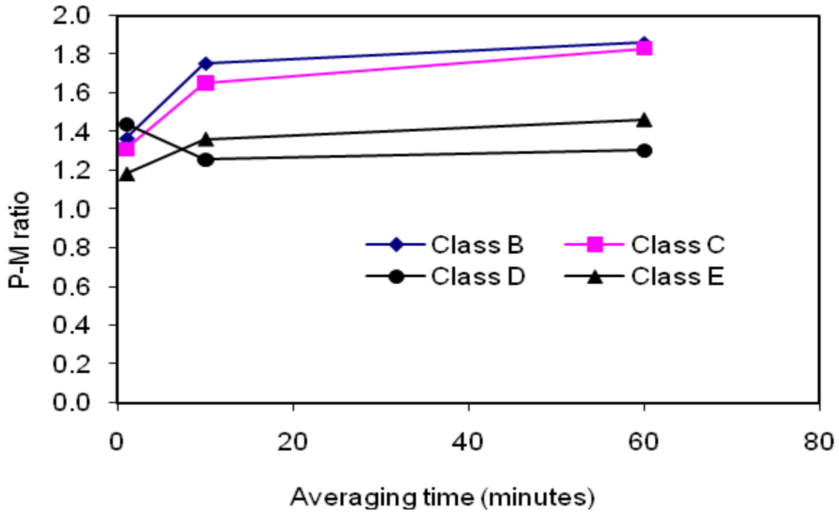


**Figure 4.18.** Variation of peak-to-mean ratio with averaging time for downwind distance of 100 m

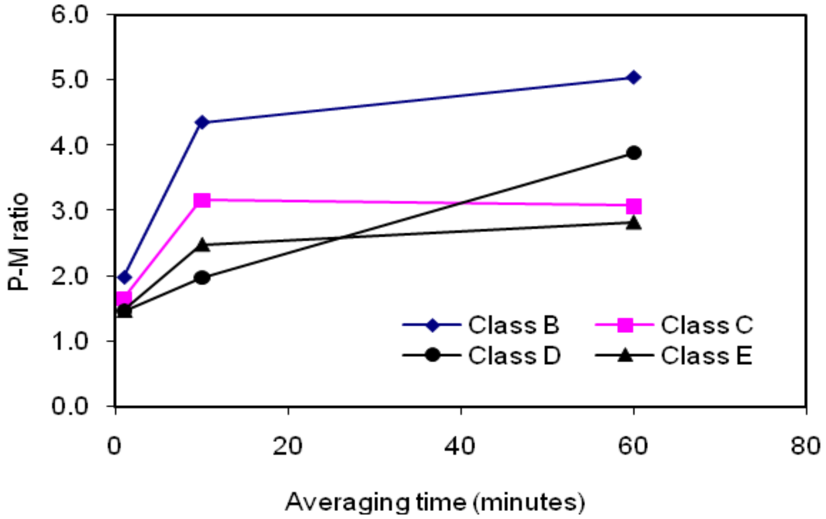


**Figure 4.19.** Variation of peak-to-mean ratio with averaging time for downwind distance of 500 m.

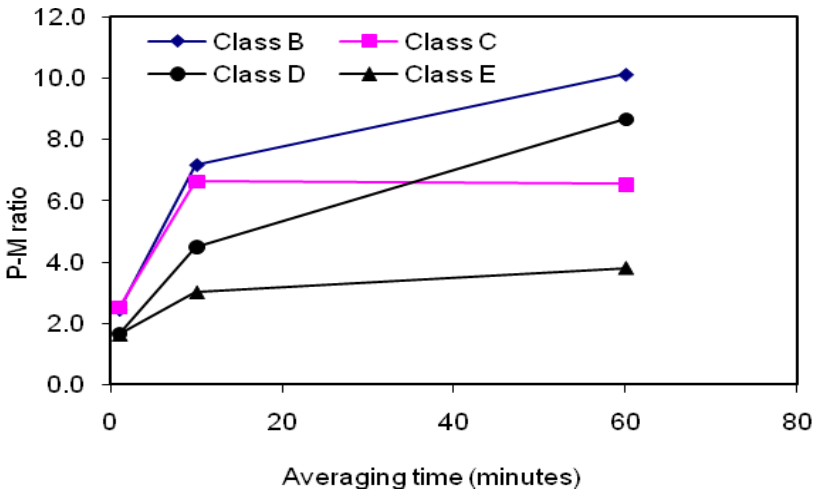


**Figure 4.20.** Variation of peak-to-mean ratio with averaging time for downwind distance of 1000 m

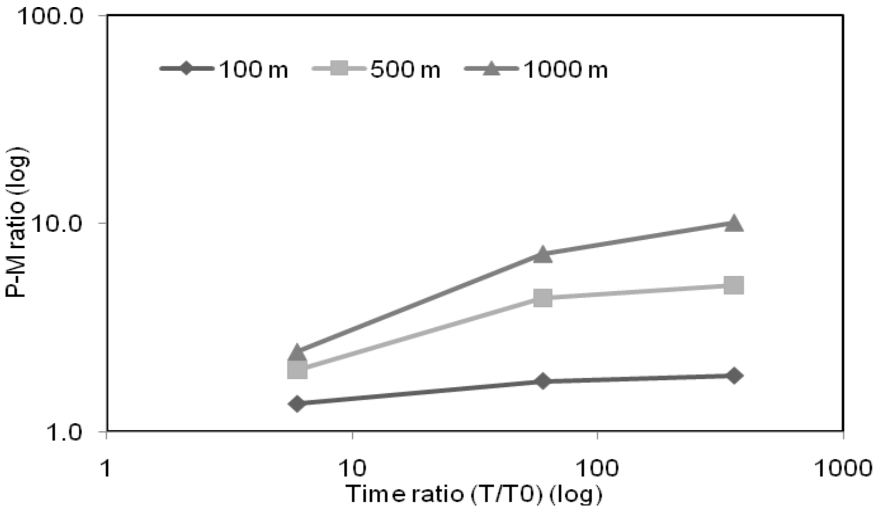


**Figure 4.21.** Peak-to-mean ratio as a function of averaging time to sniffing time ratio for stability class B

**Table 4.10.** Empirical exponent (q) in regression equation $R_T = (T/\ T_0)^{\ q}$ for correlating P-M odour ratio to averaging time

| Stability Class | B | C | D | E |
|---|---|---|---|---|
| 100 m | 0.12 | 0.11 | 0.06 | 0.07 |
| 500 m | 0.31 | 0.22 | 0.21 | 0.19 |
| 1000 m | 0.43 | 0.37 | 0.36 | 0.24 |

It is apparent that the exponent q increased with the downwind distance, reflecting the increase of P-M odour ratio with the distance. It was also observed that the exponent q decreased with the atmospheric stability. For example the q-value decreased from 0.43 to 0.24 for 1000 m when the stability changed from B to E. The similar trend was reported by other researchers. Smith (1993) gave the following values of the exponent q for three stability classes: 0.65 (stability class B), 0.52 (C) and 0.35 (D). Duffee et al. (1991) reported values of q being 0.5 for stability class A or B, 0.33 for C, 0.20 for D, and 0.17 for E and F. The distance effect on the exponent q is rarely considered in the literature. Since separation distances from livestock operations are generally greater than 500 m, the exponent q values determined for 1000 m in this study should be used when comparing with the values reported in the literature. It can be seen that the exponent values determined in this study were lower than those by Smith (1993) and close to those of Duffee et al. (1991). Mahin (1997, 1998) pointed out that there was no agreement on the appropriate power law exponent for different stability classes.

# Chapter 5. CONCLUSIONS

## 1. Odour emission

1.1. On Farm B which had open earthen manure storage (EMS), the total odour emission was 321,190 OU/s, of which 129,267 OU/s was contributed by buildings and 191,923 OU/s were by EMS. In other words, the open EMS contributed 60% to the total odour emission.

1.2. On Farm A which had negative air pressure (NAP) covered EMS, the total odour emission was 174,476 OU/s, of which 170,707 OU/s was contributed by buildings and 3,770 OU/s were by EMS. In other words, the covered EMS contributed 2% to the total odour emission.

1.3. Odour emission from farrowing rooms was 2 to 3 times higher than that from gestation rooms. The average odour emission rate of the two farms was 22.9 OU/s-m$^2$ from farrowing rooms and 9.6 OU/s-m$^2$ from gestation rooms.

## 2. Effect of covering manure storage

2.1. The average odour emission rate from the negative pressure covered earthen manure storage (NAP EMS) was negligible in comparison with the open EMS (0.3 vs 20.3 OU/ s-m$^2$). The total odour emission (combined building and manure storage) from Farm A with NAP EMS was 58% of that from Farm B with open EMS (174,552 vs. 303,120 OU/s).

2.2. Downwind odour intensity measured by trained human sniffers on Farm A with covered manure storage was significantly ($P<0.05$) lower than that on Farm B with open manure storage at 100 and 500 m, but the difference in odour intensity at 1000 m was not significant (P>0.05) between the two farms.

2.3. A reduction in odour emission by covering manure storage resulted in a reduction in separation distance required for odour annoyance-free, but the magnitude (percentage) of reduction in separation distance was considerably less than that in emission rate. In other words, the reduction in odour emission should not be directly translated to the reduction in separate distance. Specifically, a 46% difference in odour emission rate between Farms A and B resulted in a 14% difference in the separation distance for odour annoyance-free between the two farms.

## 3. Dispersion models

3.1. Three commonly used dispersion models, namely AUSPLUME, ISCST3, and INPUFF-2, were used to predict downwind odour from the farms. The percentage of agreement between model predictions and field measurements was adequate for downwind distances of 500 and 1000 m, but relatively low for 100 m for all three models. Since the long-distance (>1000 m) predictions are of more practical value, all three models were considered to be adequate in predicting odours downwind from the hog operations.

## 4. The peak-to-mean ratio

4.1. The peak-to-mean ratio of field odour intensity increased with downwind distance. The largest difference in peak-to-mean ratio between 100 m and 1000 m was 5.5 times (1.86 vs. 10.13) for unstable atmospheric conditions (stability class B).

4.2. The longer the averaging time, the higher the odour intensity peak-to-mean ratio. The largest difference in peak-to-mean ratio between 1-min and 1-h averaging times was 4.2 times (2.43 vs. 10.13) for stability class B at 1000 m.

4.3. Higher peak-to-mean ratios occurred under unstable atmosphere conditions. The largest difference in peak-to-mean ratio between classes B and E was 2.7 times (10.13 vs. 3.81) for 1-h averaging time at 1000 m.

# Chapter 6. RECOMMENDATIONS

## 6.1 Odour Emission Measurement

Source emission and odour dispersion in the atmosphere are two important factors in determining the impact of livestock odour on the downwind neighborhood community. It is well known that for a particular livestock farm, both source odour concentration and emission can vary significantly upon seasonal, diurnal, and climatic variations. This makes the quantification of odour emission from animal farms a challenge, especially when conducting field odour dispersion studies while odour emission needs to be quantified simultaneously. In this study, “grab” samples were taken from building exhaust and manure storage throughout summer and fall seasons to determine the odour emission rates. These grab samples were taken over a time period reflected the general trend of odour emission, but did not reveal the true variations in odour emission. For future studies, odour samples should be taken continuously for certain time period to quantify the relationship between odour emission and ventilation, and diurnal and seasonal variations in odour emission. However, it is difficult, if not impossible, to use the current method of choice for odour measurement – olfactometry, for continuous odour measurement. Therefore, there is a need for quick and accurate methods to quantify odour concentration, such as electronic noses, in order to quantify odour emission.

Furthermore, the odour emission rate from animal buildings is calculated as the product of odour concentration and ventilation rate. Continuous measurement of building ventilation rate should be performed using reliable methods, such as the multiport averaging Pitot tube method proposed by Clark et al. (2008), along with odour measurement so that source emission can be determined accurately.

Measuring odour emission from the liquid manure surface in manure storage presents particular difficulties, because there is usually no well-defined airflow associated with emission. Odour emission from manure surface may vary substantially both spatially and temporally, which is affected by the factors like manure properties, temperature, and wind. The wind tunnel technique has been identified as the best available method for sampling odour emission from area sources and was used in this study. In wind tunnel sampling, a fan pulls air through an activated carbon filter mounted at the inlet of the wind tunnel to remove any odour that might exist in the incoming air. The bottom of the wind tunnel chamber is open to the manure and the air picks up odour when passing through the chamber. The odour emission rate is determined as the difference in measured odour concentrations between inlet and outlet, multiplied by the airflow rate. The basic principles governing the mass transfer from the manure surface to the air flowing through the wind tunnel suggest that emissions are dependent on the air velocity near the manure surface. A constant airflow rate was used in this study. Therefore, the odour emission rates measured in this study were “nominal” rates for a given air (wind) speed. Further research should be conducted to develop relationships between wind speed and emission rate. This will allow the use of variable emission rates in subsequent odour dispersion modeling.

It was also observed that the carbon filter could not effectively remove odour in the incoming airstream at the inlet, and occasionally caused the odour concentration at the inlet to be higher than that at outlet. This consequently resulted in negative odour emission rates. It is recommended that the wind tunnel design should be improved to ensure that the air entering the wind tunnel is free of odour.

## 6.2 Dispersion Modelling

Most of the dispersion models used for odour studies were originally designed for industrial gas dispersion. Compared with constant industrial source emission, livestock odour sources are usually low or ground level area sources with little plume rise and large variations; the target downwind receptor zone for livestock odour emission is closer to the emission source compared to long distance industrial pollutant travelling; and furthermore, most industrial dispersion models can only predict mean concentrations (typically one-hour average). A short-term (a few seconds) burst of odour in the environment may cause annoyance or even complaints. From the field measurements in this study, it was shown that the peak odour level was 10 times as high as the one-hour mean. It is clear that more research is needed to develop odour dispersion models that can predict instantaneous odour levels downwind from the livestock operations. The models should be able to account for variations in odour emission and instantaneous changes in atmospheric conditions, and are accurate for short distance transportation of odour.

Dispersion modelling simulates the process of dilution of gaseous and particulate pollutants in the atmosphere. However, when odour is diluted in the atmosphere, its intensity decreases differently depending on the persistence of odour. In other words, the dispersion models developed for gaseous and particulate pollutants are not capable of simulating the changes in odour intensity in the atmosphere without considering the odour persistence. Some researchers (e.g., Zhu et al. 2000b) suggested that the odour emission rate be amplified by a scaling factor when using the rate in the dispersion model. They used different scaling factors for difference livestock odour sources (buildings and manure storage). Further research is recommended to develop dispersing models that are capable of predicting the changes in other odour attributes (e.g., intensity) besides concentration during atmosphere transport.

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# APPENDIX A

## Measured Airflow Rates in Three Consecutive Sessions for Farm A

**Table A.1.** Measured airflow rates in three consecutive sessions for Farm A

| | Airflow rate ($m^3/s$) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Fan #** | July 6 | July 13 | July 20 | Mean | Min | Max | Discrepancy* |
| 1 | 3.74 | 3.57 | 3.44 | 3.58 | 3.44 | 3.74 | 8% |
| 3 | 2.23 | 2.24 | 2.21 | 2.23 | 2.21 | 2.24 | 2% |
| 4 | 1.93 | 1.86 | 1.74 | 1.84 | 1.74 | 1.93 | 10% |
| 6 | 2.00 | 2.13 | 1.65 | 1.93 | 1.65 | 2.13 | 25% |
| 8 | 1.90 | 1.90 | 1.81 | 1.87 | 1.81 | 1.90 | 5% |
| 10 | 2.33 | 2.51 | 2.32 | 2.38 | 2.32 | 2.51 | 8% |
| 12 | 3.59 | 4.02 | 3.64 | 3.75 | 3.59 | 4.02 | 11% |
| 13 | 3.47 | 3.52 | 3.77 | 3.59 | 3.47 | 3.77 | 8% |
| 15 | 1.77 | 1.90 | 1.74 | 1.80 | 1.74 | 1.90 | 9% |
| 16 | 2.43 | 1.94 | 1.82 | 2.06 | 1.82 | 2.43 | 30% |
| 18 | 2.00 | 1.77 | 1.89 | 1.88 | 1.77 | 2.00 | 12% |
| 20 | 1.83 | 1.79 | 1.74 | 1.79 | 1.74 | 1.83 | 5% |
| 22 | 3.13 | 3.44 | 4.05 | 3.54 | 3.13 | 4.05 | 26% |
| 25 | 0.74 | 0.67 | 0.63 | 0.68 | 0.63 | 0.74 | 16% |
| 28 | 0.89 | 1.05 | 0.88 | 0.94 | 0.88 | 1.05 | 19% |
| 29 | 4.07 | 3.78 | 3.55 | 3.80 | 3.55 | 4.07 | 14% |
| 31 | 1.70 | 1.83 | 1.84 | 1.79 | 1.70 | 1.84 | 8% |
| 32 | 2.14 | 2.34 | 1.95 | 2.14 | 1.95 | 2.34 | 18% |
| 34 | 2.06 | 1.79 | 1.62 | 1.82 | 1.62 | 2.06 | 24% |
| 55 | 1.73 | 1.67 | 1.78 | 1.73 | 1.67 | 1.78 | 6% |
| 56 | 0.68 | 0.72 | 0.58 | 0.66 | 0.58 | 0.72 | 21% |
| 59 | 0.56 | 0.67 | 0.72 | 0.65 | 0.56 | 0.72 | 25% |
| 61 | 1.65 | 1.57 | 1.81 | 1.68 | 1.57 | 1.81 | 14% |
| 62 | 0.62 | 0.74 | 0.59 | 0.65 | 0.59 | 0.74 | 24% |
| 65 | 0.60 | 0.70 | 0.77 | 0.69 | 0.60 | 0.77 | 24% |
| 66 | 1.85 | 1.77 | 1.82 | 1.81 | 1.77 | 1.85 | 5% |
| 67 | 1.73 | 1.60 | 1.55 | 1.63 | 1.55 | 1.73 | 11% |
| 69 | 1.67 | 1.71 | 1.68 | 1.69 | 1.67 | 1.71 | 2% |
| 71 | 0.60 | 0.66 | 0.64 | 0.63 | 0.60 | 0.66 | 10% |
| 72 | 1.71 | 1.52 | 1.71 | 1.64 | 1.52 | 1.71 | 11% |
| 75 | 1.75 | 1.94 | 1.71 | 1.80 | 1.71 | 1.94 | 13% |
| 76 | 1.65 | 1.82 | 1.51 | 1.66 | 1.51 | 1.82 | 18% |
| 78 | 1.83 | 1.77 | 1.68 | 1.76 | 1.68 | 1.83 | 9% |
| 79 | 1.52 | 1.70 | 1.81 | 1.68 | 1.52 | 1.81 | 17% |
| 83 | 0.81 | 0.73 | 0.61 | 0.72 | 0.61 | 0.81 | 27% |
| 86 | 0.28 | 0.64 | 0.62 | 0.52 | 0.28 | 0.64 | 69% |
| 87 | 1.73 | 1.64 | 1.78 | 1.72 | 1.64 | 1.78 | 8% |
| 89 | 0.52 | 0.47 | 0.64 | 0.54 | 0.47 | 0.64 | 32% |
| 90 | 1.66 | 1.78 | 1.84 | 1.76 | 1.66 | 1.84 | 10% |

*Discrepancy = (Max – Min) ÷ Mean

# APPENDIX B

## Data Recording Sheet for Field Sniffing

**Table B.1.** Data recording sheet for field sniffing

ODOUR INTENSITY DATA RECORDING FORM - FOR SESSION: ________________________________

| | | |
|---|---|---|
| Sniffer ____________________________________ | **Date** ________ | **Position** ________ |
| **Sequence #** | **GPS Position**<br>**Latitude:** _________ | **Longitude:** ________ |

**Instructions:**

1. Put mask in place and move to field position. Record GPS position above.
2. On signal or at agreed time, begin data collection for sequence 1:
   - remove mask for 1-2 sec, sniff air, replace mask
   - record swine odour intensity by circling the appropriate scale point
3. Wait 10 minutes until next signal to do sequence 2 and then sequence 3.

| Time | Swine odour - standard intensity scale(circle the number of the standard closest to the swine odour intensity in the air you sniff) | Comments and/or Observations |
|---|---|---|
| **at 0 min** | Section 1.02<br>0 1 2 3 4 5 6 7 8 | |
| 10 sec | 0 1 2 3 4 5 6 7 8 | |
| 20 sec | 0 1 2 3 4 5 6 7 8 | |
| 30 sec | 0 1 2 3 4 5 6 7 8 | |
| 40 sec | 0 1 2 3 4 5 6 7 8 | |
| 50 sec | 0 1 2 3 4 5 6 7 8 | |
| **at 1 min** | Section 1.03<br>0 1 2 3 4 5 6 7 8 | |
| 10 sec | 0 1 2 3 4 5 6 7 8 | |
| 20 sec | 0 1 2 3 4 5 6 7 8 | |
| 30 sec | 0 1 2 3 4 5 6 7 8 | |
| 40 sec | 0 1 2 3 4 5 6 7 8 | |
| 50 sec | 0 1 2 3 4 5 6 7 8 | |
| **at 2 min** | Section 1.04<br>0 1 2 3 4 5 6 7 8 | |
| 10 sec | 0 1 2 3 4 5 6 7 8 | |
| 20 sec | 0 1 2 3 4 5 6 7 8 | |
| 30 sec | 0 1 2 3 4 5 6 7 8 | |
| 40 sec | 0 1 2 3 4 5 6 7 8 | |
| 50 sec | 0 1 2 3 4 5 6 7 8 | |
| **at 3 min** | Section 1.05<br>0 1 2 3 4 5 6 7 8 | |
| 10 sec | 0 1 2 3 4 5 6 7 8 | |
| 20 sec | 0 1 2 3 4 5 6 7 8 | |
| 30 sec | 0 1 2 3 4 5 6 7 8 | |
| 40 sec | 0 1 2 3 4 5 6 7 8 | |
| 50 sec | 0 1 2 3 4 5 6 7 8 | |
| **at 4 min** | Section 1.06<br>0 1 2 3 4 5 6 7 8 | |
| 10 sec | 0 1 2 3 4 5 6 7 8 | |
| 20 sec | 0 1 2 3 4 5 6 7 8 | |
| 30 sec | 0 1 2 3 4 5 6 7 8 | |
| 40 sec | 0 1 2 3 4 5 6 7 8 | |
| 50 sec | 0 1 2 3 4 5 6 7 8 | |

Sequence __ continued

| | | |
|---|---|---|
| **at 5 min** | Section 1.07<br>0 1 2 3 4 5 6 7 8 | |
| 10 sec | 0 1 2 3 4 5 6 7 8 | |
| 20 sec | 0 1 2 3 4 5 6 7 8 | |
| 30 sec | 0 1 2 3 4 5 6 7 8 | |
| 40 sec | 0 1 2 3 4 5 6 7 8 | |
| 50 sec | 0 1 2 3 4 5 6 7 8 | |
| **at 6 min** | Section 1.08<br>0 1 2 3 4 5 6 7 8 | |
| 10 sec | 0 1 2 3 4 5 6 7 8 | |
| 20 sec | 0 1 2 3 4 5 6 7 8 | |
| 30 sec | 0 1 2 3 4 5 6 7 8 | |
| 40 sec | 0 1 2 3 4 5 6 7 8 | |
| 50 sec | 0 1 2 3 4 5 6 7 8 | |
| **at 7 min** | Section 1.09<br>0 1 2 3 4 5 6 7 8 | |
| 10 sec | 0 1 2 3 4 5 6 7 8 | |
| 20 sec | 0 1 2 3 4 5 6 7 8 | |
| 30 sec | 0 1 2 3 4 5 6 7 8 | |
| 40 sec | 0 1 2 3 4 5 6 7 8 | |
| 50 sec | 0 1 2 3 4 5 6 7 8 | |
| **at 8 min** | Section 1.10<br>0 1 2 3 4 5 6 7 8 | |
| 10 sec | 0 1 2 3 4 5 6 7 8 | |
| 20 sec | 0 1 2 3 4 5 6 7 8 | |
| 30 sec | 0 1 2 3 4 5 6 7 8 | |
| 40 sec | 0 1 2 3 4 5 6 7 8 | |
| 50 sec | 0 1 2 3 4 5 6 7 8 | |
| **at 9 min** | Section 1.11<br>0 1 2 3 4 5 6 7 8 | |
| 10 sec | 0 1 2 3 4 5 6 7 8 | |
| 20 sec | 0 1 2 3 4 5 6 7 8 | |
| 30 sec | 0 1 2 3 4 5 6 7 8 | |
| 40 sec | 0 1 2 3 4 5 6 7 8 | |
| 50 sec | 0 1 2 3 4 5 6 7 8 | |
| **at 10 min** | Section 1.12<br>0 1 2 3 4 5 6 7 8 | |

<u>Summary of odours perceived during this 10 minute sequence:</u>

Were all of the odours manure odours?    Yes    No    (circle one).  If "no", what other odours did you perceive?

What were your surroundings at your location?  (grass, crop (which one?), open field, etc.)

Any other comments:

# APPENDIX C

## Summary of Statistical Analysis for Comparing Building Odour Emission Rates

**Table C.1.** t-test results (output from Microsoft Excel) for comparing the means of measured odour concentrations in farrowing rooms between two farms.

| | *Farm A* | *Farm B* |
|---|---|---|
| Mean | 1026 | 900 |
| Variance | 237158 | 255174 |
| Observations | 40 | 43 |
| Hypothesized Mean Difference | 0 | |
| df | 81 | |
| t Stat | 1.156818 | |
| P(T<=t) one-tail | 0.125373 | |
| t Critical one-tail | 1.663884 | |
| P(T<=t) two-tail | 0.250747 | |
| t Critical two-tail | 1.989686 | |

**Table C.2.** t-test results (output from Microsoft Excel) for comparing the means of measured odour concentrations in gestation rooms between two farms.

| | *Farm A* | *Farm B* |
|---|---|---|
| Mean | 927 | 799 |
| Variance | 99004 | 157317 |
| Observations | 14 | 13 |
| Hypothesized Mean Difference | 0 | |
| df | 23 | |
| t Stat | 0.924054 | |
| P(T<=t) one-tail | 0.182526 | |
| t Critical one-tail | 1.713872 | |
| P(T<=t) two-tail | 0.365052 | |
| t Critical two-tail | 2.068658 | |

**Table C.3.** t-test results (output from Microsoft Excel) for comparing the means of measured odour emission rates in farrowing rooms between two farms.

| | *Farm A* | *Farm B* |
|---|---|---|
| Mean | 22.7 | 23.0 |
| Variance | 241.7 | 206.3 |
| Observations | 40 | 43 |
| Hypothesized Mean Difference | 0 | |
| df | 79 | |
| t Stat | -0.07889 | |
| P(T<=t) one-tail | 0.46866 | |
| t Critical one-tail | 1.664371 | |
| P(T<=t) two-tail | 0.937321 | |
| t Critical two-tail | 1.99045 | |

**Table C.4.** t-Test results (output from Microsoft Excel) for comparing the means of measured odour emission rates in gestation rooms between two farms.

| | *Farm A* | *Farm B* |
|---|---|---|
| Mean | 11.6 | 7.6 |
| Variance | 36.3 | 11.4 |
| Observations | 14 | 13 |
| Hypothesized Mean Difference | 0 | |
| df | 21 | |
| t Stat | 2.145092 | |
| P(T<=t) one-tail | 0.021898 | |
| t Critical one-tail | 1.720743 | |
| P(T<=t) two-tail | 0.043796 | |
| t Critical two-tail | 2.079614 | |

**Table C.5.** t-Test results (output from Microsoft Excel) for comparing the means of measured odour emission rates between farrowing and gestation rooms for Farm A.

| | *Farrowing* | *Gestation* |
|---|---|---|
| Mean | 22.7 | 11.6 |
| Variance | 241.7 | 36.3 |
| Observations | 40 | 14 |
| Hypothesized Mean Difference | 0 | |
| df | 51 | |
| t Stat | 3.77544 | |
| P(T<=t) one-tail | 0.000209 | |
| t Critical one-tail | 1.675285 | |
| P(T<=t) two-tail | 0.000418 | |
| t Critical two-tail | 2.007584 | |

**Table C.6.** t-Test results (output from Microsoft Excel) for comparing the means of measured odour emission rates between farrowing and gestation rooms for Farm B.

| | *Farrowing* | *Gestation* |
|---|---|---|
| Mean | 23.0 | 7.64 |
| Variance | 206.3 | 11.4 |
| Observations | 43 | 13 |
| Hypothesized Mean Difference | 0 | |
| df | 53 | |
| t Stat | 6.443152 | |
| P(T<=t) one-tail | 1.77E-08 | |
| t Critical one-tail | 1.674116 | |
| P(T<=t) two-tail | 3.54E-08 | |
| t Critical two-tail | 2.005746 | |

**Table C.7.** Turkey multiple comparison test (output from Minitab) for comparing the means of measured odour emission rates between June, July, August and September for farrowing rooms.

### One-way ANOVA: Jun, Jul, Aug, Sep

```
Source  DF       SS      MS     F      P
Factor   3   866398  288799  8.33  0.000
Error   94  3257959   34659
Total   97  4124357

S = 186.2   R-Sq = 21.01%   R-Sq(adj) = 18.49%


                         Individual 95% CIs For Mean Based on
                         Pooled StDev
Level   N   Mean  StDev  ---+---------+---------+---------+------
Jun    13  378.7  260.6                  (--------*-------)
Jul    33  355.4  134.8                   (-----*----)
Aug    23  330.7  260.7                (------*-----)
Sep    29  147.9  114.3  (----*-----)
                         ---+---------+---------+---------+------
                          120       240       360       480

Pooled StDev = 186.2


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons

Individual confidence level = 98.96%


Jun subtracted from:

      Lower  Center  Upper     +---------+---------+---------+---------
Jul  -182.9   -23.4  136.1                (-------*-------)
Aug  -217.1   -48.1  120.9              (--------*-------)
Sep  -393.4  -230.8  -68.2     (-------*--------)
                               +---------+---------+---------+---------
                            -400      -200         0       200


Jul subtracted from:

      Lower  Center  Upper     +---------+---------+---------+---------
Aug  -157.0   -24.7  107.6                 (------*-----)
Sep  -331.4  -207.4  -83.4        (------*-----)
                               +---------+---------+---------+---------
                            -400      -200         0       200


Aug subtracted from:

      Lower  Center  Upper     +---------+---------+---------+---------
Sep  -318.7  -182.7  -46.7         (------*------)
                               +---------+---------+---------+---------
                            -400      -200         0       200
```

**Table C.8.** Turkey multiple comparison test (output from Minitab) for comparing the means of measured odour emission rates between June, July, August and September for gestation rooms.

### One-way ANOVA: Jun, Jul, Aug, Sep

```
Source  DF      SS     MS     F      P
Factor   3   58518  19506  6.71  0.001
Error   29   84267   2906
Total   32  142785

S = 53.90   R-Sq = 40.98%   R-Sq(adj) = 34.88%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean  StDev  -------+---------+---------+---------+--
Jun     4  103.23  70.73         (----------*----------)
Jul    11  153.83  62.36                       (------*-----)
Aug     8  100.63  60.54           (-------*-------)
Sep    10   48.18  22.91  (------*------)
                          -------+---------+---------+---------+--
                                50       100       150       200

Pooled StDev = 53.90


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons

Individual confidence level = 98.91%


Jun subtracted from:

         Lower  Center   Upper  -------+---------+---------+---------+--
Jul     -35.08   50.60  136.28               (---------*---------)
Aug     -92.47   -2.60   87.26          (---------*---------)
Sep    -141.87  -55.05   31.77     (--------*---------)
                                -------+---------+---------+---------+--
                                    -100         0       100       200


Jul_1 subtracted from:

         Lower   Center   Upper  -------+---------+---------+---------+--
Aug    -121.39   -53.20   14.99       (------*-----)
Sep    -169.77  -105.65  -41.53  (-----*------)
                                 -------+---------+---------+---------+--
                                     -100         0       100       200


Aug_1 subtracted from:

         Lower  Center  Upper  -------+---------+---------+---------+--
Sep    -122.06  -52.45  17.16       (------*------)
                               -------+---------+---------+---------+--
                                   -100         0       100       200
```

**Table C.9.** Turkey multiple comparison test (output from Minitab) for comparing the means of measured odour emission rates in four temperatures ranges (11-14°C, 15-19°C, 20-14°C, and 25-30°C) for farrowing rooms.

## One-way ANOVA: 11-14C, 15-19C, 20-24C, 25-30C

```
Source   DF       SS      MS      F      P
Factor    3  1098799  366266  11.51  0.000
Error    99  3150481   31823
Total   102  4249280

S = 178.4   R-Sq = 25.86%   R-Sq(adj) = 23.61%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level    N   Mean  StDev  ----+---------+---------+---------+-----
11-14C  29  124.1  101.0  (-----*------)
15-19C  26  304.7  229.4                    (-----*------)
20-24C  28  361.3  204.5                         (------*------)
25-30C  20  378.6  148.7                          (-------*-------)
                          ----+---------+---------+---------+-----
                            100       200       300       400

Pooled StDev = 178.4


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons

Individual confidence level = 98.97%


11-14C subtracted from:

        Lower  Center  Upper  ---+---------+---------+---------+------
15-19C   54.6   180.6  306.7                  (-------*-------)
20-24C  113.5   237.2  360.8                      (-------*-------)
25-30C  118.8   254.5  390.1                      (--------*-------)
                              ---+---------+---------+---------+------
                              -160         0       160       320


15-19C subtracted from:

        Lower  Center  Upper  ---+---------+---------+---------+------
20-24C  -70.6    56.6  183.7           (-------*------)
25-30C  -65.0    73.9  212.7           (--------*-------)
                              ---+---------+---------+---------+------
                              -160         0       160       320


20-24C subtracted from:

         Lower  Center  Upper  ---+---------+---------+---------+------
25-30C  -119.3    17.3  153.9        (-------*--------)
                               ---+---------+---------+---------+------
                               -160         0       160       320
```

**Table C.10.** Turkey multiple comparison test (output from Minitab) for comparing the means of measured odour emission rates in four temperatures ranges (11-14°C, 15-19°C, 20-14°C, and 25-30°C) for gestation rooms.

### One-way ANOVA: 11-14C, 15-19C, 20-24C, 25-30C

```
Source  DF      SS     MS     F      P
Factor   3   62387  20796  7.79  0.001
Error   31   82734   2669
Total   34  145122

S = 51.66   R-Sq = 42.99%   R-Sq(adj) = 37.47%


                             Individual 95% CIs For Mean Based on
                             Pooled StDev
Level      N    Mean  StDev  --------+---------+---------+---------+-
11-14C    10   43.36  15.00  (------*-----)
15-19C    10  100.63  53.58             (------*------)
20-24C     9  123.76  56.79                  (------*------)
25-30C     6  164.91  76.25                        (--------*--------)
                             --------+---------+---------+---------+-
                                    50       100       150       200

Pooled StDev = 51.66


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons

Individual confidence level = 98.93%


11-14C subtracted from:

          Lower  Center   Upper  ----+---------+---------+---------+-----
15-19C    -5.47   57.26  120.00               (------*-----)
20-24C    15.95   80.40  144.85                  (-----*-----)
25-30C    49.11  121.54  193.98                     (------*------)
                                 ----+---------+---------+---------+-----
                                  -100         0       100       200


15-19C subtracted from:

           Lower  Center   Upper  ----+---------+---------+---------+-----
20-24C    -41.32   23.14   87.59            (-----*------)
25-30C     -8.16   64.28  136.72               (------*-------)
                                  ----+---------+---------+---------+-----
                                   -100         0       100       200


20-24C subtracted from:

           Lower  Center   Upper  ----+---------+---------+---------+-----
25-30C    -32.79   41.14  115.08             (------*-------)
                                  ----+---------+---------+---------+-----
                                   -100         0       100       200
```

# APPENDIX D

## Odour Concentrations Predicted by Dispersion Models

**Table D. 1.** Odour concentrations predicted by ISCST3 at 15 locations (see Fig. 3.5) where odour was sniffed by human assessors for Farm A.

| **Date-session** | **Odour Concentration (OU/m$^3$)** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Location*** | | | | | | | | | | | | | | |
| | **1-1** | **1-2** | **1-3** | **1-4** | **1-5** | **2-1** | **2-2** | **2-3** | **2-4** | **2-5** | **3-1** | **3-2** | **3-3** | **3-4** | **3-5** |
| **Jul6-1** | 0.9 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul6-2** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul6-3** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul13-1** | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul13-2** | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul13-3** | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul20-1** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul20-2** | 5.9 | 37.3 | 18.6 | 7.5 | 0.6 | 1.3 | 4.3 | 0.5 | 0.0 | 0.0 | 0.6 | 1.2 | 0.0 | 0.0 | 0.0 |
| **Jul20-3** | 21.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul26-1** | 6.6 | 3.4 | 5.8 | 0.4 | | 1.5 | 0.4 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul26-2** | 5.7 | 2.3 | 4.8 | 0.1 | | 1.1 | 0.2 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul26-3** | 6.5 | 1.3 | 5.1 | 0.0 | | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul26-4** | 5.9 | 0.8 | 4.2 | 0.0 | | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Aug5-2** | 2.0 | 0.7 | 0.2 | 0.1 | | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Aug5-3** | 4.2 | 1.8 | 0.5 | 0.2 | | 1.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Aug24-1** | 8.5 | 0.0 | 0.0 | 0.0 | 0.0 | 6.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Aug24-2** | 24.5 | 0.2 | 0.0 | 0.0 | 0.0 | 7.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 |
| **Sep26-1** | | | | | | 16.6 | 0.5 | 0.0 | 0.0 | 0.0 | 1.1 | 0.0 | 0.0 | 0.0 | |
| **Sep26-2** | | | | | | 2.2 | 10.4 | 0.0 | 0.0 | 0.0 | 0.0 | 4.4 | 0.0 | 0.0 | |
| **Sep26-3** | | | | | | 1.1 | 2.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 0.0 | 0.0 | |
| **Sep26-4** | | | | | | 1.2 | 2.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.8 | 0.0 | 0.0 | |

*Locations 1-1 to 1-5 were 100 m from the facility; 2-1 to 2-5 500 m; 3-1 to 3-5 1000 m (see Fig. 3.5 for details)

**Table D. 2.** Odour concentrations predicted by ISCST3 at 15 locations (see Fig. 3.5) where odour was sniffed by human assessors for Farm B.

| **Date-session** | **Odour Concentration (OU/m$^3$)** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Location*** | | | | | | | | | | | | | | |
| | **1-1** | **1-2** | **1-3** | **1-4** | **1-5** | **2-1** | **2-2** | **2-3** | **2-4** | **2-5** | **3-1** | **3-2** | **3-3** | **3-4** | **3-5** |
| **Jun29-1** | 8.6 | 9.9 | 5.0 | 0.9 | 0.1 | 0.4 | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 |
| **Jun29-2** | 6.4 | 12.7 | 10.1 | 3.3 | 0.8 | 0.1 | 0.7 | 0.3 | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 |
| **Jun29-3** | 3.8 | 15.2 | 18.7 | 11.3 | 4.0 | 0.0 | 0.2 | 1.3 | 0.0 | 0.0 | 0.0 | 0.4 | 0.3 | 0.0 | 0.0 |
| **Jul15-1** | 1.1 | 4.1 | 10.3 | 21.9 | | 0.0 | 0.2 | 0.6 | 1.3 | 0.7 | 0.0 | 0.0 | 0.1 | 0.2 | 0.1 |
| **Jul15-2** | 0.0 | 0.0 | 0.2 | 4.8 | | 0.0 | 0.0 | 0.0 | 0.6 | 2.7 | 0.0 | 0.0 | 0.0 | 0.2 | 0.9 |
| **Jul15-3** | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Aug12-1** | | 17.6 | 0.0 | 0.0 | | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Aug12-2** | | 109.6 | 4.2 | 0.0 | | 118.5 | 0.0 | 0.0 | 0.0 | 0.0 | 61.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Aug17-1** | 16.7 | 26.7 | 21.9 | 3.9 | 0.2 | 0.2 | 3.1 | 4.2 | 0.0 | 0.0 | 0.0 | 0.8 | 0.5 | 0.0 | 0.0 |
| **Aug17-2** | 10.9 | 24.2 | 25.1 | 8.4 | 0.7 | 0.0 | 1.9 | 4.9 | 0.1 | 0.0 | 0.0 | 0.5 | 1.0 | 0.0 | 0.0 |
| **Aug17-3** | 7.2 | 19.8 | 23.6 | 11.0 | 1.3 | 0.0 | 1.2 | 4.5 | 0.2 | 0.0 | 0.0 | 0.2 | 1.1 | 0.0 | 0.0 |
| **Sep19-1** | | | | | | 89.4 | 0.0 | 0.0 | 0.0 | 0.0 | 16.6 | 0.0 | 0.0 | | 0.0 |
| **Sep19-2** | | | | | | 77.0 | 0.2 | 0.0 | 0.0 | 0.0 | 7.7 | 0.0 | 0.0 | | 0.0 |

*Locations 1-1 to 1-5 were 100 m from the facility; 2-1 to 2-5 500 m; 3-1 to 3-5 1000 m (see Fig. 3.5 for details)

**Table D. 3.** Odour concentrations predicted by AUSPLUME at 15 locations (see Fig. 3.5) where odour was sniffed by human assessors for Farm A.

| **Date-session** | **Odour Concentration (OU/m$^3$)** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Location*** | | | | | | | | | | | | | | |
| | **1-1** | **1-2** | **1-3** | **1-4** | **1-5** | **2-1** | **2-2** | **2-3** | **2-4** | **2-5** | **3-1** | **3-2** | **3-3** | **3-4** | **3-5** |
| **Jul6-1** | 3.8 | 2.5 | 0.5 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul6-2** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul6-3** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul13-1** | 1.8 | 0.9 | 0.4 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul13-2** | 2.0 | 1.0 | 0.4 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul13-3** | 1.7 | 0.8 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul20-1** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul20-2** | 9.5 | 23.7 | 18.2 | 14.2 | 6.2 | 2.2 | 2.7 | 1.3 | 0.3 | 0.0 | 0.7 | 0.8 | 0.3 | 0.0 | 0.0 |
| **Jul20-3** | 18.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul26-1** | 5.7 | 3.4 | 5.0 | 1.3 | | 1.1 | 0.6 | 0.2 | 0.0 | 0.0 | 0.3 | 0.2 | 0.0 | 0.0 | 0.0 |
| **Jul26-2** | 4.7 | 2.5 | 4.0 | 0.8 | | 0.9 | 0.4 | 0.1 | 0.0 | 0.0 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 |
| **Jul26-3** | 5.3 | 1.8 | 4.2 | 0.1 | | 0.9 | 0.1 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul26-4** | 5.0 | 1.6 | 3.8 | 0.1 | | 0.8 | 0.1 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Aug5-2** | 5.4 | 3.4 | 1.5 | 0.7 | | 1.1 | 0.4 | 0.0 | 0.0 | 0.0 | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 |
| **Aug5-3** | 7.9 | 5.5 | 2.9 | 1.6 | | 1.7 | 0.8 | 0.1 | 0.0 | 0.0 | 0.5 | 0.3 | 0.0 | 0.0 | 0.0 |
| **Aug24-1** | 0.2 | 0.0 | 0.5 | 0.0 | 0.0 | 0.3 | 1.3 | 11.5 | 0.0 | 0.0 | 0.1 | 1.9 | 0.0 | 0.0 | 0.0 |
| **Aug24-2** | 0.4 | 0.0 | 0.2 | 0.0 | 0.0 | 0.5 | 0.8 | 20.1 | 0.0 | 0.0 | 0.1 | 2.5 | 0.0 | 0.0 | 0.0 |
| **Sep26-1** | | | | | | 9.3 | 2.1 | 0.0 | 0.0 | 0.0 | 2.2 | 0.5 | 0.0 | 0.0 | |
| **Sep26-2** | | | | | | 3.1 | 5.4 | 0.0 | 0.0 | 0.0 | 0.1 | 2.4 | 0.0 | 0.0 | |
| **Sep26-3** | | | | | | 1.4 | 1.6 | 0.2 | 0.0 | 0.0 | 0.3 | 0.6 | 0.0 | 0.0 | |
| **Sep26-4** | | | | | | 1.3 | 1.6 | 0.2 | 0.0 | 0.0 | 0.3 | 0.6 | 0.0 | 0.0 | |

*Locations 1-1 to 1-5 were 100 m from the facility; 2-1 to 2-5 500 m; 3-1 to 3-5 1000 m (see Fig. 3.5 for details)

**Table D. 4.** Odour concentrations predicted by AUSPLUME at 15 locations (see Fig. 3.5) where odour was sniffed by human assessors for Farm B.

| **Date-session** | **Odour Concentration (OU/m$^3$)** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Location*** | | | | | | | | | | | | | | |
| | **1-1** | **1-2** | **1-3** | **1-4** | **1-5** | **2-1** | **2-2** | **2-3** | **2-4** | **2-5** | **3-1** | **3-2** | **3-3** | **3-4** | **3-5** |
| **Jun29-1** | 6.4 | 7.0 | 5.6 | 3.0 | 1.2 | 0.6 | 0.8 | 0.3 | 0.0 | 0.0 | 0.1 | 0.3 | 0.0 | 0.0 | 0.0 |
| **Jun29-2** | 5.9 | 8.2 | 7.6 | 5.2 | 2.5 | 0.4 | 0.7 | 0.6 | 0.1 | 0.0 | 0.1 | 0.3 | 0.1 | 0.0 | 0.0 |
| **Jun29-3** | 5.6 | 11.0 | 12.2 | 10.7 | 6.6 | 0.2 | 0.6 | 1.2 | 0.3 | 0.0 | 0.0 | 0.4 | 0.3 | 0.1 | 0.0 |
| **Jul15-1** | 4.6 | 7.7 | 10.6 | 13.1 | | 0.2 | 0.5 | 0.7 | 0.8 | 0.7 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 |
| **Jul15-2** | 0.0 | 0.3 | 1.3 | 8.6 | | 0.0 | 0.0 | 0.0 | 1.1 | 1.8 | 0.0 | 0.0 | 0.0 | 0.4 | 0.5 |
| **Jul15-3** | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Aug12-1** | | 30.7 | 1.0 | 0.0 | | 15.1 | 0.0 | 0.0 | 0.0 | 0.0 | 4.7 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Aug12-2** | | 135.0 | 17.2 | 0.1 | | 96.5 | 0.1 | 0.0 | 0.0 | 0.0 | 44.6 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Aug17-1** | 14.7 | 18.4 | 16.5 | 9.5 | 2.6 | 0.8 | 2.0 | 2.8 | 0.4 | 0.1 | 0.2 | 0.6 | 0.6 | 0.1 | 0.0 |
| **Aug17-2** | 12.2 | 17.0 | 16.8 | 11.3 | 3.8 | 0.5 | 1.7 | 2.8 | 0.6 | 0.2 | 0.1 | 0.5 | 0.7 | 0.1 | 0.0 |
| **Aug17-3** | 9.3 | 14.6 | 15.7 | 12.4 | 4.9 | 0.3 | 1.4 | 2.6 | 0.8 | 0.3 | 0.0 | 0.4 | 0.7 | 0.2 | 0.0 |
| **Sep19-1** | | | | | | 43.2 | 2.7 | 0.0 | 0.0 | 0.0 | 12.4 | 0.6 | 0.0 | | 0.0 |
| **Sep19-2** | | | | | | 48.0 | 7.4 | 0.0 | 0.0 | 0.0 | 12.0 | 1.9 | 0.0 | | 0.0 |

*Locations 1-1 to 1-5 were 100 m from the facility; 2-1 to 2-5 500 m; 3-1 to 3-5 1000 m (see Fig. 3.5 for details)

**Table D. 5.** Odour concentrations predicted by INPUFF-2 at 15 locations (see Fig. 3.5) where odour was sniffed by human assessors for Farm A.

| **Date-session** | **Odour Concentration (OU/m$^3$)** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Location*** | | | | | | | | | | | | | | |
| | **1-1** | **1-2** | **1-3** | **1-4** | **1-5** | **2-1** | **2-2** | **2-3** | **2-4** | **2-5** | **3-1** | **3-2** | **3-3** | **3-4** | **3-5** |
| **Jul6-1** | 3.8 | 2.5 | 0.5 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul6-2** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul6-3** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul13-1** | 1.8 | 0.9 | 0.4 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul13-2** | 2.0 | 1.0 | 0.4 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul13-3** | 1.7 | 0.8 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul20-1** | 4.6 | 7.7 | 10.6 | 13.1 | | 0.2 | 0.5 | 0.7 | 0.8 | 0.7 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 |
| **Jul20-2** | 0.0 | 0.3 | 1.3 | 8.6 | | 0.0 | 0.0 | 0.0 | 1.1 | 1.8 | 0.0 | 0.0 | 0.0 | 0.4 | 0.5 |
| **Jul20-3** | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul26-1** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul26-2** | 9.5 | 23.7 | 18.2 | 14.2 | 6.2 | 2.2 | 2.7 | 1.3 | 0.3 | 0.0 | 0.7 | 0.8 | 0.3 | 0.0 | 0.0 |
| **Jul26-3** | 18.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Jul26-4** | 5.7 | 3.4 | 5.0 | 1.3 | | 1.1 | 0.6 | 0.2 | 0.0 | 0.0 | 0.3 | 0.2 | 0.0 | 0.0 | 0.0 |
| **Aug5-2** | 5.4 | 3.4 | 1.5 | 0.7 | | 1.1 | 0.4 | 0.0 | 0.0 | 0.0 | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 |
| **Aug5-3** | 7.9 | 5.5 | 2.9 | 1.6 | | 1.7 | 0.8 | 0.1 | 0.0 | 0.0 | 0.5 | 0.3 | 0.0 | 0.0 | 0.0 |
| **Aug24-1** | 0.2 | 0.0 | 0.5 | 0.0 | 0.0 | 0.3 | 1.3 | 11.5 | 0.0 | 0.0 | 0.1 | 1.9 | 0.0 | 0.0 | 0.0 |
| **Aug24-2** | 0.4 | 0.0 | 0.2 | 0.0 | 0.0 | 0.5 | 0.8 | 20.1 | 0.0 | 0.0 | 0.1 | 2.5 | 0.0 | 0.0 | 0.0 |
| **Sep26-1** | | | | | | 9.3 | 2.1 | 0.0 | 0.0 | 0.0 | 2.2 | 0.5 | 0.0 | 0.0 | |
| **Sep26-2** | | | | | | 3.1 | 5.4 | 0.0 | 0.0 | 0.0 | 0.1 | 2.4 | 0.0 | 0.0 | |
| **Sep26-3** | | | | | | 1.4 | 1.6 | 0.2 | 0.0 | 0.0 | 0.3 | 0.6 | 0.0 | 0.0 | |
| **Sep26-4** | | | | | | 1.3 | 1.6 | 0.2 | 0.0 | 0.0 | 0.3 | 0.6 | 0.0 | 0.0 | |

*Locations 1-1 to 1-5 were 100 m from the facility; 2-1 to 2-5 500 m; 3-1 to 3-5 1000 m (see Fig. 3.5 for details)

**Table D. 6.** Odour concentrations predicted by INPUFF-2 at 15 locations (see Fig. 3.5) where odour was sniffed by human assessors for Farm B.

| **Date-session** | **Odour Concentration (OU/m$^3$)** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Location** | | | | | | | | | | | | | | |
| | **1-1** | **1-2** | **1-3** | **1-4** | **1-5** | **2-1** | **2-2** | **2-3** | **2-4** | **2-5** | **3-1** | **3-2** | **3-3** | **3-4** | **3-5** |
| **Jun29-1** | 6.4 | 7.0 | 5.6 | 3.0 | 1.2 | 0.6 | 0.8 | 0.3 | 0.0 | 0.0 | 0.1 | 0.3 | 0.0 | 0.0 | 0.0 |
| **Jun29-2** | 5.9 | 8.2 | 7.6 | 5.2 | 2.5 | 0.4 | 0.7 | 0.6 | 0.1 | 0.0 | 0.1 | 0.3 | 0.1 | 0.0 | 0.0 |
| **Jun29-3** | 5.6 | 11.0 | 12.2 | 10.7 | 6.6 | 0.2 | 0.6 | 1.2 | 0.3 | 0.0 | 0.0 | 0.4 | 0.3 | 0.1 | 0.0 |
| **Jul15-1** | 4.6 | 7.7 | 10.6 | 13.1 | | 0.2 | 0.5 | 0.7 | 0.8 | 0.7 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 |
| **Jul15-2** | 0.0 | 0.3 | 1.3 | 8.6 | | 0.0 | 0.0 | 0.0 | 1.1 | 1.8 | 0.0 | 0.0 | 0.0 | 0.4 | 0.5 |
| **Jul15-3** | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Aug12-1** | | 30.7 | 1.0 | 0.0 | | 15.1 | 0.0 | 0.0 | 0.0 | 0.0 | 4.7 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Aug12-2** | | 135.0 | 17.2 | 0.1 | | 96.5 | 0.1 | 0.0 | 0.0 | 0.0 | 44.6 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Aug17-1** | 14.7 | 18.4 | 16.5 | 9.5 | 2.6 | 0.8 | 2.0 | 2.8 | 0.4 | 0.1 | 0.2 | 0.6 | 0.6 | 0.1 | 0.0 |
| **Aug17-2** | 12.2 | 17.0 | 16.8 | 11.3 | 3.8 | 0.5 | 1.7 | 2.8 | 0.6 | 0.2 | 0.1 | 0.5 | 0.7 | 0.1 | 0.0 |
| **Aug17-3** | 9.3 | 14.6 | 15.7 | 12.4 | 4.9 | 0.3 | 1.4 | 2.6 | 0.8 | 0.3 | 0.0 | 0.4 | 0.7 | 0.2 | 0.0 |
| **Sep19-1** | | | | | | 43.2 | 2.7 | 0.0 | 0.0 | 0.0 | 12.4 | 0.6 | 0.0 | | 0.0 |
| **Sep19-2** | | | | | | 48.0 | 7.4 | 0.0 | 0.0 | 0.0 | 12.0 | 1.9 | 0.0 | | 0.0 |

*Locations 1-1 to 1-5 were 100 m from the facility; 2-1 to 2-5 500 m; 3-1 to 3-5 1000 m (see Fig. 3.5 for details).

# APPENDIX E
## Comparisons of Dispersion Models with Field Data

**Table E.1.** Comparison of odour intensity between AUSPLUME predictions and field measurements at 15 locations (see Fig. 3.5) for Farm A

| Date-session | Odour Intensity | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Location* | | | | | | | | | | | | | | | | | | | |
| | 1-1 | | | | 1-2 | | | | 1-3 | | | | 1-4 | | | | 1-5 | | | |
| | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | |
| | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | |
| **Jul6-1** | 2.5 | 4.2 | 3.5 | 4.8 | 2.1 | 3.7 | 2.9 | 4.5 | 0.0 | 3.0 | 2.0 | 4.2 | 0.0 | 2.5 | 1.2 | 3.9 | 0.0 | 5.3 | 4.9 | 5.7 |
| **Jul6-2** | 0.0 | 1.8 | -0.1 | 3.7 | 0.0 | 0.7 | -2.0 | 3.5 | 0.0 | 2.7 | 1.5 | 4.0 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 1.7 | -0.1 | 3.7 |
| **Jul6-3** | 0.0 | 1.5 | -0.5 | 3.6 | 0.0 | 0.8 | -1.8 | 3.5 | 0.0 | 1.0 | -1.5 | 3.5 | 0.0 | 0.2 | -3.0 | 3.5 | 0.0 | 0.5 | -2.3 | 3.5 |
| **Jul13-1** | 1.9 | 2.7 | 1.4 | 4.0 | 1.3 | 3.8 | 3.0 | 4.6 | 0.0 | 3.8 | 3.0 | 4.6 | 0.0 | 2.9 | 1.8 | 4.1 | 0.0 | 2.2 | 0.7 | 3.8 |
| **Jul13-2** | 2.0 | 1.3 | -1.0 | 3.6 | 1.4 | 4.6 | 4.1 | 5.2 | 0.0 | 4.7 | 4.2 | 5.3 | 0.0 | 3.9 | 3.2 | 4.6 | 0.0 | 1.6 | -0.3 | 3.6 |
| **Jul13-3** | 1.8 | 1.0 | -1.5 | 3.5 | 1.3 | 5.1 | 4.6 | 5.6 | 0.0 | 3.8 | 3.1 | 4.6 | 0.0 | 2.3 | 0.9 | 3.9 | 0.0 | 2.5 | 1.2 | 3.9 |
| **Jul20-1** | 0.0 | 0.8 | -1.7 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul20-2** | 3.2 | 3.4 | 2.5 | 4.3 | 3.9 | 2.6 | 1.4 | 4.0 | 3.7 | 1.9 | 0.2 | 3.7 | 3.5 | 0.1 | -3.1 | 3.5 | 2.8 | 0.1 | -3.3 | 3.5 |
| **Jul20-3** | 3.7 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul26-1** | 2.8 | 3.5 | 2.6 | 4.4 | 2.4 | 3.9 | 3.2 | 4.6 | 2.7 | 3.7 | 3.0 | 4.5 | 1.6 | 1.7 | -0.1 | 3.7 | | | -3.4 | 3.5 |
| **Jul26-2** | 2.6 | 4.0 | 3.4 | 4.7 | 2.1 | 3.0 | 1.9 | 4.1 | 2.5 | 3.6 | 2.7 | 4.5 | 1.2 | 2.3 | 0.8 | 3.9 | | | -3.4 | 3.5 |
| **Jul26-3** | 2.7 | 3.0 | 2.0 | 4.2 | 1.9 | 3.8 | 3.0 | 4.6 | 2.5 | 2.4 | 0.9 | 3.9 | 0.0 | 0.8 | -1.8 | 3.5 | | | -3.4 | 3.5 |
| **Jul26-4** | 2.7 | 2.5 | 1.1 | 3.9 | 1.8 | 1.8 | 0.0 | 3.7 | 2.5 | 1.2 | -1.1 | 3.6 | 0.0 | 0.2 | -2.9 | 3.5 | | | -3.4 | 3.5 |
| **Aug5-2** | 2.7 | 0.9 | -1.7 | 3.5 | 2.4 | 1.1 | -1.3 | 3.5 | 1.7 | 2.3 | 0.8 | 3.8 | 1.2 | 1.3 | -0.8 | 3.6 | | 0.0 | -3.4 | 3.5 |
| **Aug5-3** | 3.0 | 1.6 | -0.3 | 3.6 | 2.7 | 1.6 | -0.4 | 3.6 | 2.3 | 1.6 | -0.4 | 3.6 | 1.8 | 1.2 | -1.1 | 3.6 | | 0.0 | -3.4 | 3.5 |
| **Aug24-1** | 0.0 | 5.3 | 4.9 | 5.8 | 0.0 | 4.4 | 3.8 | 5.0 | 0.0 | 1.4 | -0.6 | 3.6 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.7 | -2.0 | 3.5 |
| **Aug24-2** | 0.0 | 5.5 | 5.1 | 5.9 | 0.0 | 4.6 | 4.1 | 5.2 | 0.0 | 0.6 | -2.1 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 1.0 | -1.4 | 3.5 |
| **Sep26-1** | | | | | | | | | | | | | | | | | | | | |
| **Sep26-2** | | | | | | | | | | | | | | | | | | | | |
| **Sep26-3** | | | | | | | | | | | | | | | | | | | | |
| **Sep26-4** | | | | | | | | | | | | | | | | | | | | |

**Table E.1.** (continued)

| Date-session | Odour Intensity | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Location* | | | | | | | | | | | | | | | | | | | |
| | 2-1 | | | | 2-2 | | | | 2-3 | | | | 2-4 | | | | 2-5 | | | |
| | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | |
| | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | |
| **Jul6-1** | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 1.1 | -1.3 | 3.5 | 0.0 | 0.1 | -3.3 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul6-2** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.1 | -3.1 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul6-3** | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.5 | -2.4 | 3.5 | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul13-1** | 0.0 | 0.2 | -3.0 | 3.5 | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.2 | -3.1 | 3.5 | 0.0 | 0.3 | -2.7 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul13-2** | 0.0 | 0.1 | -3.1 | 3.5 | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.2 | -3.0 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul13-3** | 0.0 | 0.3 | -2.8 | 3.5 | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.1 | -3.1 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul20-1** | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.1 | -3.3 | 3.5 |
| **Jul20-2** | 2.0 | 0.0 | -3.3 | 3.5 | 2.2 | 0.1 | -3.1 | 3.5 | 1.6 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul20-3** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.2 | -3.0 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul26-1** | 1.5 | 0.6 | -2.2 | 3.5 | 1.0 | 1.1 | -1.2 | 3.6 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul26-2** | 1.3 | 0.2 | -3.0 | 3.5 | 0.0 | 0.7 | -2.0 | 3.5 | 0.0 | 0.1 | -3.1 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul26-3** | 1.4 | 0.2 | -2.9 | 3.5 | 0.0 | 0.6 | -2.2 | 3.5 | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul26-4** | 1.3 | 0.2 | -2.9 | 3.5 | 0.0 | 0.7 | -2.0 | 3.5 | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug5-2** | 1.5 | 0.7 | -1.9 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.3 | -2.8 | 3.5 |
| **Aug5-3** | 1.8 | 0.0 | -3.3 | 3.5 | 1.3 | 0.0 | -3.3 | 3.5 | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 |
| **Aug24-1** | 0.0 | 0.0 | -3.4 | 3.5 | 1.6 | 0.2 | -2.9 | 3.5 | 3.3 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug24-2** | 0.0 | 0.0 | -3.4 | 3.5 | 1.3 | 0.7 | -2.0 | 3.5 | 3.8 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Sep26-1** | 3.2 | 0.0 | -3.4 | 3.5 | 2.0 | 1.8 | 0.0 | 3.7 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.2 | -3.0 | 3.5 |
| **Sep26-2** | 2.3 | 0.0 | -3.4 | 3.5 | 2.7 | 1.8 | 0.0 | 3.7 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.2 | -3.1 | 3.5 |
| **Sep26-3** | 1.7 | 0.0 | -3.4 | 3.5 | 1.8 | 1.2 | -1.0 | 3.6 | 0.0 | 1.0 | -1.5 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.5 | -2.3 | 3.5 |
| **Sep26-4** | 1.6 | 0.0 | -3.4 | 3.5 | 1.8 | 0.0 | -3.3 | 3.5 | 0.0 | 1.0 | -1.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.2 | -2.9 | 3.5 |

**Table E.1.** (continued)

| Date-session | Odour Intensity | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Location* | | | | | | | | | | | | | | | | | | | |
| | 3-1 | | | | 3-2 | | | | 3-3 | | | | 3-4 | | | | 3-5 | | | |
| | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | |
| | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | |
| **Jul6-1** | 0.0 | 0.8 | -1.8 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.1 | -3.3 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul6-2** | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul6-3** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul13-1** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul13-2** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul13-3** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul20-1** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul20-2** | 1.2 | 0.0 | -3.4 | 3.5 | 1.2 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul20-3** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul26-1** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.1 | -3.3 | 3.5 |
| **Jul26-2** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul26-3** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul26-4** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug5-2** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug5-3** | 0.9 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug24-1** | 0.0 | 0.1 | -3.3 | 3.5 | 1.9 | 0.1 | -3.3 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug24-2** | 0.0 | 0.0 | -3.4 | 3.5 | 2.1 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Sep26-1** | 2.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | | | | 3.5 |
| **Sep26-2** | 0.0 | 0.0 | -3.4 | 3.5 | 2.1 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | | | | 3.5 |
| **Sep26-3** | 0.0 | 0.0 | -3.4 | 3.5 | 1.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | | | | 3.5 |
| **Sep26-4** | 0.0 | 0.0 | -3.4 | 3.5 | 1.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.2 | -3.0 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | | | | 3.5 |

**Table E.2.** Comparison of odour intensity between AUSPLUME predictions and field measurements at 15 locations (see Fig. 3.5) for Farm B

| Date-session | Odour Intensity | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Location* | | | | | | | | | | | | | | | | | | | |
| | 1-1 | | | | 1-2 | | | | 1-3 | | | | 1-4 | | | | 1-5 | | | |
| | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | |
| | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | |
| **Jun29-1** | 2.9 | 0.1 | -3.2 | 3.5 | 2.9 | 4.5 | 3.9 | 5.1 | 2.8 | 3.3 | 2.3 | 4.3 | 2.3 | 3.3 | 2.4 | 4.3 | 1.6 | 0.6 | -2.1 | 3.5 |
| **Jun29-2** | 2.8 | 0.1 | -3.1 | 3.5 | 3.1 | 5.0 | 4.5 | 5.5 | 3.0 | 3.6 | 2.7 | 4.4 | 2.7 | 2.0 | 0.3 | 3.7 | 2.1 | 0.4 | -2.7 | 3.5 |
| **Jun29-3** | 2.8 | 0.0 | -3.3 | 3.5 | 3.3 | 3.9 | 3.2 | 4.7 | 3.4 | 4.7 | 4.1 | 5.2 | 3.3 | 4.6 | 4.0 | 5.1 | 2.9 | 1.1 | -1.2 | 3.6 |
| **Jul15-1** | 2.6 | 0.1 | -3.3 | 3.5 | 3.0 | 0.4 | -2.6 | 3.5 | 3.3 | 0.8 | -1.8 | 3.5 | 3.4 | 0.1 | -3.2 | 3.5 | | | -3.4 | 3.5 |
| **Jul15-2** | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.1 | -3.3 | 3.5 | 1.6 | 0.6 | -2.1 | 3.5 | 3.1 | 0.0 | -3.4 | 3.5 | | | -3.4 | 3.5 |
| **Jul15-3** | 0.0 | 0.2 | -2.9 | 3.5 | 0.0 | 0.8 | -1.8 | 3.5 | 0.0 | 2.1 | 0.4 | 3.8 | 0.0 | 0.0 | -3.3 | 3.5 | | | -3.4 | 3.5 |
| **Aug12-1** | | | | | 4.1 | 3.3 | 2.3 | 4.3 | 1.4 | 4.2 | 3.6 | 4.9 | 0.0 | 1.4 | -0.7 | 3.6 | | | -3.4 | 3.5 |
| **Aug12-2** | | | | | 5.2 | 4.0 | 3.3 | 4.7 | 3.6 | 4.2 | 3.6 | 4.9 | 0.0 | 3.7 | 2.9 | 4.5 | | | -3.4 | 3.5 |
| **Aug17-1** | 3.5 | 5.8 | 5.4 | 6.2 | 3.7 | 3.1 | 2.0 | 4.2 | 3.6 | 2.8 | 1.6 | 4.1 | 3.2 | 3.7 | 2.9 | 4.5 | 2.2 | 6.3 | 5.9 | 6.8 |
| **Aug17-2** | 3.4 | 3.8 | 3.0 | 4.6 | 3.6 | 4.7 | 4.2 | 5.2 | 3.6 | 6.7 | 6.2 | 7.2 | 3.3 | 3.3 | 2.3 | 4.3 | 2.5 | 3.8 | 3.1 | 4.6 |
| **Aug17-3** | 3.2 | 3.2 | 2.2 | 4.3 | 3.5 | 1.7 | -0.1 | 3.7 | 3.6 | 6.7 | 6.2 | 7.2 | 3.4 | 0.0 | -3.4 | 3.5 | 2.7 | 4.3 | 3.7 | 4.9 |
| **Sep19-1** | | | | | | | | | | | | | | | | | | | | |
| **Sep19-2** | | | | | | | | | | | | | | | | | | | | |

**Table E.2.** (continued)

| Date-session | Odour Intensity | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Location* | | | | | | | | | | | | | | | | | | | |
| | 2-1 | | | | 2-2 | | | | 2-3 | | | | 2-4 | | | | 2-5 | | | |
| | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | |
| | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | |
| **Jun29-1** | 1.0 | 0.0 | -3.4 | 3.5 | 1.3 | 2.5 | 1.1 | 3.9 | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.1 | -3.3 | 3.5 | 0.0 | 0.3 | -2.8 | 3.5 |
| **Jun29-2** | 0.0 | 0.0 | -3.4 | 3.5 | 1.2 | 3.2 | 2.3 | 4.3 | 1.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.1 | -3.3 | 3.5 | 0.0 | 0.1 | -3.1 | 3.5 |
| **Jun29-3** | 0.0 | 0.0 | -3.4 | 3.5 | 1.0 | 2.6 | 1.3 | 4.0 | 1.6 | 0.1 | -3.3 | 3.5 | 0.0 | 0.3 | -2.9 | 3.5 | 0.0 | 0.1 | -3.1 | 3.5 |
| **Jul15-1** | 0.0 | 0.0 | -3.4 | 3.5 | 0.9 | 2.0 | 0.4 | 3.8 | 1.2 | 0.0 | -3.3 | 3.5 | 1.3 | 0.0 | -3.4 | 3.5 | 1.2 | 0.0 | -3.4 | 3.5 |
| **Jul15-2** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 1.6 | -0.3 | 3.6 | 0.0 | 0.0 | -3.4 | 3.5 | 1.5 | 0.0 | -3.4 | 3.5 | 1.9 | 0.0 | -3.4 | 3.5 |
| **Jul15-3** | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug12-1** | 3.5 | 0.2 | -3.1 | 3.5 | 0.0 | 1.7 | -0.2 | 3.7 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 1.3 | -0.9 | 3.6 |
| **Aug12-2** | 5.0 | 0.6 | -2.1 | 3.5 | 0.0 | 2.4 | 0.9 | 3.9 | 0.0 | 0.8 | -1.7 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 1.2 | -1.1 | 3.6 |
| **Aug17-1** | 1.3 | 0.0 | -3.4 | 3.5 | 2.0 | 0.0 | -3.4 | 3.5 | 2.2 | 0.1 | -3.1 | 3.5 | 0.0 | 0.1 | -3.3 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 |
| **Aug17-2** | 0.9 | 0.3 | -2.8 | 3.5 | 1.8 | 0.0 | -3.3 | 3.5 | 2.2 | 0.2 | -3.0 | 3.5 | 1.0 | 0.2 | -2.9 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug17-3** | 0.0 | 0.3 | -2.7 | 3.5 | 1.7 | 0.0 | -3.4 | 3.5 | 2.2 | 0.1 | -3.2 | 3.5 | 1.2 | 0.8 | -1.8 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Sep19-1** | 4.3 | 0.2 | -3.0 | 3.5 | 2.2 | 2.6 | 1.4 | 4.0 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Sep19-2** | 4.4 | 0.0 | -3.4 | 3.5 | 3.0 | 1.6 | -0.4 | 3.6 | 0.0 | 0.1 | -3.1 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |

**Table E.2.** (continued)

| Date-session | Odour Intensity | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Location* | | | | | | | | | | | | | | | | | | | |
| | 3-1 | | | | 3-2 | | | | 3-3 | | | | 3-4 | | | | 3-5 | | | |
| | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | |
| | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | |
| **Jun29-1** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.9 | -1.6 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jun29-2** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.2 | -3.0 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jun29-3** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul15-1** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul15-2** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.9 | 0.0 | -3.4 | 3.5 |
| **Jul15-3** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug12-1** | 2.6 | 0.0 | -3.4 | 3.5 | 0.0 | 0.4 | -2.7 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug12-2** | 4.4 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.1 | -3.3 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug17-1** | 0.0 | 0.0 | -3.4 | 3.5 | 1.0 | 0.0 | -3.4 | 3.5 | 1.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug17-2** | 0.0 | 0.0 | -3.4 | 3.5 | 0.9 | 0.0 | -3.4 | 3.5 | 1.1 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug17-3** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 1.1 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Sep19-1** | 3.4 | 0.0 | -3.4 | 3.5 | 1.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | | | | | 0.0 | 0.0 | -3.4 | 3.5 |
| **Sep19-2** | 3.4 | 0.0 | -3.4 | 3.5 | 1.9 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | | | | | 0.0 | 0.0 | -3.4 | 3.5 |

**Table E.3.** Comparison of odour intensity between ISCST3 predictions and field measurements at 15 locations (see Fig. 3.5) for Farm A

| Date-session | Odour Intensity | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Location* | | | | | | | | | | | | | | | | | | | |
| | 1-1 | | | | 1-2 | | | | 1-3 | | | | 1-4 | | | | 1-5 | | | |
| | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | |
| | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | |
| **Jul6-1** | 1.3 | 4.2 | 3.5 | 4.8 | 0.0 | 3.7 | 2.9 | 4.5 | 0.0 | 3.0 | 2.0 | 4.2 | 0.0 | 2.5 | 1.2 | 3.9 | 0.0 | 5.3 | 4.9 | 5.7 |
| **Jul6-2** | 0.0 | 1.8 | -0.1 | 3.7 | 0.0 | 0.7 | -2.0 | 3.5 | 0.0 | 2.7 | 1.5 | 4.0 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 1.7 | -0.1 | 3.7 |
| **Jul6-3** | 0.0 | 1.5 | -0.5 | 3.6 | 0.0 | 0.8 | -1.8 | 3.5 | 0.0 | 1.0 | -1.5 | 3.5 | 0.0 | 0.2 | -3.0 | 3.5 | 0.0 | 0.5 | -2.3 | 3.5 |
| **Jul13-1** | 0.0 | 2.7 | 1.4 | 4.0 | 0.0 | 3.8 | 3.0 | 4.6 | 0.0 | 3.8 | 3.0 | 4.6 | 0.0 | 2.9 | 1.8 | 4.1 | 0.0 | 2.2 | 0.7 | 3.8 |
| **Jul13-2** | 0.0 | 1.3 | -1.0 | 3.6 | 0.0 | 4.6 | 4.1 | 5.2 | 0.0 | 4.7 | 4.2 | 5.3 | 0.0 | 3.9 | 3.2 | 4.6 | 0.0 | 1.6 | -0.3 | 3.6 |
| **Jul13-3** | 0.0 | 1.0 | -1.5 | 3.5 | 0.0 | 5.1 | 4.6 | 5.6 | 0.0 | 3.8 | 3.1 | 4.6 | 0.0 | 2.3 | 0.9 | 3.9 | 0.0 | 2.5 | 1.2 | 3.9 |
| **Jul20-1** | 0.0 | 0.8 | -1.7 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul20-2** | 2.8 | 3.4 | 2.5 | 4.3 | 4.2 | 2.6 | 1.4 | 4.0 | 3.7 | 1.9 | 0.2 | 3.7 | 3.0 | 0.1 | -3.1 | 3.5 | 1.0 | 0.1 | -3.3 | 3.5 |
| **Jul20-3** | 3.8 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul26-1** | 2.9 | 3.5 | 2.6 | 4.4 | 2.4 | 3.9 | 3.2 | 4.6 | 2.8 | 3.7 | 3.0 | 4.5 | 0.0 | 1.7 | -0.1 | 3.7 | | | -3.4 | 3.5 |
| **Jul26-2** | 2.8 | 4.0 | 3.4 | 4.7 | 2.1 | 3.0 | 1.9 | 4.1 | 2.6 | 3.6 | 2.7 | 4.5 | 0.0 | 2.3 | 0.8 | 3.9 | | | -3.4 | 3.5 |
| **Jul26-3** | 2.9 | 3.0 | 2.0 | 4.2 | 1.6 | 3.8 | 3.0 | 4.6 | 2.7 | 2.4 | 0.9 | 3.9 | 0.0 | 0.8 | -1.8 | 3.5 | | | -3.4 | 3.5 |
| **Jul26-4** | 2.8 | 2.5 | 1.1 | 3.9 | 1.3 | 1.8 | 0.0 | 3.7 | 2.5 | 1.2 | -1.1 | 3.6 | 0.0 | 0.2 | -2.9 | 3.5 | | | -3.4 | 3.5 |
| **Aug5-2** | 2.0 | 0.9 | -1.7 | 3.5 | 1.2 | 1.1 | -1.3 | 3.5 | 0.0 | 2.3 | 0.8 | 3.8 | 0.0 | 1.3 | -0.8 | 3.6 | | 0.0 | -3.4 | 3.5 |
| **Aug5-3** | 2.5 | 1.6 | -0.3 | 3.6 | 1.9 | 1.6 | -0.4 | 3.6 | 0.9 | 1.6 | -0.4 | 3.6 | 0.0 | 1.2 | -1.1 | 3.6 | | 0.0 | -3.4 | 3.5 |
| **Aug24-1** | 3.1 | 5.3 | 4.9 | 5.8 | 0.0 | 4.4 | 3.8 | 5.0 | 0.0 | 1.4 | -0.6 | 3.6 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.7 | -2.0 | 3.5 |
| **Aug24-2** | 3.9 | 5.5 | 5.1 | 5.9 | 0.0 | 4.6 | 4.1 | 5.2 | 0.0 | 0.6 | -2.1 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 1.0 | -1.4 | 3.5 |
| **Sep26-1** | | | | | | | | | | | | | | | | | | | | |
| **Sep26-2** | | | | | | | | | | | | | | | | | | | | |
| **Sep26-3** | | | | | | | | | | | | | | | | | | | | |
| **Sep26-4** | | | | | | | | | | | | | | | | | | | | |

**Table E.3.** (continued)

| Date-session | Odour Intensity | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Location* | | | | | | | | | | | | | | | | | | | |
| | 2-1 | | | | 2-2 | | | | 2-3 | | | | 2-4 | | | | 2-5 | | | |
| | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | | Pred. | Measured | | |
| | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | |
| **Jul6-1** | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.2 | -3.1 | 3.5 | 0.0 | 0.1 | -3.3 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul6-2** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.2 | -3.0 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul6-3** | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.1 | -3.1 | 3.5 | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul13-1** | 0.0 | 0.2 | -3.0 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.3 | -2.7 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul13-2** | 0.0 | 0.1 | -3.1 | 3.5 | 2.6 | 0.1 | -3.1 | 3.5 | 0.9 | 0.0 | -3.4 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul13-3** | 0.0 | 0.3 | -2.8 | 3.5 | 0.0 | 0.2 | -3.0 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul20-1** | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 1.1 | -1.2 | 3.6 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.1 | -3.3 | 3.5 |
| **Jul20-2** | 1.6 | 0.0 | -3.3 | 3.5 | 0.0 | 0.7 | -2.0 | 3.5 | 0.0 | 0.1 | -3.1 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul20-3** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.6 | -2.2 | 3.5 | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul26-1** | 1.7 | 0.6 | -2.2 | 3.5 | 0.0 | 0.7 | -2.0 | 3.5 | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul26-2** | 1.5 | 0.2 | -3.0 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul26-3** | 1.3 | 0.2 | -2.9 | 3.5 | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul26-4** | 0.9 | 0.2 | -2.9 | 3.5 | 0.0 | 0.2 | -2.9 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug5-2** | 0.0 | 0.7 | -1.9 | 3.5 | 0.0 | 0.7 | -2.0 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.3 | -2.8 | 3.5 |
| **Aug5-3** | 1.5 | 0.0 | -3.3 | 3.5 | 0.9 | 1.8 | 0.0 | 3.7 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 |
| **Aug24-1** | 2.9 | 0.0 | -3.4 | 3.5 | 3.2 | 1.8 | 0.0 | 3.7 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug24-2** | 3.0 | 0.0 | -3.4 | 3.5 | 2.0 | 1.2 | -1.0 | 3.6 | 0.0 | 1.0 | -1.5 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Sep26-1** | 3.6 | 0.0 | -3.4 | 3.5 | 2.0 | 0.0 | -3.3 | 3.5 | 0.0 | 1.0 | -1.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.2 | -3.0 | 3.5 |
| **Sep26-2** | 2.0 | 0.0 | -3.4 | 3.5 | | | | | | | | | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.2 | -3.1 | 3.5 |
| **Sep26-3** | 1.5 | 0.0 | -3.4 | 3.5 | | | | | | | | | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.5 | -2.3 | 3.5 |
| **Sep26-4** | 1.6 | 0.0 | -3.4 | 3.5 | | | | | | | | | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.2 | -2.9 | 3.5 |

**Table E.3.** (continued)

| Date-session | Odour Intensity | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Location* | | | | | | | | | | | | | | | | | | | |
| | 3-1 | | | | 3-2 | | | | 3-3 | | | | 3-4 | | | | 3-5 | | | |
| | Pred | Measured | | | Pred. | Measured | | | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | |
| | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | |
| **Jul6-1** | 0.0 | 0.8 | -1.8 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.1 | -3.3 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul6-2** | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul6-3** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul13-1** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul13-2** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul13-3** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul20-1** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul20-2** | 1.0 | 0.0 | -3.4 | 3.5 | 1.6 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul20-3** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul26-1** | 1.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.1 | -3.3 | 3.5 |
| **Jul26-2** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul26-3** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul26-4** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug5-2** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug5-3** | 0.9 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug24-1** | 0.0 | 0.1 | -3.3 | 3.5 | 0.0 | 0.1 | -3.3 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug24-2** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Sep26-1** | 1.5 | 0.0 | -3.4 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | | | | |
| **Sep26-2** | 0.0 | 0.0 | -3.4 | 3.5 | 2.6 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | | | | |
| **Sep26-3** | 0.0 | 0.0 | -3.4 | 3.5 | 1.3 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | | | | |
| **Sep26-4** | 0.0 | 0.0 | -3.4 | 3.5 | 1.3 | 0.0 | -3.4 | 3.5 | 0.0 | 0.2 | -3.0 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | | | | |

**Table E.4.** Comparison of odour intensity between ISCST3 predictions and field measurements at 15 locations (see Fig. 3.5) for Farm B

| Date-session | Odour Intensity | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Location* | | | | | | | | | | | | | | | | | | | |
| | 1-1 | | | | 1-2 | | | | 1-3 | | | | 1-4 | | | | 1-5 | | | |
| | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | |
| | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | |
| **Jun29-1** | 3.1 | 0.1 | -3.2 | 3.5 | 3.2 | 4.5 | 3.9 | 5.1 | 2.7 | 3.3 | 2.3 | 4.3 | 1.3 | 3.3 | 2.4 | 4.3 | 0.0 | 0.6 | -2.1 | 3.5 |
| **Jun29-2** | 2.9 | 0.1 | -3.1 | 3.5 | 3.4 | 5.0 | 4.5 | 5.5 | 3.2 | 3.6 | 2.7 | 4.4 | 2.4 | 2.0 | 0.3 | 3.7 | 1.3 | 0.4 | -2.7 | 3.5 |
| **Jun29-3** | 2.5 | 0.0 | -3.3 | 3.5 | 3.5 | 3.9 | 3.2 | 4.7 | 3.7 | 4.7 | 4.1 | 5.2 | 3.3 | 4.6 | 4.0 | 5.1 | 2.5 | 1.1 | -1.2 | 3.6 |
| **Jul15-1** | 1.5 | 0.1 | -3.3 | 3.5 | 2.5 | 0.4 | -2.6 | 3.5 | 3.2 | 0.8 | -1.8 | 3.5 | 3.8 | 0.1 | -3.2 | 3.5 | | | -3.4 | 3.5 |
| **Jul15-2** | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.1 | -3.3 | 3.5 | 0.0 | 0.6 | -2.1 | 3.5 | 2.6 | 0.0 | -3.4 | 3.5 | | | -3.4 | 3.5 |
| **Jul15-3** | 0.0 | 0.2 | -2.9 | 3.5 | 0.0 | 0.8 | -1.8 | 3.5 | 0.0 | 2.1 | 0.4 | 3.8 | 0.0 | 0.0 | -3.3 | 3.5 | | | -3.4 | 3.5 |
| **Aug12-1** | | | | | 3.7 | 3.3 | 2.3 | 4.3 | 0.0 | 4.2 | 3.6 | 4.9 | 0.0 | 1.4 | -0.7 | 3.6 | | | -3.4 | 3.5 |
| **Aug12-2** | | | | | 5.1 | 4.0 | 3.3 | 4.7 | 2.5 | 4.2 | 3.6 | 4.9 | 0.0 | 3.7 | 2.9 | 4.5 | | | -3.4 | 3.5 |
| **Aug17-1** | 3.6 | 5.8 | 5.4 | 6.2 | 4.0 | 3.1 | 2.0 | 4.2 | 3.8 | 2.8 | 1.6 | 4.1 | 2.5 | 3.7 | 2.9 | 4.5 | 0.0 | 6.3 | 5.9 | 6.8 |
| **Aug17-2** | 3.3 | 3.8 | 3.0 | 4.6 | 3.9 | 4.7 | 4.2 | 5.2 | 3.9 | 6.7 | 6.2 | 7.2 | 3.1 | 3.3 | 2.3 | 4.3 | 1.2 | 3.8 | 3.1 | 4.6 |
| **Aug17-3** | 3.0 | 3.2 | 2.2 | 4.3 | 3.7 | 1.7 | -0.1 | 3.7 | 3.9 | 6.7 | 6.2 | 7.2 | 3.3 | 0.0 | -3.4 | 3.5 | 1.6 | 4.3 | 3.7 | 4.9 |
| **Sep19-1** | | | | | | | | | | | | | | | | | | | | |
| **Sep19-2** | | | | | | | | | | | | | | | | | | | | |

**Table E.4.** (continued)

| Date-session | Odour Intensity | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Location* | | | | | | | | | | | | | | | | | | | |
| | 2-1 | | | | 2-2 | | | | 2-3 | | | | 2-4 | | | | 2-5 | | | |
| | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | |
| | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | |
| **Jun29-1** | 0.0 | 0.0 | -3.4 | 3.5 | 1.6 | 2.5 | 1.1 | 3.9 | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.1 | -3.3 | 3.5 | 0.0 | 0.3 | -2.8 | 3.5 |
| **Jun29-2** | 0.0 | 0.0 | -3.4 | 3.5 | 1.2 | 3.2 | 2.3 | 4.3 | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.1 | -3.3 | 3.5 | 0.0 | 0.1 | -3.1 | 3.5 |
| **Jun29-3** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 2.6 | 1.3 | 4.0 | 1.6 | 0.1 | -3.3 | 3.5 | 0.0 | 0.3 | -2.9 | 3.5 | 0.0 | 0.1 | -3.1 | 3.5 |
| **Jul15-1** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 2.0 | 0.4 | 3.8 | 1.0 | 0.0 | -3.3 | 3.5 | 1.6 | 0.0 | -3.4 | 3.5 | 1.2 | 0.0 | -3.4 | 3.5 |
| **Jul15-2** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 1.6 | -0.3 | 3.6 | 0.0 | 0.0 | -3.4 | 3.5 | 1.0 | 0.0 | -3.4 | 3.5 | 2.2 | 0.0 | -3.4 | 3.5 |
| **Jul15-3** | 0.0 | 0.0 | -3.3 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug12-1** | 1.3 | 0.2 | -3.1 | 3.5 | 0.0 | 1.7 | -0.2 | 3.7 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 1.3 | -0.9 | 3.6 |
| **Aug12-2** | 5.1 | 0.6 | -2.1 | 3.5 | 0.0 | 2.4 | 0.9 | 3.9 | 0.0 | 0.8 | -1.7 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 1.2 | -1.1 | 3.6 |
| **Aug17-1** | 0.0 | 0.0 | -3.4 | 3.5 | 2.3 | 0.0 | -3.4 | 3.5 | 2.5 | 0.1 | -3.1 | 3.5 | 0.0 | 0.1 | -3.3 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 |
| **Aug17-2** | 0.0 | 0.3 | -2.8 | 3.5 | 1.9 | 0.0 | -3.3 | 3.5 | 2.7 | 0.2 | -3.0 | 3.5 | 0.0 | 0.2 | -2.9 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug17-3** | 0.0 | 0.3 | -2.7 | 3.5 | 1.6 | 0.0 | -3.4 | 3.5 | 2.6 | 0.1 | -3.2 | 3.5 | 0.0 | 0.8 | -1.8 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Sep19-1** | 4.9 | 0.2 | -3.0 | 3.5 | 0.0 | 2.6 | 1.4 | 4.0 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Sep19-2** | 4.8 | 0.0 | -3.4 | 3.5 | 0.0 | 1.6 | -0.4 | 3.6 | 0.0 | 0.1 | -3.1 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |

**Table E.4.** (continued)

| Date-session | Odour Intensity | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Location* | | | | | | | | | | | | | | | | | | | |
| | 3-1 | | | | 3-2 | | | | 3-3 | | | | 3-4 | | | | 3-5 | | | |
| | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | |
| | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | |
| **Jun29-1** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.9 | -1.6 | 3.5 | 0.0 | 0.1 | -3.2 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jun29-2** | 0.0 | 0.0 | -3.4 | 3.5 | 0.9 | 0.2 | -3.0 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jun29-3** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul15-1** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Jul15-2** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 1.3 | 0.0 | -3.4 | 3.5 |
| **Jul15-3** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug12-1** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.4 | -2.7 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug12-2** | 4.6 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.1 | -3.3 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug17-1** | 0.0 | 0.0 | -3.4 | 3.5 | 1.3 | 0.0 | -3.4 | 3.5 | 0.9 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug17-2** | 0.0 | 0.0 | -3.4 | 3.5 | 0.9 | 0.0 | -3.4 | 3.5 | 1.4 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Aug17-3** | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 1.5 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 |
| **Sep19-1** | 3.6 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | | | | | 0.0 | 0.0 | -3.4 | 3.5 |
| **Sep19-2** | 3.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | 0.0 | 0.0 | -3.4 | 3.5 | | | | | 0.0 | 0.0 | -3.4 | 3.5 |

**Table E.5.** Comparison of odour intensity between INPUFF-2 predictions and field measurements at 15 locations (see Fig. 3.5) for Farm A

| Date-session | Odour Intensity | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Location* | | | | | | | | | | | | | | | | | | | |
| | 1-1 | | | | 1-2 | | | | 1-3 | | | | 1-4 | | | | 1-5 | | | |
| | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | |
| | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | |
| **Jul6 1-1** | 3.84 | 3.67 | 2.9 | 4.5 | 4.08 | 4.69 | 4.2 | 5.2 | 3.92 | 3.26 | 2.3 | 4.3 | 3.19 | 2.64 | 1.4 | 4.0 | 2.15 | 2.54 | 1.2 | 3.9 |
| **Jul6 1-2** | 4.32 | 4.54 | 4.0 | 5.1 | 4.50 | 4.69 | 4.2 | 5.2 | 3.81 | 3.25 | 2.3 | 4.3 | 2.55 | 3.84 | 3.1 | 4.6 | 1.26 | 5.16 | 4.7 | 5.6 |
| **Jul6 1-3** | 4.39 | 4.92 | 4.5 | 5.4 | 4.39 | 3.97 | 3.3 | 4.7 | 3.35 | 2.75 | 1.5 | 4.0 | 2.27 | 3.51 | 2.7 | 4.4 | 1.21 | 5.31 | 4.9 | 5.8 |
| **Jul6 2-1** | 2.54 | 3.70 | 2.9 | 4.5 | 2.95 | 3.04 | 2.0 | 4.2 | 3.98 | 3.18 | 2.2 | 4.2 | 4.28 | 1.41 | -0.7 | 3.6 | 3.77 | 3.18 | 2.2 | 4.2 |
| **Jul6 2-2** | 4.08 | 3.24 | 2.3 | 4.3 | 4.17 | 2.87 | 1.7 | 4.1 | 3.79 | 2.90 | 1.8 | 4.1 | 3.30 | 1.20 | -1.1 | 3.6 | 2.82 | 2.74 | 1.5 | 4.0 |
| **Jul6 2-3** | 4.31 | 2.15 | 0.6 | 3.8 | 4.17 | 1.90 | 0.2 | 3.7 | 3.19 | 2.48 | 1.1 | 3.9 | 2.29 | 0.61 | -2.2 | 3.5 | 1.44 | 1.54 | -0.5 | 3.6 |
| **Jul6 3-1** | 2.93 | 1.46 | -0.6 | 3.6 | 3.37 | 3.64 | 2.8 | 4.5 | 4.09 | 1.80 | 0.0 | 3.7 | 3.82 | 1.30 | -0.9 | 3.6 | 3.24 | 1.79 | 0.0 | 3.7 |
| **Jul6 3-2** | 0.00 | 1.38 | -0.7 | 3.6 | 0.00 | 0.86 | -1.7 | 3.5 | 0.00 | 0.74 | -1.9 | 3.5 | 0.00 | 0.37 | -2.6 | 3.5 | 0.00 | 0.55 | -2.3 | 3.5 |
| **Jul6 3-3** | 4.85 | 4.90 | 4.4 | 5.4 | 4.35 | 4.25 | 3.6 | 4.9 | 2.24 | 3.36 | 2.4 | 4.3 | 1.17 | 3.30 | 2.4 | 4.3 | 0.53 | 2.90 | 1.8 | 4.1 |
| **Jul13 1-1** | 1.60 | 2.59 | 1.3 | 4.0 | 0.39 | 4.36 | 3.8 | 5.0 | 0.00 | 3.79 | 3.0 | 4.6 | 0.00 | 3.30 | 2.4 | 4.3 | 0.00 | 2.79 | 1.6 | 4.0 |
| **Jul13 1-2** | 2.53 | 2.89 | 1.7 | 4.1 | 1.26 | 3.91 | 3.2 | 4.7 | 0.00 | 4.05 | 3.4 | 4.8 | 0.00 | 3.10 | 2.1 | 4.2 | 0.00 | 2.59 | 1.3 | 4.0 |
| **Jul13 1-3** | 1.10 | 3.64 | 2.8 | 4.5 | 0.00 | 3.37 | 2.5 | 4.3 | 0.00 | 3.79 | 3.0 | 4.6 | 0.00 | 2.84 | 1.7 | 4.1 | 0.00 | 1.75 | -0.1 | 3.7 |
| **Jul13 2-1** | 1.58 | 2.39 | 1.0 | 3.9 | 0.65 | 5.02 | 4.6 | 5.5 | 0.00 | 4.36 | 3.8 | 5.0 | 0.00 | 3.56 | 2.7 | 4.4 | 0.00 | 1.51 | -0.5 | 3.6 |
| **Jul13 2-2** | 2.00 | 2.77 | 1.6 | 4.0 | 1.37 | 4.23 | 3.6 | 4.9 | 0.59 | 4.52 | 4.0 | 5.1 | 0.00 | 3.93 | 3.2 | 4.7 | 0.00 | 1.62 | -0.3 | 3.6 |
| **Jul13 2-3** | 2.54 | 1.59 | -0.4 | 3.6 | 1.45 | 1.88 | 0.1 | 3.7 | 0.69 | 1.23 | -1.0 | 3.6 | 0.00 | 4.52 | 4.0 | 5.1 | 0.00 | 2.21 | 0.7 | 3.8 |
| **Jul13 3-1** | 1.67 | 1.08 | -1.3 | 3.5 | 0.64 | 1.43 | -0.6 | 3.6 | 0.00 | 3.82 | 3.1 | 4.6 | 0.00 | 2.92 | 1.8 | 4.1 | 0.00 | 3.43 | 2.5 | 4.4 |
| **Jul13 3-2** | 2.64 | 3.33 | 2.4 | 4.3 | 1.01 | 5.07 | 4.6 | 5.5 | 0.00 | 4.15 | 3.5 | 4.8 | 0.00 | 2.26 | 0.8 | 3.8 | 0.73 | 2.87 | 1.7 | 4.1 |
| **Jul13 3-3** | 1.23 | 2.41 | 1.0 | 3.9 | 0.00 | 5.08 | 4.6 | 5.6 | 0.00 | 3.82 | 3.1 | 4.6 | 0.00 | 2.30 | 0.8 | 3.8 | 0.00 | 2.11 | 0.5 | 3.8 |
| **Jul20 1-1** | 0.00 | 1.36 | -0.8 | 3.6 | 0.00 | 0.24 | -2.9 | 3.5 | 0.00 | 0.07 | -3.3 | 3.5 | 0.00 | 0.05 | -3.3 | 3.5 | 0.00 | 0.31 | -2.8 | 3.5 |
| **Jul20 1-2** | 0.00 | 1.54 | -0.5 | 3.6 | 0.00 | 0.17 | -3.0 | 3.5 | 0.00 | 0.02 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.18 | -3.0 | 3.5 |
| **Jul20 1-3** | 0.00 | 0.93 | -1.6 | 3.5 | 0.00 | 0.02 | -3.3 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 1.14 | 0.00 | -3.4 | 3.5 | 3.07 | 0.08 | -3.2 | 3.5 |
| **Jul20 2-1** | 0.00 | 3.79 | 3.0 | 4.6 | 3.82 | 3.47 | 2.6 | 4.4 | 3.98 | 3.34 | 2.4 | 4.3 | 3.74 | 1.52 | -0.5 | 3.6 | 2.73 | 2.49 | 1.1 | 3.9 |
| **Jul20 2-2** | 0.32 | 5.30 | 4.9 | 5.7 | 4.62 | 4.93 | 4.5 | 5.4 | 3.58 | 4.11 | 3.5 | 4.8 | 2.69 | 0.89 | -1.6 | 3.5 | 1.56 | 0.49 | -2.4 | 3.5 |
| **Jul20 2-3** | 1.85 | 3.90 | 3.2 | 4.7 | 3.48 | 2.95 | 1.8 | 4.1 | 2.65 | 2.28 | 0.8 | 3.8 | 2.03 | 1.13 | -1.2 | 3.6 | 1.21 | 0.44 | -2.5 | 3.5 |
| **Jul20 3-1** | 2.09 | 1.82 | 0.0 | 3.7 | 3.84 | 0.74 | -1.9 | 3.5 | 3.23 | 0.20 | -3.0 | 3.5 | 2.65 | 0.00 | -3.4 | 3.5 | 1.73 | 0.00 | -3.4 | 3.5 |
| **Jul20 3-2** | 1.40 | 0.08 | -3.2 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.05 | -3.3 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul20 3-3** | 2.80 | 0.02 | -3.4 | 3.5 | 0.00 | 0.04 | -3.3 | 3.5 | 0.00 | 0.23 | -2.9 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.08 | -3.2 | 3.5 |
| **Jul26 1-1** | 3.24 | 3.39 | 2.5 | 4.4 | 3.18 | 4.11 | 3.5 | 4.8 | 3.86 | 4.48 | 3.9 | 5.1 | 0.00 | 2.33 | 0.9 | 3.9 | | | | |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Jul26 1-2** | 3.90 | 3.39 | 2.5 | 4.4 | 2.60 | 4.46 | 3.9 | 5.1 | 4.08 | 3.66 | 2.9 | 4.5 | 0.00 | 1.98 | 0.3 | 3.7 | | | | |
| **Jul26 1-3** | 3.77 | 3.77 | 3.0 | 4.6 | 2.90 | 4.54 | 4.0 | 5.1 | 4.28 | 3.62 | 2.8 | 4.5 | 0.00 | 1.89 | 0.2 | 3.7 | | | | |
| **Jul26 2-1** | 4.10 | 3.97 | 3.3 | 4.7 | 1.99 | 3.53 | 2.7 | 4.4 | 3.98 | 3.85 | 3.1 | 4.6 | 0.00 | 2.42 | 1.0 | 3.9 | | | | |
| **Jul26 2-2** | 3.64 | 4.02 | 3.3 | 4.7 | 2.34 | 3.12 | 2.1 | 4.2 | 4.32 | 3.54 | 2.7 | 4.4 | 0.00 | 2.37 | 0.9 | 3.9 | | | | |
| **Jul26 2-3** | 3.78 | 4.16 | 3.5 | 4.8 | 1.90 | 3.76 | 3.0 | 4.6 | 4.22 | 3.80 | 3.1 | 4.6 | 0.00 | 3.12 | 2.1 | 4.2 | | | | |
| **Jul26 3-1** | 3.84 | 2.82 | 1.7 | 4.1 | 1.42 | 3.87 | 3.2 | 4.6 | 3.45 | 3.43 | 2.5 | 4.4 | 0.00 | 1.43 | -0.7 | 3.6 | | | | |
| **Jul26 3-2** | 3.79 | 3.11 | 2.1 | 4.2 | 1.55 | 4.30 | 3.7 | 4.9 | 3.81 | 3.77 | 3.0 | 4.6 | 0.00 | 1.16 | -1.1 | 3.6 | | | | |
| **Jul26 3-3** | 3.55 | 3.23 | 2.3 | 4.3 | 0.97 | 4.11 | 3.5 | 4.8 | 3.23 | 4.26 | 3.7 | 4.9 | 0.00 | 1.80 | 0.0 | 3.7 | | | | |
| **Jul26 4-1** | 4.20 | 2.44 | 1.1 | 3.9 | 0.00 | 1.72 | -0.1 | 3.7 | 3.71 | 3.05 | 2.0 | 4.2 | 0.00 | 0.88 | -1.7 | 3.5 | | | | |
| **Jul26 4-2** | 3.96 | 2.90 | 1.8 | 4.1 | 0.00 | 4.93 | 4.5 | 5.4 | 3.20 | 3.82 | 3.1 | 4.6 | 0.00 | 1.39 | -0.7 | 3.6 | | | | |
| **Jul26 4-3** | 3.58 | 2.28 | 0.8 | 3.8 | 1.43 | 2.74 | 1.5 | 4.0 | 3.68 | 2.20 | 0.7 | 3.8 | 0.00 | 0.77 | -1.9 | 3.5 | | | | |
| **Aug5 1-1** | 0.00 | 0.03 | -3.3 | 3.5 | 0.00 | 0.22 | -2.9 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.12 | -3.1 | 3.5 | | | | |
| **Aug5 1-2** | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.09 | -3.2 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.12 | -3.1 | 3.5 | | | | |
| **Aug5 1-3** | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | | | | |
| **Aug5 2-1** | 4.23 | 1.54 | -0.5 | 3.6 | 4.22 | 1.03 | -1.4 | 3.5 | 2.84 | 3.89 | 3.2 | 4.6 | 1.67 | 3.41 | 2.5 | 4.4 | | | | |
| **Aug5 2-2** | 3.80 | 2.95 | 1.8 | 4.1 | 3.28 | 1.98 | 0.3 | 3.7 | 1.88 | 3.16 | 2.2 | 4.2 | 1.06 | 3.38 | 2.5 | 4.3 | | | | |
| **Aug5 2-3** | 4.07 | 1.36 | -0.8 | 3.6 | 3.36 | 1.59 | -0.4 | 3.6 | 1.62 | 2.98 | 1.9 | 4.1 | 0.00 | 2.51 | 1.2 | 3.9 | | | | |
| **Aug5 3-1** | 4.31 | 2.26 | 0.8 | 3.8 | 4.17 | 1.97 | 0.3 | 3.7 | 2.51 | 2.66 | 1.4 | 4.0 | 1.39 | 2.36 | 0.9 | 3.9 | | | | |
| **Aug5 3-2** | 4.49 | 2.07 | 0.4 | 3.8 | 4.18 | 1.64 | -0.3 | 3.7 | 2.56 | 2.93 | 1.8 | 4.1 | 1.55 | 3.08 | 2.0 | 4.2 | | | | |
| **Aug5 3-3** | 3.99 | 2.34 | 0.9 | 3.9 | 4.12 | 2.34 | 0.9 | 3.9 | 2.93 | 3.33 | 2.4 | 4.3 | 1.82 | 3.98 | 3.3 | 4.7 | | | | |
| **Aug24 1-1** | 4.11 | 5.28 | 4.9 | 5.7 | 2.70 | 4.38 | 3.8 | 5.0 | 1.41 | 3.72 | 3.0 | 4.5 | 0.00 | 0.27 | -2.8 | 3.5 | 0.00 | 1.05 | -1.3 | 3.5 |
| **Aug24 1-2** | 2.83 | 2.62 | 1.3 | 4.0 | 0.96 | 4.74 | 4.2 | 5.3 | 0.00 | 1.95 | 0.3 | 3.7 | 0.00 | 0.03 | -3.3 | 3.5 | 0.00 | 0.92 | -1.6 | 3.5 |
| **Aug24 1-3** | 2.03 | 5.23 | 4.8 | 5.7 | 0.00 | 4.57 | 4.0 | 5.1 | 0.00 | 2.18 | 0.6 | 3.8 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.92 | -1.6 | 3.5 |
| **Aug24 2-1** | 3.26 | 3.22 | 2.2 | 4.3 | 1.72 | 4.92 | 4.5 | 5.4 | 0.76 | 1.66 | -0.2 | 3.7 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 1.00 | -1.4 | 3.5 |
| **Aug24 2-2** | 3.36 | 3.46 | 2.6 | 4.4 | 1.39 | 4.88 | 4.4 | 5.4 | 0.52 | 1.51 | -0.5 | 3.6 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 1.00 | -1.4 | 3.5 |
| **Aug24 2-3** | 1.69 | 5.28 | 4.9 | 5.7 | 0.00 | 4.39 | 3.8 | 5.0 | 0.00 | 1.46 | -0.6 | 3.6 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 1.00 | -1.4 | 3.5 |
| **Sep26 1-1** | | | | | | | | | | | | | | | | | | | | |
| **Sep26 1-2** | | | | | | | | | | | | | | | | | | | | |
| **Sep26 1-3** | | | | | | | | | | | | | | | | | | | | |
| **Sep26 2-1** | | | | | | | | | | | | | | | | | | | | |
| **Sep26 2-2** | | | | | | | | | | | | | | | | | | | | |
| **Sep26 2-3** | | | | | | | | | | | | | | | | | | | | |
| **Sep26 3-1** | | | | | | | | | | | | | | | | | | | | |
| **Sep26 3-2** | | | | | | | | | | | | | | | | | | | | |
| **Sep26 3-3** | | | | | | | | | | | | | | | | | | | | |
| **Sep26 4-1** | | | | | | | | | | | | | | | | | | | | |
| **Sep26 4-2** | | | | | | | | | | | | | | | | | | | | |
| **Sep26 4-3** | | | | | | | | | | | | | | | | | | | | |

**Table E.5.** (continued)

| Date-session | Odour Intensity | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Location* | | | | | | | | | | | | | | | | | | | |
| | 2-1 | | | | 2-2 | | | | 2-3 | | | | 2-4 | | | | 2-5 | | | |
| | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | |
| | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | |
| **Jul6 1-1** | 2.17 | 0.20 | -3.0 | 3.5 | 2.55 | 0.71 | -2.0 | 3.5 | 2.52 | 1.79 | 0.0 | 3.7 | 2.17 | 0.32 | -2.7 | 3.5 | 1.70 | 0.66 | -2.1 | 3.5 |
| **Jul6 1-2** | 2.84 | 0.17 | -3.0 | 3.5 | 2.84 | 0.87 | -1.7 | 3.5 | 2.21 | 1.99 | 0.3 | 3.7 | 1.37 | 0.55 | -2.3 | 3.5 | 0.80 | 0.17 | -3.0 | 3.5 |
| **Jul6 1-3** | 2.92 | 0.30 | -2.8 | 3.5 | 2.52 | 0.63 | -2.1 | 3.5 | 1.73 | 1.80 | 0.0 | 3.7 | 0.94 | 0.30 | -2.8 | 3.5 | 0.48 | 0.01 | -3.4 | 3.5 |
| **Jul6 2-1** | 1.64 | 0.01 | -3.4 | 3.5 | 2.23 | 0.01 | -3.4 | 3.5 | 2.56 | 0.64 | -2.1 | 3.5 | 2.56 | 0.53 | -2.3 | 3.5 | 2.25 | 0.06 | -3.3 | 3.5 |
| **Jul6 2-2** | 1.48 | 0.14 | -3.1 | 3.5 | 1.64 | 0.24 | -2.9 | 3.5 | 1.60 | 0.56 | -2.3 | 3.5 | 1.52 | 0.56 | -2.3 | 3.5 | 1.34 | 0.12 | -3.1 | 3.5 |
| **Jul6 2-3** | 2.64 | 0.09 | -3.2 | 3.5 | 2.38 | 0.07 | -3.2 | 3.5 | 1.88 | 0.61 | -2.2 | 3.5 | 1.30 | 0.27 | -2.8 | 3.5 | 0.86 | 0.06 | -3.3 | 3.5 |
| **Jul6 3-1** | 1.54 | 0.01 | -3.4 | 3.5 | 2.26 | 0.12 | -3.1 | 3.5 | 2.38 | 0.86 | -1.7 | 3.5 | 2.02 | 0.38 | -2.6 | 3.5 | 1.49 | 0.07 | -3.2 | 3.5 |
| **Jul6 3-2** | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.22 | -2.9 | 3.5 | 0.00 | 0.67 | -2.1 | 3.5 | 0.00 | 0.22 | -2.9 | 3.5 | 0.00 | 0.22 | -2.9 | 3.5 |
| **Jul6 3-3** | 2.60 | 1.97 | 0.3 | 3.7 | 1.74 | 1.90 | 0.2 | 3.7 | 0.85 | 2.34 | 0.9 | 3.9 | 0.85 | 0.19 | -3.0 | 3.5 | 0.85 | 0.01 | -3.4 | 3.5 |
| **Jul13 1-1** | 0.00 | 0.84 | -1.7 | 3.5 | 0.00 | 0.49 | -2.4 | 3.5 | 0.00 | 1.51 | -0.5 | 3.6 | 0.00 | 0.89 | -1.6 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul13 1-2** | 0.90 | 0.87 | -1.7 | 3.5 | 0.00 | 0.21 | -3.0 | 3.5 | 0.00 | 0.43 | -2.5 | 3.5 | 0.00 | 0.84 | -1.7 | 3.5 | 0.00 | 0.07 | -3.3 | 3.5 |
| **Jul13 1-3** | 0.00 | 1.41 | -0.7 | 3.6 | 0.00 | 0.18 | -3.0 | 3.5 | 0.00 | 0.36 | -2.7 | 3.5 | 0.00 | 0.58 | -2.2 | 3.5 | 0.00 | 0.05 | -3.3 | 3.5 |
| **Jul13 2-1** | 0.36 | 1.18 | -1.1 | 3.6 | 0.00 | 0.31 | -2.8 | 3.5 | 0.00 | 0.72 | -2.0 | 3.5 | 0.00 | 0.64 | -2.1 | 3.5 | 0.00 | 0.16 | -3.1 | 3.5 |
| **Jul13 2-2** | 0.78 | 1.18 | -1.1 | 3.6 | 0.00 | 0.30 | -2.8 | 3.5 | 0.00 | 0.59 | -2.2 | 3.5 | 0.00 | 0.26 | -2.9 | 3.5 | 0.00 | 0.11 | -3.2 | 3.5 |
| **Jul13 2-3** | 1.12 | 0.35 | -2.7 | 3.5 | 0.00 | 0.26 | -2.9 | 3.5 | 0.00 | 1.66 | -0.3 | 3.7 | 0.00 | 0.58 | -2.2 | 3.5 | 0.00 | 0.03 | -3.3 | 3.5 |
| **Jul13 3-1** | 0.00 | 2.25 | 0.7 | 3.8 | 0.00 | 0.31 | -2.8 | 3.5 | 0.00 | 0.66 | -2.1 | 3.5 | 0.00 | 0.45 | -2.5 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul13 3-2** | 0.00 | 0.51 | -2.4 | 3.5 | 0.00 | 0.30 | -2.8 | 3.5 | 0.00 | 1.26 | -1.0 | 3.6 | 0.00 | 0.57 | -2.2 | 3.5 | 0.00 | 0.02 | -3.4 | 3.5 |
| **Jul13 3-3** | 0.00 | 1.44 | -0.6 | 3.6 | 0.00 | 0.18 | -3.0 | 3.5 | 0.00 | 0.48 | -2.4 | 3.5 | 0.00 | 0.30 | -2.8 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul20 1-1** | 0.00 | 1.23 | -1.0 | 3.6 | 0.00 | 0.23 | -2.9 | 3.5 | 0.00 | 0.03 | -3.3 | 3.5 | 0.00 | 0.02 | -3.4 | 3.5 | 0.00 | 0.46 | -2.5 | 3.5 |
| **Jul20 1-2** | 0.00 | 0.39 | -2.6 | 3.5 | 0.00 | 0.05 | -3.3 | 3.5 | 0.00 | 0.03 | -3.3 | 3.5 | 0.00 | 0.03 | -3.3 | 3.5 | 0.00 | 0.30 | -2.8 | 3.5 |
| **Jul20 1-3** | 0.00 | 0.08 | -3.2 | 3.5 | 0.00 | 0.18 | -3.0 | 3.5 | 0.00 | 0.05 | -3.3 | 3.5 | 0.00 | 0.11 | -3.2 | 3.5 | 0.00 | 0.18 | -3.0 | 3.5 |
| **Jul20 2-1** | 1.93 | 0.05 | -3.3 | 3.5 | 2.48 | 0.52 | -2.3 | 3.5 | 2.29 | 0.51 | -2.4 | 3.5 | 1.83 | 0.01 | -3.4 | 3.5 | 1.08 | 0.00 | -3.4 | 3.5 |
| **Jul20 2-2** | 2.90 | 0.34 | -2.7 | 3.5 | 2.82 | 1.10 | -1.3 | 3.5 | 1.84 | 0.03 | -3.3 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.10 | -3.2 | 3.5 |
| **Jul20 2-3** | 2.60 | 0.25 | -2.9 | 3.5 | 2.54 | 0.67 | -2.1 | 3.5 | 1.73 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul20 3-1** | 2.72 | 0.10 | -3.2 | 3.5 | 2.76 | 0.67 | -2.1 | 3.5 | 1.87 | 0.03 | -3.3 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul20 3-2** | 0.00 | 0.10 | -3.2 | 3.5 | 0.00 | 0.51 | -2.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul20 3-3** | 0.00 | 0.18 | -3.0 | 3.5 | 0.00 | 0.74 | -1.9 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.03 | -3.3 | 3.5 |
| **Jul26 1-1** | 2.67 | 0.90 | -1.6 | 3.5 | 2.68 | 2.05 | 0.4 | 3.8 | 1.98 | 0.56 | -2.3 | 3.5 | 0.00 | 0.10 | -3.2 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul26 1-2** | 2.83 | 1.25 | -1.0 | 3.6 | 2.27 | 1.43 | -0.7 | 3.6 | 1.51 | 0.77 | -1.9 | 3.5 | 0.00 | 0.03 | -3.3 | 3.5 | 0.00 | 0.05 | -3.3 | 3.5 |
| **Jul26 1-3** | 2.95 | 1.61 | -0.3 | 3.6 | 2.48 | 2.13 | 0.6 | 3.8 | 1.67 | 0.28 | -2.8 | 3.5 | 0.00 | 0.03 | -3.3 | 3.5 | 0.00 | 0.02 | -3.4 | 3.5 |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Jul26 2-1** | 2.75 | 1.21 | -1.0 | 3.6 | 1.91 | 1.83 | 0.0 | 3.7 | 0.00 | 0.89 | -1.6 | 3.5 | 0.00 | 0.08 | -3.2 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul26 2-2** | 3.00 | 0.89 | -1.6 | 3.5 | 2.37 | 1.02 | -1.4 | 3.5 | 1.38 | 0.56 | -2.3 | 3.5 | 0.00 | 0.07 | -3.3 | 3.5 | 0.00 | 0.02 | -3.4 | 3.5 |
| **Jul26 2-3** | 2.86 | 0.21 | -3.0 | 3.5 | 1.99 | 1.67 | -0.2 | 3.7 | 0.00 | 0.62 | -2.1 | 3.5 | 0.00 | 0.13 | -3.1 | 3.5 | 0.00 | 0.05 | -3.3 | 3.5 |
| **Jul26 3-1** | 2.29 | 0.70 | -2.0 | 3.5 | 1.35 | 0.79 | -1.8 | 3.5 | 0.00 | 0.23 | -2.9 | 3.5 | 0.00 | 0.10 | -3.2 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul26 3-2** | 2.70 | 1.34 | -0.8 | 3.6 | 1.83 | 1.95 | 0.3 | 3.7 | 0.00 | 0.23 | -2.9 | 3.5 | 0.00 | 0.03 | -3.3 | 3.5 | 0.00 | 0.05 | -3.3 | 3.5 |
| **Jul26 3-3** | 2.03 | 0.51 | -2.4 | 3.5 | 0.92 | 1.80 | 0.0 | 3.7 | 0.00 | 0.33 | -2.7 | 3.5 | 0.00 | 0.13 | -3.1 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul26 4-1** | 2.30 | 0.90 | -1.6 | 3.5 | 0.00 | 1.36 | -0.8 | 3.6 | 0.00 | 0.23 | -2.9 | 3.5 | 0.00 | 0.08 | -3.2 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul26 4-2** | 2.04 | 1.39 | -0.7 | 3.6 | 0.00 | 1.56 | -0.4 | 3.6 | 0.00 | 0.26 | -2.9 | 3.5 | 0.00 | 0.07 | -3.3 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul26 4-3** | 2.47 | 0.59 | -2.2 | 3.5 | 1.61 | 1.64 | -0.3 | 3.7 | 0.00 | 0.16 | -3.1 | 3.5 | 0.00 | 0.05 | -3.3 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug5 1-1** | 0.00 | 0.03 | -3.3 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 |
| **Aug5 1-2** | 0.00 | 0.06 | -3.3 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.11 | -3.2 | 3.5 | 0.00 | 0.03 | -3.3 | 3.5 |
| **Aug5 1-3** | 0.00 | 0.12 | -3.1 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.74 | -1.9 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 |
| **Aug5 2-1** | 3.04 | 1.56 | -0.4 | 3.6 | 2.52 | 0.96 | -1.5 | 3.5 | 1.35 | 0.99 | -1.5 | 3.5 | 0.00 | 0.23 | -2.9 | 3.5 | 0.00 | 0.79 | -1.8 | 3.5 |
| **Aug5 2-2** | 2.35 | 1.61 | -0.3 | 3.6 | 1.82 | 0.82 | -1.8 | 3.5 | 1.04 | 0.56 | -2.3 | 3.5 | 0.00 | 0.77 | -1.9 | 3.5 | 0.00 | 0.99 | -1.5 | 3.5 |
| **Aug5 2-3** | 2.46 | 2.36 | 0.9 | 3.9 | 1.66 | 0.42 | -2.6 | 3.5 | 0.00 | 0.43 | -2.5 | 3.5 | 0.00 | 1.10 | -1.2 | 3.6 | 0.00 | 0.58 | -2.2 | 3.5 |
| **Aug5 3-1** | 3.06 | 0.47 | -2.5 | 3.5 | 2.53 | 0.48 | -2.4 | 3.5 | 1.42 | 0.63 | -2.1 | 3.5 | 0.00 | 0.50 | -2.4 | 3.5 | 0.00 | 0.82 | -1.8 | 3.5 |
| **Aug5 3-2** | 2.96 | 0.43 | -2.5 | 3.5 | 2.38 | 0.21 | -3.0 | 3.5 | 1.35 | 0.25 | -2.9 | 3.5 | 0.00 | 0.54 | -2.3 | 3.5 | 0.00 | 0.68 | -2.0 | 3.5 |
| **Aug5 3-3** | 2.98 | 0.16 | -3.1 | 3.5 | 2.73 | 0.01 | -3.4 | 3.5 | 1.75 | 0.25 | -2.9 | 3.5 | 0.91 | 1.04 | -1.4 | 3.5 | 0.00 | 0.20 | -3.0 | 3.5 |
| **Aug24 1-1** | 2.12 | 0.01 | -3.4 | 3.5 | 2.50 | 0.74 | -1.9 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.45 | -2.5 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug24 1-2** | 2.35 | 0.01 | -3.4 | 3.5 | 1.46 | 1.28 | -0.9 | 3.6 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.33 | -2.7 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug24 1-3** | 3.73 | 0.01 | -3.4 | 3.5 | 0.00 | 0.74 | -1.9 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.35 | -2.7 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug24 2-1** | 2.97 | 0.01 | -3.4 | 3.5 | 1.45 | 1.33 | -0.8 | 3.6 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.12 | -3.1 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug24 2-2** | 2.81 | 0.01 | -3.4 | 3.5 | 1.68 | 2.28 | 0.8 | 3.8 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.14 | -3.1 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug24 2-3** | 3.67 | 0.01 | -3.4 | 3.5 | 0.00 | 0.79 | -1.8 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Sep26 1-1** | 2.88 | 0.00 | -3.4 | 3.5 | 0.93 | 2.66 | 1.4 | 4.0 | 0.00 | 0.13 | -3.1 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.58 | -2.2 | 3.5 |
| **Sep26 1-2** | 1.40 | 0.00 | -3.4 | 3.5 | 2.44 | 1.48 | -0.6 | 3.6 | 0.00 | 0.20 | -3.0 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.63 | -2.1 | 3.5 |
| **Sep26 1-3** | 2.06 | 0.00 | -3.4 | 3.5 | 1.44 | 2.95 | 1.8 | 4.1 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.77 | -1.9 | 3.5 |
| **Sep26 2-1** | 1.37 | 0.00 | -3.4 | 3.5 | 2.42 | 2.89 | 1.7 | 4.1 | 0.00 | 0.09 | -3.2 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.42 | -2.6 | 3.5 |
| **Sep26 2-2** | 0.00 | 0.00 | -3.4 | 3.5 | 3.42 | 2.54 | 1.2 | 3.9 | 0.00 | 0.81 | -1.8 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.58 | -2.2 | 3.5 |
| **Sep26 2-3** | 1.03 | 0.00 | -3.4 | 3.5 | 3.23 | 1.30 | -0.9 | 3.6 | 0.00 | 1.28 | -0.9 | 3.6 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.99 | -1.5 | 3.5 |
| **Sep26 3-1** | 1.96 | 0.00 | -3.4 | 3.5 | 3.05 | 2.41 | 1.0 | 3.9 | 0.78 | 1.36 | -0.8 | 3.6 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 1.35 | -0.8 | 3.6 |
| **Sep26 3-2** | 1.30 | 0.00 | -3.4 | 3.5 | 3.08 | 1.44 | -0.6 | 3.6 | 1.14 | 2.24 | 0.7 | 3.8 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 1.05 | -1.3 | 3.5 |
| **Sep26 3-3** | 1.82 | 0.00 | -3.4 | 3.5 | 3.01 | 2.15 | 0.6 | 3.8 | 1.10 | 1.44 | -0.6 | 3.6 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.83 | -1.8 | 3.5 |
| **Sep26 4-1** | 1.62 | 0.00 | -3.4 | 3.5 | 3.02 | 0.19 | -3.0 | 3.5 | 1.22 | 1.20 | -1.1 | 3.6 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.85 | -1.7 | 3.5 |
| **Sep26 4-2** | 1.35 | 0.00 | -3.4 | 3.5 | 2.98 | 0.79 | -1.8 | 3.5 | 1.51 | 1.62 | -0.3 | 3.6 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.72 | -2.0 | 3.5 |
| **Sep26 4-3** | 0.97 | 0.00 | -3.4 | 3.5 | 2.72 | 0.29 | -2.8 | 3.5 | 1.93 | 1.48 | -0.6 | 3.6 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.56 | -2.3 | 3.5 |

**Table E.5.** (continued)

| Date-session | Odour Intensity | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Location* | | | | | | | | | | | | | | | | | | | |
| | 3-1 | | | | 3-2 | | | | 3-3 | | | | 3-4 | | | | 3-5 | | | |
| | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | |
| | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | |
| **Jul6 1-1** | | | | | 1.88 | 0.00 | -3.4 | 3.5 | 1.99 | 0.01 | -3.4 | 3.5 | 1.73 | 0.00 | -3.4 | 3.5 | 1.28 | 0.37 | -2.6 | 3.5 |
| **Jul6 1-2** | 1.75 | 0.95 | -1.5 | 3.5 | 2.14 | 0.00 | -3.4 | 3.5 | 1.80 | 0.75 | -1.9 | 3.5 | 1.10 | 0.00 | -3.4 | 3.5 | 0.65 | 0.12 | -3.1 | 3.5 |
| **Jul6 1-3** | 2.21 | 0.95 | -1.5 | 3.5 | 1.50 | 0.00 | -3.4 | 3.5 | 0.98 | 0.51 | -2.4 | 3.5 | 0.41 | 0.00 | -3.4 | 3.5 | 0.16 | 0.03 | -3.3 | 3.5 |
| **Jul6 2-1** | 0.77 | 0.77 | -1.9 | 3.5 | 1.77 | 0.00 | -3.4 | 3.5 | 1.92 | 0.04 | -3.3 | 3.5 | 1.71 | 0.11 | -3.2 | 3.5 | 1.32 | 0.09 | -3.2 | 3.5 |
| **Jul6 2-2** | 0.31 | 0.69 | -2.0 | 3.5 | 0.44 | 0.00 | -3.4 | 3.5 | 0.42 | 0.04 | -3.3 | 3.5 | 0.33 | 0.00 | -3.4 | 3.5 | 0.25 | 0.07 | -3.2 | 3.5 |
| **Jul6 2-3** | 1.22 | 0.11 | -3.2 | 3.5 | 1.22 | 0.00 | -3.4 | 3.5 | 0.94 | 0.03 | -3.3 | 3.5 | 0.50 | 0.00 | -3.4 | 3.5 | 0.27 | 0.06 | -3.3 | 3.5 |
| **Jul6 3-1** | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | | | | | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul6 3-2** | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.04 | -3.3 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.09 | -3.2 | 3.5 |
| **Jul6 3-3** | 0.35 | 0.00 | -3.4 | 3.5 | 0.85 | 0.16 | -3.1 | 3.5 | 0.85 | 0.07 | -3.2 | 3.5 | 0.85 | 0.00 | -3.4 | 3.5 | 0.85 | 0.00 | -3.4 | 3.5 |
| **Jul13 1-1** | 0.00 | 0.05 | -3.3 | 3.5 | 0.00 | 0.05 | -3.3 | 3.5 | 0.00 | 0.16 | -3.1 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul13 1-2** | 0.00 | 0.03 | -3.3 | 3.5 | 0.00 | 0.05 | -3.3 | 3.5 | 0.00 | 0.15 | -3.1 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul13 1-3** | 0.00 | 0.08 | -3.2 | 3.5 | 0.00 | 0.20 | -3.0 | 3.5 | 0.00 | 0.11 | -3.2 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul13 2-1** | 0.00 | 0.16 | -3.1 | 3.5 | 0.00 | 0.20 | -3.0 | 3.5 | 0.00 | 0.07 | -3.3 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul13 2-2** | 0.00 | 0.08 | -3.2 | 3.5 | 0.00 | 0.08 | -3.2 | 3.5 | 0.00 | 0.13 | -3.1 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul13 2-3** | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.03 | -3.3 | 3.5 | 0.00 | 0.31 | -2.8 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul13 3-1** | 0.00 | 0.33 | -2.7 | 3.5 | 0.00 | 0.41 | -2.6 | 3.5 | 0.00 | 0.05 | -3.3 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul13 3-2** | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.18 | -3.0 | 3.5 | 0.00 | 0.05 | -3.3 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul13 3-3** | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.48 | -2.4 | 3.5 | 0.00 | 0.26 | -2.9 | 3.5 | 0.00 | 0.02 | -3.3 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul20 1-1** | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul20 1-2** | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul20 1-3** | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.05 | -3.3 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul20 2-1** | 2.09 | 0.00 | -3.4 | 3.5 | 2.15 | 0.00 | -3.4 | 3.5 | 1.58 | 0.00 | -3.4 | 3.5 | 0.94 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul20 2-2** | 2.44 | 0.00 | -3.4 | 3.5 | 2.12 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul20 2-3** | 2.33 | 0.00 | -3.4 | 3.5 | 2.02 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul20 3-1** | 2.36 | 0.00 | -3.4 | 3.5 | 2.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul20 3-2** | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.08 | -3.2 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul20 3-3** | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.05 | -3.3 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul26 1-1** | 2.19 | 0.00 | -3.4 | 3.5 | 2.12 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.11 | -3.2 | 3.5 | 0.00 | 0.95 | -1.5 | 3.5 |
| **Jul26 1-2** | 2.31 | 0.02 | -3.4 | 3.5 | 1.84 | 0.15 | -3.1 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.15 | -3.1 | 3.5 | 0.00 | 0.38 | -2.6 | 3.5 |
| **Jul26 1-3** | 2.41 | 0.00 | -3.4 | 3.5 | 2.00 | 0.13 | -3.1 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.05 | -3.3 | 3.5 | 0.00 | 0.08 | -3.2 | 3.5 |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Jul26 2-1** | 2.35 | 0.03 | -3.3 | 3.5 | 1.56 | 0.31 | -2.8 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.07 | -3.3 | 3.5 | 0.00 | 0.23 | -2.9 | 3.5 |
| **Jul26 2-2** | 2.47 | 0.02 | -3.4 | 3.5 | 1.90 | 0.48 | -2.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.15 | -3.1 | 3.5 | 0.00 | 0.15 | -3.1 | 3.5 |
| **Jul26 2-3** | 2.41 | 0.00 | -3.4 | 3.5 | 0.00 | 0.05 | -3.3 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.11 | -3.2 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul26 3-1** | 2.03 | 0.00 | -3.4 | 3.5 | 0.00 | 0.10 | -3.2 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.11 | -3.2 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul26 3-2** | 2.40 | 0.00 | -3.4 | 3.5 | 1.38 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.10 | -3.2 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul26 3-3** | 1.49 | 0.00 | -3.4 | 3.5 | 0.00 | 0.02 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.10 | -3.2 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul26 4-1** | 2.00 | 0.08 | -3.2 | 3.5 | 0.00 | 0.07 | -3.3 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.03 | -3.3 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul26 4-2** | 1.78 | 0.00 | -3.4 | 3.5 | 0.00 | 0.03 | -3.3 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.07 | -3.3 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul26 4-3** | 2.14 | 0.00 | -3.4 | 3.5 | 0.00 | 0.05 | -3.3 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.10 | -3.2 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug5 1-1** | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug5 1-2** | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug5 1-3** | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug5 2-1** | 2.44 | 0.16 | -3.1 | 3.5 | 1.89 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug5 2-2** | 2.02 | 0.04 | -3.3 | 3.5 | 1.46 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug5 2-3** | 1.85 | 0.32 | -2.7 | 3.5 | 1.14 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug5 3-1** | 2.59 | 0.06 | -3.3 | 3.5 | 2.14 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug5 3-2** | 2.42 | 0.22 | -2.9 | 3.5 | 1.88 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug5 3-3** | 2.40 | 0.03 | -3.3 | 3.5 | 2.33 | 0.00 | -3.4 | 3.5 | 1.41 | 0.00 | -3.4 | 3.5 | 0.78 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug24 1-1** | 1.24 | 0.66 | -2.1 | 3.5 | | | | | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug24 1-2** | 1.33 | 0.24 | -2.9 | 3.5 | 1.64 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug24 1-3** | 2.56 | 0.29 | -2.8 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug24 2-1** | 2.28 | 0.43 | -2.5 | 3.5 | 1.33 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug24 2-2** | 1.65 | 0.29 | -2.8 | 3.5 | 1.81 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug24 2-3** | 2.86 | 0.19 | -3.0 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Sep26 1-1** | 2.17 | 0.00 | -3.4 | 3.5 | 0.00 | 1.02 | -1.4 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | | | | |
| **Sep26 1-2** | 0.62 | 0.00 | -3.4 | 3.5 | 1.91 | 0.32 | -2.7 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | | | | |
| **Sep26 1-3** | 1.31 | 0.00 | -3.4 | 3.5 | 1.02 | 0.22 | -2.9 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | | | | |
| **Sep26 2-1** | 0.64 | 0.00 | -3.4 | 3.5 | 1.74 | 0.19 | -3.0 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | | | | |
| **Sep26 2-2** | 0.00 | 0.00 | -3.4 | 3.5 | 3.06 | 0.01 | -3.4 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | | | | |
| **Sep26 2-3** | 0.00 | 0.00 | -3.4 | 3.5 | 2.81 | 0.03 | -3.3 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | | | | |
| **Sep26 3-1** | 1.37 | 0.00 | -3.4 | 3.5 | 2.48 | 0.01 | -3.4 | 3.5 | 0.00 | 0.09 | -3.2 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | | | | |
| **Sep26 3-2** | 1.00 | 0.00 | -3.4 | 3.5 | 2.58 | 0.01 | -3.4 | 3.5 | 0.86 | 0.43 | -2.5 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | | | | |
| **Sep26 3-3** | 1.33 | 0.00 | -3.4 | 3.5 | 2.46 | 0.01 | -3.4 | 3.5 | 0.79 | 0.50 | -2.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | | | | |
| **Sep26 4-1** | 1.18 | 0.00 | -3.4 | 3.5 | 2.49 | 0.01 | -3.4 | 3.5 | 1.02 | 1.49 | -0.5 | 3.6 | 0.00 | 0.00 | -3.4 | 3.5 | | | | |
| **Sep26 4-2** | 1.00 | 0.00 | -3.4 | 3.5 | 2.48 | 0.01 | -3.4 | 3.5 | 1.28 | 1.40 | -0.7 | 3.6 | 0.00 | 0.00 | -3.4 | 3.5 | | | | |
| **Sep26 4-3** | 0.75 | 0.00 | -3.4 | 3.5 | 2.30 | 0.07 | -3.2 | 3.5 | 1.56 | 0.11 | -3.2 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | | | | |

**Table E.6.** Comparison of odour intensity between INPUFF-2 predictions and field measurements at 15 locations (see Fig. 3.5) for Farm B

| Date-session | Odour Intensity | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Location* | | | | | | | | | | | | | | | | | | | |
| | 1-1 | | | | 1-2 | | | | 1-3 | | | | 1-4 | | | | 1-5 | | | |
| | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | |
| | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | |
| **Jun29 1-1** | 2.56 | 1.64 | -0.3 | 3.7 | 3.92 | 5.51 | 5.1 | 5.9 | 2.76 | 3.80 | 3.1 | 4.6 | 1.51 | 3.66 | 2.9 | 4.5 | 0.57 | 2.38 | 1.0 | 3.9 |
| **Jun29 1-2** | 2.69 | 1.01 | -1.4 | 3.5 | 4.06 | 4.49 | 3.9 | 5.1 | 3.73 | 3.53 | 2.7 | 4.4 | 2.34 | 3.56 | 2.7 | 4.4 | 0.81 | 2.12 | 0.5 | 3.8 |
| **Jun29 1-3** | 2.78 | 1.01 | -1.4 | 3.5 | 4.31 | 5.15 | 4.7 | 5.6 | 3.24 | 6.41 | 6.0 | 6.9 | 1.52 | 3.61 | 2.8 | 4.5 | 0.27 | 1.71 | -0.2 | 3.7 |
| **Jun29 2-1** | 3.24 | 2.22 | 0.7 | 3.8 | 3.90 | 5.92 | 5.5 | 6.3 | 2.93 | 5.30 | 4.9 | 5.7 | 1.66 | 3.93 | 3.2 | 4.7 | 0.59 | 2.02 | 0.4 | 3.8 |
| **Jun29 2-2** | 3.71 | 1.58 | -0.4 | 3.6 | 3.92 | 6.03 | 5.6 | 6.5 | 2.73 | 4.97 | 4.5 | 5.5 | 1.31 | 3.62 | 2.8 | 4.5 | 0.40 | 2.38 | 1.0 | 3.9 |
| **Jun29 2-3** | 3.16 | 1.56 | -0.4 | 3.6 | 4.27 | 4.95 | 4.5 | 5.4 | 3.53 | 4.13 | 3.5 | 4.8 | 1.96 | 4.05 | 3.4 | 4.8 | 0.68 | 2.20 | 0.7 | 3.8 |
| **Jun29 3-1** | 2.00 | 0.32 | -2.7 | 3.5 | 4.08 | 3.57 | 2.8 | 4.5 | 4.34 | 5.36 | 4.9 | 5.8 | 3.20 | 5.81 | 5.4 | 6.2 | 1.17 | 1.85 | 0.1 | 3.7 |
| **Jun29 3-2** | 2.34 | 0.30 | -2.8 | 3.5 | 3.98 | 4.44 | 3.9 | 5.0 | 4.07 | 4.21 | 3.6 | 4.9 | 3.04 | 5.20 | 4.8 | 5.7 | 1.27 | 2.57 | 1.3 | 4.0 |
| **Jun29 3-3** | 3.52 | 1.61 | -0.3 | 3.6 | 4.26 | 6.20 | 5.8 | 6.6 | 3.31 | 6.08 | 5.7 | 6.5 | 1.75 | 4.21 | 3.6 | 4.9 | 0.57 | 2.25 | 0.7 | 3.8 |
| **Jul15 1-1** | 1.97 | 0.67 | -2.1 | 3.5 | 3.24 | 1.87 | 0.1 | 3.7 | 4.04 | 2.10 | 0.5 | 3.8 | 3.04 | 1.28 | -0.9 | 3.6 | | | | |
| **Jul15 1-2** | 1.66 | 0.62 | -2.1 | 3.5 | 2.94 | 0.79 | -1.8 | 3.5 | 3.97 | 1.30 | -0.9 | 3.6 | 3.66 | 0.44 | -2.5 | 3.5 | | | | |
| **Jul15 1-3** | 0.00 | 0.19 | -3.0 | 3.5 | 0.00 | 0.90 | -1.6 | 3.5 | 0.00 | 1.61 | -0.3 | 3.6 | 0.00 | 0.38 | -2.6 | 3.5 | | | | |
| **Jul15 2-1** | 2.39 | 0.10 | -3.2 | 3.5 | 3.45 | 0.52 | -2.3 | 3.5 | 4.07 | 1.87 | 0.1 | 3.7 | 2.97 | 0.10 | -3.2 | 3.5 | | | | |
| **Jul15 2-2** | 2.73 | 0.30 | -2.8 | 3.5 | 3.54 | 0.43 | -2.5 | 3.5 | 3.85 | 1.16 | -1.1 | 3.6 | 3.01 | 0.13 | -3.1 | 3.5 | | | | |
| **Jul15 2-3** | 1.67 | 0.18 | -3.0 | 3.5 | 2.85 | 0.30 | -2.8 | 3.5 | 3.90 | 0.87 | -1.7 | 3.5 | 3.63 | 0.13 | -3.1 | 3.5 | | | | |
| **Jul15 3-1** | 0.00 | 1.68 | -0.2 | 3.7 | 0.00 | 1.79 | 0.0 | 3.7 | 0.00 | 3.66 | 2.9 | 4.5 | 0.00 | 0.72 | -2.0 | 3.5 | | | | |
| **Jul15 3-2** | 0.00 | 0.99 | -1.4 | 3.5 | 0.00 | 1.33 | -0.8 | 3.6 | 0.00 | 2.80 | 1.6 | 4.1 | 0.00 | 0.05 | -3.3 | 3.5 | | | | |
| **Jul15 3-3** | 0.00 | 0.53 | -2.3 | 3.5 | 0.00 | 0.79 | -1.8 | 3.5 | 0.00 | 1.43 | -0.7 | 3.6 | 0.00 | 0.00 | -3.4 | 3.5 | | | | |
| **Aug12 1-1** | | | | | 0.00 | 3.53 | 2.7 | 4.4 | 0.00 | 4.69 | 4.2 | 5.2 | 0.00 | 1.79 | 0.0 | 3.7 | | | | |
| **Aug12 1-2** | | | | | 1.14 | 2.83 | 1.7 | 4.1 | 0.00 | 4.18 | 3.6 | 4.8 | 0.00 | 3.17 | 2.2 | 4.2 | | | | |
| **Aug12 1-3** | | | | | 0.00 | 3.96 | 3.3 | 4.7 | 0.00 | 3.82 | 3.1 | 4.6 | 0.00 | 4.85 | 4.4 | 5.4 | | | | |
| **Aug12 2-1** | | | | | 0.25 | 3.37 | 2.5 | 4.3 | 0.00 | 3.56 | 2.7 | 4.4 | 0.00 | 4.93 | 4.5 | 5.4 | | | | |
| **Aug12 2-2** | | | | | 1.14 | 4.67 | 4.2 | 5.2 | 0.00 | 4.77 | 4.3 | 5.3 | 0.00 | 5.08 | 4.6 | 5.6 | | | | |
| **Aug12 2-3** | | | | | 0.18 | 4.34 | 3.8 | 5.0 | 0.00 | 4.61 | 4.1 | 5.2 | 0.00 | 3.85 | 3.1 | 4.6 | | | | |
| **Aug17 1-1** | 1.11 | 6.30 | 5.9 | 6.7 | 1.93 | 3.00 | 1.9 | 4.1 | 3.52 | 3.11 | 2.1 | 4.2 | 4.29 | 3.54 | 2.7 | 4.4 | 3.15 | 6.21 | 5.8 | 6.7 |
| **Aug17 1-2** | 0.86 | 6.05 | 5.6 | 6.5 | 1.48 | 3.15 | 2.1 | 4.2 | 2.73 | 3.10 | 2.1 | 4.2 | 3.66 | 3.57 | 2.8 | 4.5 | 3.32 | 6.15 | 5.7 | 6.6 |
| **Aug17 1-3** | 0.49 | 5.94 | 5.5 | 6.4 | 0.91 | 3.67 | 2.9 | 4.5 | 2.03 | 2.93 | 1.8 | 4.1 | 3.57 | 4.44 | 3.9 | 5.0 | 3.66 | 6.82 | 6.3 | 7.3 |
| **Aug17 2-1** | 2.50 | 3.70 | 2.9 | 4.5 | 4.29 | 5.46 | 5.0 | 5.9 | 4.58 | 6.93 | 6.4 | 7.5 | 2.72 | 6.12 | 5.7 | 6.6 | 1.23 | 3.49 | 2.6 | 4.4 |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Aug17 2-2** | 2.91 | 4.48 | 3.9 | 5.1 | 4.60 | 4.59 | 4.1 | 5.2 | 4.42 | 6.61 | 6.1 | 7.1 | 2.22 | 4.61 | 4.1 | 5.2 | 0.91 | 4.08 | 3.4 | 4.8 |
| **Aug17 2-3** | 2.16 | 3.44 | 2.6 | 4.4 | 3.93 | 4.44 | 3.9 | 5.0 | 4.48 | 6.61 | 6.1 | 7.1 | 2.95 | 5.48 | 5.1 | 5.9 | 1.37 | 4.20 | 3.6 | 4.9 |
| **Aug17 3-1** | 1.50 | 2.62 | 1.3 | 4.0 | 3.48 | 2.43 | 1.0 | 3.9 | 4.39 | 6.54 | 6.1 | 7.0 | 3.61 | 0.39 | -2.6 | 3.5 | 1.99 | 4.39 | 3.8 | 5.0 |
| **Aug17 3-2** | 2.49 | 3.87 | 3.2 | 4.6 | 4.36 | 3.64 | 2.8 | 4.5 | 4.58 | 6.67 | 6.2 | 7.2 | 2.61 | 0.30 | -2.8 | 3.5 | 1.03 | 4.57 | 4.0 | 5.1 |
| **Aug17 3-3** | 2.66 | 3.90 | 3.2 | 4.7 | 4.61 | 3.72 | 3.0 | 4.5 | 4.35 | 6.84 | 6.3 | 7.4 | 1.77 | 2.28 | 0.8 | 3.8 | 0.59 | 4.08 | 3.4 | 4.8 |
| **Sep19 1-1** | | | | | | | | | | | | | | | | | | | | |
| **Sep19 1-2** | | | | | | | | | | | | | | | | | | | | |
| **Sep19 1-3** | | | | | | | | | | | | | | | | | | | | |
| **Sep19 2-1** | | | | | | | | | | | | | | | | | | | | |
| **Sep19 2-2** | | | | | | | | | | | | | | | | | | | | |
| **Sep19 2-3** | | | | | | | | | | | | | | | | | | | | |

**Table E.6.** (continued)

| Date-session | Odour Intensity | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Location* | | | | | | | | | | | | | | | | | | | |
| | 2-1 | | | | 2-2 | | | | 2-3 | | | | 2-4 | | | | 2-5 | | | |
| | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | |
| | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | |
| **Jun29 1-1** | 1.28 | 0.06 | -3.3 | 3.5 | 2.12 | 2.25 | 0.7 | 3.8 | 1.77 | 0.38 | -2.6 | 3.5 | 0.77 | 0.35 | -2.7 | 3.5 | 0.33 | 0.81 | -1.8 | 3.5 |
| **Jun29 1-2** | 1.34 | 0.03 | -3.3 | 3.5 | 2.17 | 2.56 | 1.2 | 3.9 | 2.17 | 0.16 | -3.1 | 3.5 | 0.90 | 0.60 | -2.2 | 3.5 | 0.35 | 0.95 | -1.5 | 3.5 |
| **Jun29 1-3** | 1.05 | 0.20 | -3.0 | 3.5 | 2.18 | 2.90 | 1.8 | 4.1 | 1.96 | 0.42 | -2.6 | 3.5 | 0.37 | 0.86 | -1.7 | 3.5 | 0.00 | 0.63 | -2.1 | 3.5 |
| **Jun29 2-1** | 1.99 | 0.06 | -3.3 | 3.5 | 2.67 | 3.49 | 2.6 | 4.4 | 1.45 | 0.43 | -2.5 | 3.5 | 0.42 | 0.43 | -2.5 | 3.5 | 0.09 | 0.59 | -2.2 | 3.5 |
| **Jun29 2-2** | 2.01 | 0.04 | -3.3 | 3.5 | 2.77 | 3.21 | 2.2 | 4.3 | 1.55 | 0.24 | -2.9 | 3.5 | 0.43 | 0.81 | -1.8 | 3.5 | 0.07 | 0.82 | -1.8 | 3.5 |
| **Jun29 2-3** | 1.51 | 0.01 | -3.4 | 3.5 | 2.25 | 3.31 | 2.4 | 4.3 | 2.26 | 0.27 | -2.8 | 3.5 | 1.10 | 0.78 | -1.9 | 3.5 | 0.38 | 0.48 | -2.4 | 3.5 |
| **Jun29 3-1** | 0.89 | 0.01 | -3.4 | 3.5 | 1.56 | 2.87 | 1.7 | 4.1 | 2.80 | 0.04 | -3.3 | 3.5 | 1.54 | 1.17 | -1.1 | 3.6 | 0.62 | 0.68 | -2.0 | 3.5 |
| **Jun29 3-2** | 1.04 | 0.01 | -3.4 | 3.5 | 1.75 | 2.93 | 1.8 | 4.1 | 2.67 | 0.07 | -3.2 | 3.5 | 1.64 | 1.40 | -0.7 | 3.6 | 0.79 | 0.59 | -2.2 | 3.5 |
| **Jun29 3-3** | 1.77 | 0.01 | -3.4 | 3.5 | 2.50 | 2.28 | 0.8 | 3.8 | 2.17 | 2.41 | 1.0 | 3.9 | 0.99 | 0.58 | -2.2 | 3.5 | 0.41 | 0.48 | -2.4 | 3.5 |
| **Jul15 1-1** | 0.74 | 0.13 | -3.1 | 3.5 | 1.79 | 1.79 | 0.0 | 3.7 | 2.47 | 0.07 | -3.3 | 3.5 | 2.30 | 0.18 | -3.0 | 3.5 | 1.30 | 0.23 | -2.9 | 3.5 |
| **Jul15 1-2** | 0.62 | 0.41 | -2.6 | 3.5 | 1.61 | 2.79 | 1.6 | 4.0 | 2.27 | 0.48 | -2.4 | 3.5 | 2.65 | 0.15 | -3.1 | 3.5 | 1.82 | 0.10 | -3.2 | 3.5 |
| **Jul15 1-3** | 0.00 | 0.05 | -3.3 | 3.5 | 0.00 | 1.87 | 0.1 | 3.7 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.02 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul15 2-1** | 1.31 | 0.00 | -3.4 | 3.5 | 2.31 | 1.97 | 0.3 | 3.7 | 2.63 | 0.00 | -3.4 | 3.5 | 1.86 | 0.02 | -3.4 | 3.5 | 1.04 | 0.00 | -3.4 | 3.5 |
| **Jul15 2-2** | 1.57 | 0.00 | -3.4 | 3.5 | 2.32 | 1.67 | -0.2 | 3.7 | 2.49 | 0.00 | -3.4 | 3.5 | 2.03 | 0.00 | -3.4 | 3.5 | 1.41 | 0.00 | -3.4 | 3.5 |
| **Jul15 2-3** | 0.59 | 0.00 | -3.4 | 3.5 | 1.57 | 1.48 | -0.6 | 3.6 | 2.22 | 0.00 | -3.4 | 3.5 | 2.57 | 0.00 | -3.4 | 3.5 | 1.83 | 0.00 | -3.4 | 3.5 |
| **Jul15 3-1** | 0.00 | 1.11 | -1.2 | 3.6 | 0.00 | 1.05 | -1.3 | 3.5 | 0.00 | 0.30 | -2.8 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul15 3-2** | 0.00 | 0.31 | -2.8 | 3.5 | 0.00 | 0.34 | -2.7 | 3.5 | 0.00 | 0.11 | -3.2 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul15 3-3** | 0.00 | 0.10 | -3.2 | 3.5 | 0.00 | 0.31 | -2.8 | 3.5 | 0.00 | 0.05 | -3.3 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug12 1-1** | 1.09 | 1.23 | -1.0 | 3.6 | 0.00 | 3.30 | 2.4 | 4.3 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.21 | -3.0 | 3.5 | 0.00 | 1.97 | 0.3 | 3.7 |
| **Aug12 1-2** | 0.82 | 0.77 | -1.9 | 3.5 | 0.00 | 1.92 | 0.2 | 3.7 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.03 | -3.3 | 3.5 | 0.00 | 1.20 | -1.1 | 3.6 |
| **Aug12 1-3** | 3.38 | 0.07 | -3.2 | 3.5 | 0.00 | 1.36 | -0.8 | 3.6 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 1.00 | -1.4 | 3.5 |
| **Aug12 2-1** | 0.00 | 0.64 | -2.1 | 3.5 | 0.00 | 1.75 | -0.1 | 3.7 | 0.00 | 1.23 | -1.0 | 3.6 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 1.10 | -1.2 | 3.6 |
| **Aug12 2-2** | 3.04 | 1.15 | -1.2 | 3.6 | 1.23 | 1.40 | -0.7 | 3.6 | 0.00 | 1.43 | -0.7 | 3.6 | 0.00 | 0.29 | -2.8 | 3.5 | 0.00 | 2.13 | 0.6 | 3.8 |
| **Aug12 2-3** | 1.96 | 1.26 | -1.0 | 3.6 | 0.00 | 2.26 | 0.8 | 3.8 | 0.00 | 0.89 | -1.6 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 2.49 | 1.1 | 3.9 |
| **Aug17 1-1** | 0.25 | 0.01 | -3.4 | 3.5 | 0.98 | 0.01 | -3.4 | 3.5 | 2.36 | 0.55 | -2.3 | 3.5 | 2.94 | 0.42 | -2.5 | 3.5 | 2.40 | 0.30 | -2.8 | 3.5 |
| **Aug17 1-2** | 0.12 | 0.01 | -3.4 | 3.5 | 0.71 | 0.01 | -3.4 | 3.5 | 1.74 | 0.56 | -2.3 | 3.5 | 2.63 | 0.73 | -1.9 | 3.5 | 2.70 | 0.71 | -2.0 | 3.5 |
| **Aug17 1-3** | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 1.06 | 0.71 | -2.0 | 3.5 | 1.98 | 1.38 | -0.7 | 3.6 | 2.28 | 0.69 | -2.0 | 3.5 |
| **Aug17 2-1** | 1.41 | 0.61 | -2.2 | 3.5 | 2.78 | 0.24 | -2.9 | 3.5 | 3.24 | 0.69 | -2.0 | 3.5 | 1.67 | 0.97 | -1.5 | 3.5 | 1.12 | 0.01 | -3.4 | 3.5 |
| **Aug17 2-2** | 1.63 | 0.87 | -1.7 | 3.5 | 3.02 | 1.18 | -1.1 | 3.6 | 3.26 | 0.76 | -1.9 | 3.5 | 1.26 | 0.11 | -3.2 | 3.5 | 0.76 | 0.01 | -3.4 | 3.5 |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Aug17 2-3** | 1.16 | 1.03 | -1.4 | 3.5 | 2.41 | 0.12 | -3.1 | 3.5 | 3.10 | 1.28 | -0.9 | 3.6 | 1.89 | 1.57 | -0.4 | 3.6 | 1.30 | 0.01 | -3.4 | 3.5 |
| **Aug17 3-1** | 0.78 | 0.89 | -1.6 | 3.5 | 2.05 | 0.29 | -2.8 | 3.5 | 2.93 | 0.87 | -1.7 | 3.5 | 2.24 | 1.79 | 0.0 | 3.7 | 1.72 | 0.14 | -3.1 | 3.5 |
| **Aug17 3-2** | 1.32 | 1.00 | -1.4 | 3.5 | 2.76 | 0.01 | -3.4 | 3.5 | 3.21 | 0.56 | -2.3 | 3.5 | 1.50 | 1.07 | -1.3 | 3.5 | 0.91 | 0.01 | -3.4 | 3.5 |
| **Aug17 3-3** | 1.55 | 0.61 | -2.2 | 3.5 | 3.06 | 0.01 | -3.4 | 3.5 | 3.16 | 0.82 | -1.8 | 3.5 | 0.96 | 0.99 | -1.5 | 3.5 | 0.53 | 0.01 | -3.4 | 3.5 |
| **Sep19 1-1** | 4.03 | 2.02 | 0.4 | 3.8 | 1.44 | 2.84 | 1.7 | 4.1 | 0.00 | 0.58 | -2.2 | 3.5 | 0.00 | 0.14 | -3.1 | 3.5 | 0.00 | 0.29 | -2.8 | 3.5 |
| **Sep19 1-2** | 4.47 | 0.32 | -2.7 | 3.5 | 1.21 | 3.31 | 2.4 | 4.3 | 0.00 | 0.25 | -2.9 | 3.5 | 0.00 | 0.11 | -3.2 | 3.5 | 0.00 | 0.47 | -2.5 | 3.5 |
| **Sep19 1-3** | 3.91 | 0.78 | -1.9 | 3.5 | 1.28 | 2.70 | 1.5 | 4.0 | 0.00 | 0.56 | -2.3 | 3.5 | 0.00 | 0.14 | -3.1 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 |
| **Sep19 2-1** | 1.96 | 0.71 | -2.0 | 3.5 | 4.01 | 2.31 | 0.9 | 3.9 | 0.00 | 0.50 | -2.4 | 3.5 | 0.00 | 0.03 | -3.3 | 3.5 | 0.00 | 0.24 | -2.9 | 3.5 |
| **Sep19 2-2** | 1.85 | 0.11 | -3.2 | 3.5 | 3.85 | 1.74 | -0.1 | 3.7 | 0.00 | 0.45 | -2.5 | 3.5 | 0.00 | 0.08 | -3.2 | 3.5 | 0.00 | 0.07 | -3.2 | 3.5 |
| **Sep19 2-3** | 4.40 | 0.65 | -2.1 | 3.5 | 0.53 | 1.15 | -1.2 | 3.6 | 0.00 | 0.71 | -2.0 | 3.5 | 0.00 | 0.04 | -3.3 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 |

**Table E.6.** (continued)

| Date-session | Odour Intensity | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Location* | | | | | | | | | | | | | | | | | | | |
| | 3-1 | | | | 3-2 | | | | 3-3 | | | | 3-4 | | | | 3-5 | | | |
| | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | | Pred | Measured | | |
| | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | | | Mean | 95% CI | |
| **Jun29 1-1** | 1.02 | 0.10 | -3.2 | 3.5 | 2.13 | 0.98 | -1.5 | 3.5 | 1.36 | 0.74 | -1.9 | 3.5 | 0.61 | 0.19 | -3.0 | 3.5 | 0.00 | 0.03 | -3.3 | 3.5 |
| **Jun29 1-2** | 1.00 | 0.04 | -3.3 | 3.5 | 2.28 | 0.97 | -1.5 | 3.5 | 1.58 | 0.60 | -2.2 | 3.5 | 0.73 | 0.22 | -2.9 | 3.5 | 0.00 | 0.06 | -3.3 | 3.5 |
| **Jun29 1-3** | 0.71 | 0.05 | -3.3 | 3.5 | 2.52 | 1.00 | -1.4 | 3.5 | 1.46 | 0.60 | -2.2 | 3.5 | 0.36 | 0.24 | -2.9 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 |
| **Jun29 2-1** | 1.52 | 0.03 | -3.3 | 3.5 | 2.28 | 0.84 | -1.7 | 3.5 | 1.03 | 0.38 | -2.6 | 3.5 | 0.35 | 0.04 | -3.3 | 3.5 | 0.00 | 0.03 | -3.3 | 3.5 |
| **Jun29 2-2** | 1.43 | 0.03 | -3.3 | 3.5 | 2.35 | 1.00 | -1.4 | 3.5 | 1.19 | 0.24 | -2.9 | 3.5 | 0.45 | 0.01 | -3.4 | 3.5 | 0.00 | 0.03 | -3.3 | 3.5 |
| **Jun29 2-3** | 0.82 | 0.04 | -3.3 | 3.5 | 2.23 | 0.12 | -3.1 | 3.5 | 1.84 | 0.24 | -2.9 | 3.5 | 0.94 | 0.07 | -3.2 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jun29 3-1** | 0.75 | 0.00 | -3.4 | 3.5 | 1.93 | 0.33 | -2.7 | 3.5 | 2.12 | 0.06 | -3.3 | 3.5 | 1.36 | 0.11 | -3.2 | 3.5 | 0.12 | 0.01 | -3.4 | 3.5 |
| **Jun29 3-2** | 0.57 | 0.00 | -3.4 | 3.5 | 1.95 | 0.00 | -3.4 | 3.5 | 2.22 | 0.01 | -3.4 | 3.5 | 1.56 | 0.06 | -3.3 | 3.5 | 0.20 | 0.12 | -3.1 | 3.5 |
| **Jun29 3-3** | 1.05 | 0.03 | -3.3 | 3.5 | 2.39 | 0.00 | -3.4 | 3.5 | 1.88 | 0.83 | -1.8 | 3.5 | 0.97 | 0.09 | -3.2 | 3.5 | 0.00 | 0.06 | -3.3 | 3.5 |
| **Jul15 1-1** | 0.00 | 0.00 | -3.4 | 3.5 | 1.14 | 0.00 | -3.4 | 3.5 | 2.05 | 0.00 | -3.4 | 3.5 | 1.78 | 0.05 | -3.3 | 3.5 | 0.86 | 0.00 | -3.4 | 3.5 |
| **Jul15 1-2** | 0.00 | 0.00 | -3.4 | 3.5 | 0.98 | 0.00 | -3.4 | 3.5 | 1.80 | 0.00 | -3.4 | 3.5 | 2.20 | 0.16 | -3.1 | 3.5 | 1.45 | 0.03 | -3.3 | 3.5 |
| **Jul15 1-3** | 0.00 | 0.03 | -3.3 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul15 2-1** | 0.00 | 0.00 | -3.4 | 3.5 | 1.90 | 0.00 | -3.4 | 3.5 | 2.29 | 0.00 | -3.4 | 3.5 | 1.31 | 0.00 | -3.4 | 3.5 | 0.66 | 0.00 | -3.4 | 3.5 |
| **Jul15 2-2** | 0.83 | 0.00 | -3.4 | 3.5 | 1.85 | 0.00 | -3.4 | 3.5 | 2.23 | 0.00 | -3.4 | 3.5 | 1.60 | 0.00 | -3.4 | 3.5 | 0.97 | 0.00 | -3.4 | 3.5 |
| **Jul15 2-3** | 0.00 | 0.00 | -3.4 | 3.5 | 0.90 | 0.00 | -3.4 | 3.5 | 1.72 | 0.00 | -3.4 | 3.5 | 2.24 | 0.00 | -3.4 | 3.5 | 1.56 | 0.00 | -3.4 | 3.5 |
| **Jul15 3-1** | 0.00 | 0.02 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul15 3-2** | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Jul15 3-3** | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug12 1-1** | 0.00 | 0.12 | -3.1 | 3.5 | 0.00 | 1.28 | -0.9 | 3.6 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug12 1-2** | 0.00 | 0.07 | -3.2 | 3.5 | 0.00 | 0.51 | -2.4 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug12 1-3** | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 1.43 | -0.7 | 3.6 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug12 2-1** | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.64 | -2.1 | 3.5 | 0.00 | 0.01 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug12 2-2** | 1.71 | 0.01 | -3.4 | 3.5 | 0.00 | 0.19 | -3.0 | 3.5 | 0.00 | 0.19 | -3.0 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug12 2-3** | 1.90 | 0.01 | -3.4 | 3.5 | 0.00 | 0.22 | -2.9 | 3.5 | 0.00 | 1.08 | -1.3 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 |
| **Aug17 1-1** | 0.05 | 0.00 | -3.4 | 3.5 | 0.62 | 0.00 | -3.4 | 3.5 | 1.90 | 0.00 | -3.4 | 3.5 | 2.44 | 0.00 | -3.4 | 3.5 | 1.50 | 0.00 | -3.4 | 3.5 |
| **Aug17 1-2** | 0.00 | 0.00 | -3.4 | 3.5 | 0.38 | 0.00 | -3.4 | 3.5 | 1.30 | 0.00 | -3.4 | 3.5 | 2.36 | 0.00 | -3.4 | 3.5 | 2.16 | 0.00 | -3.4 | 3.5 |
| **Aug17 1-3** | 0.00 | 0.00 | -3.4 | 3.5 | 0.14 | 0.00 | -3.4 | 3.5 | 0.61 | 0.00 | -3.4 | 3.5 | 1.27 | 0.00 | -3.4 | 3.5 | 1.22 | 0.00 | -3.4 | 3.5 |
| **Aug17 2-1** | 1.06 | 0.00 | -3.4 | 3.5 | 2.30 | 0.00 | -3.4 | 3.5 | 2.47 | 0.00 | -3.4 | 3.5 | 1.27 | 0.00 | -3.4 | 3.5 | 0.43 | 0.00 | -3.4 | 3.5 |
| **Aug17 2-2** | 1.25 | 0.00 | -3.4 | 3.5 | 2.52 | 0.00 | -3.4 | 3.5 | 2.31 | 0.00 | -3.4 | 3.5 | 0.87 | 0.00 | -3.4 | 3.5 | 0.27 | 0.00 | -3.4 | 3.5 |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Aug17 2-3** | 0.81 | 0.00 | -3.4 | 3.5 | 1.95 | 0.00 | -3.4 | 3.5 | 2.50 | 0.00 | -3.4 | 3.5 | 1.56 | 0.00 | -3.4 | 3.5 | 0.62 | 0.00 | -3.4 | 3.5 |
| **Aug17 3-1** | 0.59 | 0.00 | -3.4 | 3.5 | 1.66 | 0.00 | -3.4 | 3.5 | 2.44 | 0.00 | -3.4 | 3.5 | 1.81 | 0.00 | -3.4 | 3.5 | 0.88 | 0.00 | -3.4 | 3.5 |
| **Aug17 3-2** | 0.82 | 0.00 | -3.4 | 3.5 | 2.29 | 0.00 | -3.4 | 3.5 | 2.48 | 0.00 | -3.4 | 3.5 | 1.11 | 0.00 | -3.4 | 3.5 | 0.27 | 0.00 | -3.4 | 3.5 |
| **Aug17 3-3** | 1.17 | 0.00 | -3.4 | 3.5 | 2.55 | 0.00 | -3.4 | 3.5 | 2.09 | 0.00 | -3.4 | 3.5 | 0.67 | 0.00 | -3.4 | 3.5 | 0.07 | 0.00 | -3.4 | 3.5 |
| **Sep19 1-1** | 3.71 | 0.00 | -3.4 | 3.5 | 0.81 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | | | | | 0.00 | 0.00 | -3.4 | 3.5 |
| **Sep19 1-2** | 3.71 | 0.00 | -3.4 | 3.5 | 0.87 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | | | | | 0.00 | 0.00 | -3.4 | 3.5 |
| **Sep19 1-3** | 3.55 | 0.00 | -3.4 | 3.5 | 0.75 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | | | | | 0.00 | 0.00 | -3.4 | 3.5 |
| **Sep19 2-1** | 1.43 | 0.00 | -3.4 | 3.5 | 3.38 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | | | | | 0.00 | 0.00 | -3.4 | 3.5 |
| **Sep19 2-2** | 1.45 | 0.00 | -3.4 | 3.5 | 2.95 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | | | | | 0.00 | 0.00 | -3.4 | 3.5 |
| **Sep19 2-3** | 3.51 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | 0.00 | 0.00 | -3.4 | 3.5 | | | | | 0.00 | 0.00 | -3.4 | 3.5 |