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Use of Trained Odour Assessors to Monitor Odour Intensity, Duration and Offensiveness Downwind of Manure Application Sites

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Abstract. *The assessment of odour dispersion downwind of manure application sites is required to establish science-based separation distances that allow for the minimization of odour nuisance to farming neighbours. Nasal Rangers™, or trained odour assessors, are gaining popularity for odour intensity determination. Training of Nasal Rangers™ and the development of appropriate field protocols have been established by St. Croix Sensory Inc. as well as by the University of Alberta odour team. Wind tunnels and flux chambers are useful for obtaining surface odour concentrations that are averaged over the sampling period. However, the emitting sources and weather conditions often produce instantaneous spikes of odour that may cause annoyance to local residents but that may not be captured by chamber sampling. Nasal Rangers™ are better suited than the chamber techniques to monitor and record these instantaneous odour events. Trained odour assessors are also useful at determining duration and offensiveness of odour events in the field.*

This paper outlines the field protocols used to assess odour intensity, duration and offensiveness downwind of manure application sites using trained odour assessors. The training, field positioning, timing of measurements and other modifications to the protocol are addressed. The use of the St. Croix Sensory field olfactometer for odour concentration measurement from full scale field applications is also presented. The challenges associated with Nasal Ranging™ are discussed, including shifting winds, barn and storage effects, land obstacles and the difficulty of measuring odour from a large, variable source. The advantages and disadvantages of alternative field protocols (triangle versus line formation) are also discussed. The preliminary results of several field trials are also presented.

Keywords. Odour intensity, odour assessors, Nasal Rangers™, manure spreading, land application, field olfactometer.

Introduction

Livestock operations are an important part of the agricultural economy in the Prairie provinces. One major concern associated with the expansion of livestock production is odour nuisance to neighbours. Various methods and technologies exist to reduce neighbour exposure to offensive livestock odours, including minimum separation distances between farms and neighbours and beneficial management practices to reduce the emission of odours. Ongoing research in Alberta, Manitoba and Saskatchewan is focusing on the measurement of odour and its dispersion to better assess the efficiency of these practices and technologies at reducing odour emissions.

Odour from livestock facilities is generated from three main sources: the production buildings, manure storage facilities, and land application of manure. The majority of research to date has focused on assessing emissions from the buildings and manure storages. However, more than half of documented complaints about odour from livestock facilities arise from manure application activities (Schoenau et al. 2005). Since there are a variety of manure management methods (solid, liquid, semi-solid slurry, etc.) and several modes of manure application (surface banded, surface broadcast, incorporation, injection, irrigation gun, etc.) there exists the need for a better assessment of the relative odour contribution associated with each method and technology.

The objectives of this paper are to review the protocols for odour intensity data collection and to establish protocols for the measurement of odour intensity surrounding manure application sites.

Literature Review

Odour Measurement

Livestock odours are very complex due to the variability of the source, dispersion due to changing weather conditions, individual sensitivity to odours and the fact that odours result from the interactions of over 165 volatile compounds (Pan et al. 2005). Therefore, there are many components of odour measurement that are required in order to best characterize the impact of odour on people. The most common components of odour measurement include: frequency (F), intensity (I), duration (D), and offensiveness (O), or FIDO (AAFRD, 2006). Frequency (how often the odour occurs), duration (how long the odour is encountered) as well as offensiveness (how unpleasant the odour is) are relatively simple to determine. While several scales of odour offensiveness exist, there are few established protocols for the characterization of the frequency and duration of odours. Much of the literature is dedicated to the measurement of odour strength, or intensity.

Olfactometers are standardized instruments for the measurement of odour concentration (Feddes et al. 2001), which can be used to calculate emission rates from point and surface sources. However, olfactometry analyses require that samples be collected using chambers or vacuum boxes. These samples are often not representative of the odours actually experienced in the field due to instantaneous shifts in wind direction and speed and bursts of odour emitted from the source. The method of measuring odour directly in the field developed by St. Croix Sensory Inc. (Lake Elmo, MN, USA) uses trained human odour assessors (Nasal Rangers™) to quantify odour intensity according to standardized n-butanol reference scales (ASTM 1997). St. Croix Sensory Inc. has also developed a field olfactometer, or Scentometer, for the measurement of odour strength (dilution to threshold ratio) directly in the field. Relative strengths of both the trained odour assessors and the field olfactometer will be discussed in this paper.

Protocols for Trained Odour Assessors

In a study in Manitoba (Zhou et al. 2005), odour plume measurement downwind of several swine facilities in Manitoba was done using 15 trained odour sniffers and the 8-point n-butanol scale to quantify the field odour intensity (Xing et al., 2006). Training for the Manitoba study included a set of six sessions that focused on training the sniffers to memorize the 8-point n-butanol reference scale (Zhou et al. 2005). Other studies focused on the measurement of odour intensity used a modified, 5-point scale (Guo et al. 2001). The differences between these scales are presented in Table 1.

Table 1. 8-point and 5-point n-butanol reference scales for odour intensity measurement.

8-point Scale (ASTM 1997)			5-point Scale (Guo et al. 2001)		
Intensity Level	Annoyance	n-butanol in water (ppm)	Intensity Level	Description	n-butanol in water (ppm)
0	no odour	0	0	no odour	0
1	not annoying	120			
2	a little annoying	240	1	very faint odour	250
3	a little annoying	480			
4	annoying	960	2	faint odour	750
5	annoying	1,940	3	moderate odour	2,250
6	very annoying	3,880			
7	very annoying	7,750	4	strong odour	6,750
8	extremely annoying	15,500	5	very strong odour	20,250

The placement of the sniffers in the field in Zhou et al. (2005) was aided by hand-held global positioning units (GPS). Based on the measured wind direction, 15 sniffers were placed in a three-row grid 100, 500 and 1000 m downwind of the base point (edge of the farm) with 5 sniffers at each distance. The sniffers breathed through a mask for 10 seconds and sniffed the air for 10 seconds. Sixty observations were made in three measurement sessions over the course of 1 hour (Xing et al., 2006).

Zhu et al. (2000) utilized the 5-point n-butanol scale and 7 trained human sniffers to characterize the odour intensity downwind of livestock buildings and manure storages. Distances between 50 and 500 m (depending on site and strength of odour source) were marked off at the approximate centerline of the downstream odour plume. Perpendicular to the centerline, straight lines were marked off to locate individual sniffers between 5 and 20 m apart depending on the plume width. Essentially, Zhu et al. (2000) used a line formation rather than the grid formation described in Zhou et al. (2005).

The protocol for the odour assessors in an Alberta study (AAFRD 2006) stated that the assessors (5 or more) would position themselves 6 degrees apart up to 750 m away from the odour source. While maintaining the 6 degrees of separation, they would move toward the odour source by 150 m at a time and take 10 intensity measurements at each location. They would breathe through a mask for 45 seconds and each assessor would simultaneously sniff the air for 10 seconds and record the odour intensity based on the 8-point reference scale.

Alternatively, the assessors would position themselves in groups based on the frequency of the wind direction. For example, if the wind direction was highly variable, a pair of assessors would be positioned 6 degrees apart. For moderately variable wind, three assessors would be positioned 8 degrees apart and for stable wind directions, all 6 assessors would be positioned together in the downwind direction.

Odour Dilution to Threshold (Field Olfactometer)

The odour strength surrounding sites on which biosolids were applied was measured using the field olfactometer by Hamel et al. (2004). As described in the manual with the field olfactometer, the units of measurement are dilutions to threshold (D/T) where D/T is defined as the volume of odour free (filtered) air divided by the volume of odourous air. At each site, measurements were taken at each property boundary, the nearest road, and the nearest house. To reduce the chances of high odour being missed due to fluctuations in wind speed, wind direction, or any other odour-affecting factors, three or more D/T readings were taken at each location. Only the highest of the three readings per measurement were used in the data analysis by Hamel et al. (2004). D/T measurements were taken at biosolids application sites up to 35 days following the application event. The highest odour strength observed (4 D/T) occurred 3 days after spreading and, after 16 days, the odour strength was systematically below 2 D/T. Odour strengths at the nearest residence never exceeded 4 D/T. The authors indicated that odours dissipated more quickly from the sites where the biosolids had been incorporated in the soil.

Sheffield et al. (2005) used the field olfactometer and n-butanol scale to analyze for detection threshold and odour intensity, respectively, 50 m and 200 m downwind of dairy and feedlot facilities. Measurements of 'odour acceptability' allowed the researchers to establish which odours would be acceptable for a variety of land uses and activities. A dilution to threshold of 7, corresponding to the level used by many states and municipalities as regulatory odour threshold (Sheffield et al. 2005), was found to be objectionable by 40% of panelists if they were at a rural residence and 54% said it would be objectionable if they were at an outdoor rural party. In general, odours in excess of 15 dilutions to threshold (D/T) using the field olfactometer were found to be objectionable.

Pan et al. (2005) investigated the effects of wind speed and direction, cloud cover, time of day, temperature, species of manure and distance to the odour source on odour strength measurements obtained with the field olfactometer downwind of livestock and poultry facilities. Distance to the odour source and temperature were most highly associated with odour strength, while the other factors were found to be insignificant. Measurements were taken at different times and locations downwind of the source (at locations 3/4, 1/2 and 1/4 of the total distance from the odour source to the faintest downwind odour point). For each reading, two assessors evaluated the odour strength at the same time. Each assessor took three readings to reduce the chances of high odour being missed.

Methods and Materials

Odour Assessor Training

The odour intensity downwind of manure application sites was measured using the 5 point n-butanol scale and a team of trained odour assessors. A pool of candidates attended a training session during which they learned about livestock odour measurement and characterization and the differences between odour intensity, concentration, and offensiveness. Each candidate was presented with the 5-point n-butanol scale (Table 1) and shown the proper technique to sniff the samples. They then ordered the random samples from lowest to highest intensity and completed a nose calibration where they had to identify the odour intensity of five random jars. Successful candidates were those who could correctly order the five samples and identify the random intensity within one level of the actual intensity. Successful candidates were provided with their own n-butanol kit so they could calibrate their noses bi-weekly during the expected measurement season.

In addition to bi-weekly nose calibrations, each successful assessor completed the odour sensitivity test developed by St. Croix Sensory, Inc. The odour sensitivity test assigns a rating for each individual based on the sensitivity of their olfactory sense. The test uses an ascending concentration series, triangular testing procedure. Any candidate scoring lower than five (not sensitive enough) or higher than ten (too sensitive) did not participate in the field data collection. The individual with the highest odour sensitivity was asked to collect dilution to threshold data using the field olfactometer.

Intensity and Offensiveness

Because the number of available trained assessors was limited during the period of data collection, it was impractical to use the grid formation in the current study in Saskatchewan. Therefore, the line formation in combination with the 6 degrees of separation and 160 m increments used in Alberta were used with the simplified 5-point n-butanol scale to obtain odour intensity measurements downwind of manure application sites. The maximum distance downwind of the site was 800 m to correspond with Saskatchewan Agriculture and Food's recommendations for minimum separation distances between manure application sites and neighbours. Other changes to the protocols were required due to the complications of measuring odour from a large, variable source.

Odour intensity measurements began during or immediately after manure application events. First, a portable weather station was set up to determine the predominant wind direction and the assessors were positioned 800 m downwind of the approximate edge of the application site. Since the odour source was variable and mobile, the edge of the application site often changed by the end of the measurement session. Eight hundred meters downwind, the assessors positioned themselves six degrees apart from each other (approximately 83 m apart). Each assessor was provided with a charcoal filter mask, a clipboard to record data, and a two-way radio to communicate with the rest of the team. At the beginning of each session, the assessors breathed through the mask for five minutes to 'clean' their noses. The team leader would then instruct each assessor to remove their mask and sniff the air for 20 seconds. At the end of the 20-second period, they would replace their mask and record the maximum intensity encountered during the sniffing period. After 40 seconds of breathing through the mask, the assessors would be instructed to again sniff the air for 20 seconds. Ten readings were collected at each location over a ten minute period. At the end of each set of ten readings, the assessors were asked to record an average offensiveness rating for those ten readings from the 9-point scale shown in Table 2.

Table 2. Odour offensiveness ratings.

Rating	Description	Rating	Description
1	dislike extremely	6	like slightly
2	dislike very much	7	like moderately
3	dislike moderately	8	like very much
4	dislike slightly	9	like extremely
5	neither like or dislike		

After the ten intensity readings and the offensiveness ratings were collected, the team moved toward the odour source by 150 m while maintaining the six degrees of separation, aided by GPS. Each team member was now approximately 65 m apart. Ten more intensity readings and an offensiveness rating were recorded and the team moved on to the third location. Each assessor collected odour intensity data at six different locations using this method. By the sixth and final location, the odour assessors were grouped together at the edge of the application site. Refer to Figure 1 for a schematic diagram of the field positions. Weather conditions (wind speed and direction, temperature and relative humidity and solar radiation rating) were continually recorded during the measurement period. Other contributing factors such as the location of the barns, movement of the equipment in the field and obstacles such as trees and hills were also recorded. The manure type and species and the application method and rate were also obtained and recorded.

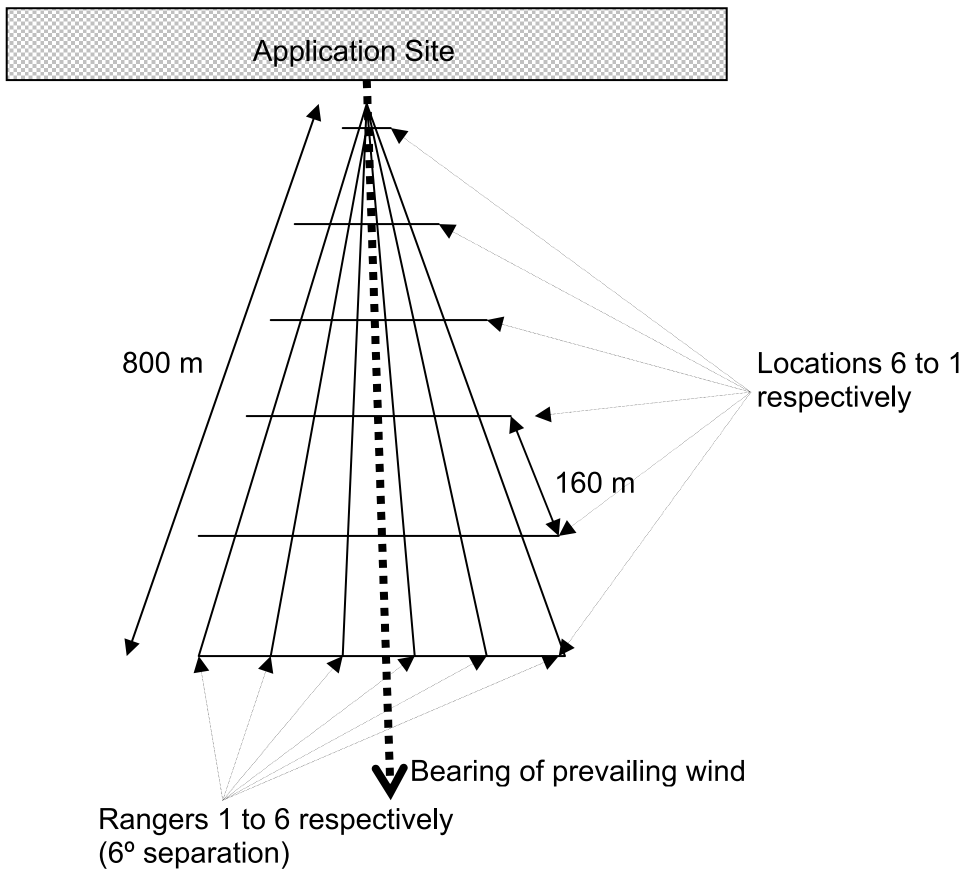

Figure 1. Schematic of assessor locations in the field.

Since measurement often began early in the morning (when manure spreading activities usually occur), the predominant wind direction had a tendency to shift during the 90 minute measurement period. In most cases, the wind shift was 45 degrees or less, in which case the team leader shifted his or her own position (aided by a GPS unit) based on the wind shift and the rest of the assessors shifted their own position based on that of the team leader. In one case, the wind shifted from N to E between the first and third locations. In this particular case, the assessors repositioned themselves for the fourth location along the new downwind direction. All shifts in position were recorded by the team leader. In some cases, the maximum distance downwind was minimized due to physical obstacles and barriers (trees, mature crops, etc.) The maximum distance downwind (and subsequent distances downwind) were measured and recorded in all cases.

Dilution to Threshold

Odour dilution to threshold readings were collected with the field olfactometer provided by St. Croix Sensory, Inc. Similar to odour concentration measured by olfactometry, the field olfactometer measured the number of fresh-air dilutions (60, 30, 15, 7, 4, 2) required so that the odour in the sample air becomes just detectable. Higher readings indicate a more odourous sample. In most cases, the dilution to threshold readings were obtained at locations 1 and 6 (800 m downwind and at the downwind edge of the site) immediately following odour intensity measurements by the assessors. In two cases, the dilution to threshold readings were collected at each of the six locations downwind of the application site.

The field olfactometer operators would first breathe through a blank cartridge on the unit at a normal breathing rate for about two minutes to 'clean' their nose. They would then turn the cartridge to the highest dilution setting (60) and sniff twice at the proper rate (between 16 and 20 litres per minute) indicated by the LED reading on the field olfactometer. If the odour was detected, the dilution the threshold reading was recorded and the operator rested for five minutes before taking another reading. If no odour was detected, the operator breathed through another blank cartridge for one minute at a normal breathing rate. They would then turn the cartridge to the next highest dilution setting (30) and sniff twice at the proper rate. This procedure was followed until the odour was detected. Three or four readings were taken at each location. If no odour was detected at the lowest setting (2), an odour dilution to threshold reading of 1 was recorded on the data sheet. To minimize the amount of time spent breathing through the unit, the operator began sniffing at lower dilution settings (15 or 30) when the dilution to threshold reading was expected to be low (i.e. at 800 m downwind and/or when the odour intensity was between 0 and 2).

Duration

Since odour duration is another important aspect of odour characterization, it was also measured by the odour assessors whenever possible. After the initial odour intensity measurements, one assessor remained at the application site and periodically measured the odour intensity 800 m downwind and at the edge of the application site. The assessor followed the same timing protocol as before. These measurements continued until the intensity at the edge of the application site was one or lower (as long as time permitted). If the odour intensity was still strong by the end of the day, the assessor returned to the site the next day to continue duration measurements. Additionally or alternatively, these duration measurements were also made using the field olfactometer whenever possible. The data collected to date do not include any odour duration measurements.

Results and Discussion

Liquid Injection Sites

The odour intensity surrounding liquid injection sites are presented in Tables 3 and 4. At site 1 (Table 3), liquid swine manure was injected using a drag line system. The earthen manure storage had been agitated for 20 hours prior to the start of data collection and approximately 80 acres had already been applied when data collection began and continued throughout. The barn and manure storages were approximately 300 m downwind of location 1 and, therefore, did not contribute to the odour perceived in the field. In this case, location 1 was only 360 m downwind of the edge of application site and location 6 was 180 m upwind of the edge of the application site (the final protocols and maximum distance downwind had not been established at the time these data were collected). Location 5 was located ten m upwind of a large puddle of liquid manure, possibly contributing to the higher intensity readings at that location. For tables 3-6, each entry in italics corresponds to the average of ten readings and the location values in brackets indicate the distance downwind from the edge of the application site.

Table 3. Odour intensity data for liquid injection (site 1). (Each entry in *italics* corresponds to the average of ten readings at the corresponding sampling point).

Position (° from downwind direction)	**Location 1 (360 m)**	**Location 2 (250 m)**	**Location 3 (140 m)**	**Location 4 (30 m)**	**Location 5 (-80 m)**	**Location 6 (-180 m)**
-9	*2.4*	*1.9*	*3.0*	*3.5*	*4.7*	*4.5*
-3	*0.8*	*0.5*	*1.2*	*1.5*	*3.3*	*3.0*
3	*1.0*	*1.3*	*1.6*	*2.3*	*3.9*	*3.3*
9	*1.2*	*1.5*	*2.7*	*3.7*	*4.6*	*4.5*
average	1.3	1.3	2.1	2.7	4.1	3.8
standard error (%)	54.7	45.8	40.0	37.5	16.1	20.3

Weather conditions: sunny and clear (solar radiation = slight), average wind speed = 1.4 m/s, temperature = 10.2°C, RH = 28.7% (Stability class B, moderately unstable).

The standard error of the intensity values indicates the high variability of the results. When the assessors were far from each other and from the odour source, the standard error of the intensity was high (40-55%) while the variability was much lower when the assessors were close to each other and the source and the intensity was relatively high (standard error = 16-20%). This indicates that there may be a significant difference in the odour intensity 360 m downwind among the positions (~80 m apart) or that it may be difficult to differentiate among the lower odour intensities. The higher intensities may be more distinct (and thus have a lower standard error) but the assessors were also positioned very close to each other during the high intensity readings. It is difficult to say whether the lower variability close to the source was due to the close proximity of the assessors or the high intensity of the measured odours.

The data in Table 3 is presented in graphical format in Figure 2. The two outer assessors recorded higher intensities than the two middle assessors, possibly indicating that the group was not positioned in the middle of the odour plume or the higher sensitivity of the two outer assessors resulted in inflated intensity readings.

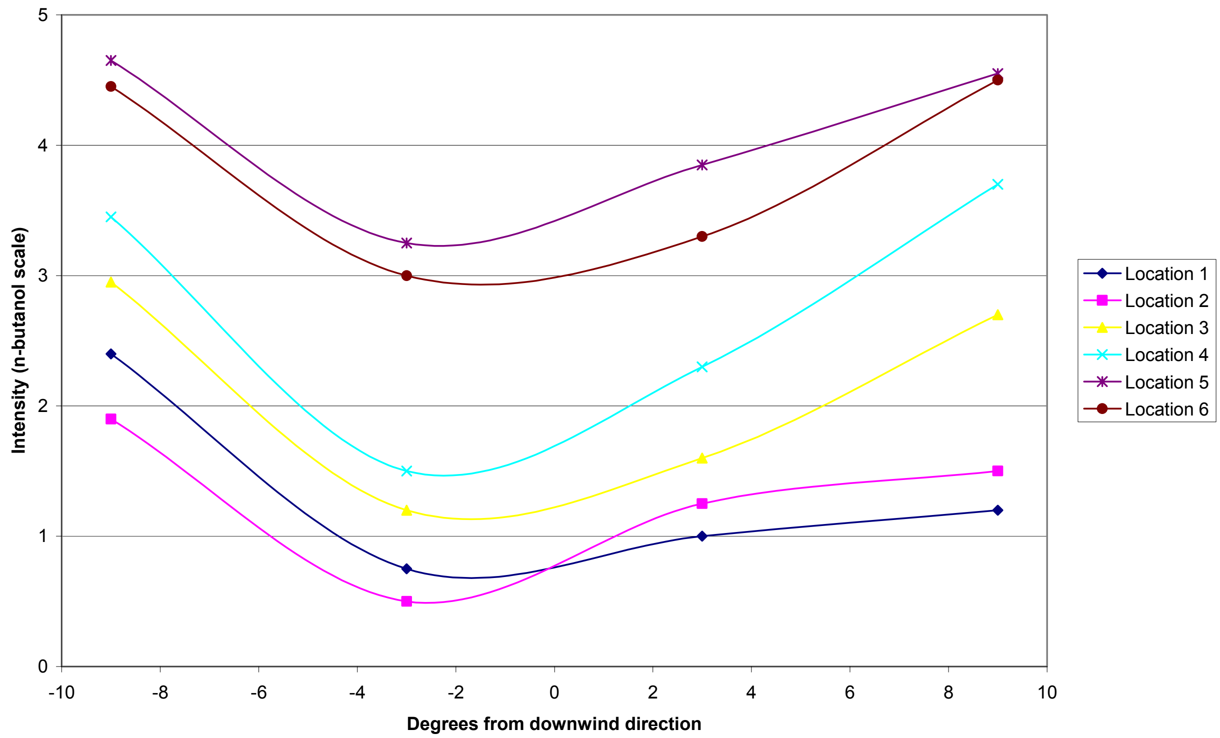

Figure 2. Odour intensity data for liquid injection site 1.

Table 4 summarizes the intensity results from another liquid injection drag-line site. In this case, location 1 was 800 m downwind of the edge of the application site and location 6 was at the edge of the application site. The barn and manure storages were approximately 1 km upwind of the application site and they may have contributed to the odour assessed in the field. Agitation of the manure storage had begun approximately 20 hours prior to data collection.

Table 4. Odour intensity data for liquid injection site 2. (Each entry in *italics* corresponds to the average of ten readings at the corresponding sampling point).

Position (° from downwind direction)	Location 1 (800 m)	Location 2 (640 m)	Location 3 (480 m)	Location 4 (320 m)	Location 5 (160 m)	Location 6 (0 m)
-12	*1.4*	*2.6*	*2.8*	*4.0*	*4.7*	*4.7*
-6	*1.8*	*2.2*	*2.8*	*4.1*	*4.5*	*4.9*
0	*1.3*	*1.7*	*2.0*	*3.1*	*3.6*	*4.7*
6	*1.4*	*1.6*	*2.4*	*3.5*	*4.5*	*5.0*
12	*2.0*	*2.3*	*2.8*	*3.8*	*4.4*	*5.0*
average	1.5	2.0	2.5	3.7	4.3	4.8
standard error (%)	15.0	22.9	15.3	12.6	11.4	3.1

Weather conditions: clear and calm (solar radiation = moderate), average wind speed 1.2 m/s (gusting to 4.3 m/s), temperature 25°C, relative humidity 34%. (Stability class A-B, very to moderately unstable).

In this case, even the lower intensities far from the source had a lower variability (standard error 15%) and the intensity increased predictably closer to the application site. However, the results from site 1 do not compare well with those from site 2. Even though liquid swine manure had been applied in the same manner and at approximately the same application rate at both sites under similar weather conditions, the average intensity 360 m downwind of site 1 was 1.3 whereas the average intensity 320 m downwind of site 2 was 3.7. The fact that the manure at site 2 had been stored in a concrete storage tank rather than an earthen manure storage basin may have contributed to the higher intensity of odours within 360 m of the application site.

Liquid Surface Application Sites

Because of the presence of a short-term manure storage facility at sites 3 and 4, the liquid splash-plate applications occurred on areas approximately 8 hectares in size. In both cases, manure application finished as the assessors were collecting data at location 4. At site 3, the assessors' positions were not corrected after an early wind shift so the data collected represent only one side of the odour plume. The assessor on the far right was at approximately the centre of the plume. In addition, an elevated (~1.5 m) road served as a barrier between the application site and the assessors. The barn and manure storages were approximately 1 km upwind of the edge of the application site and may have contributed to the odour observed in the field.

Table 5. Odour intensity data for liquid surface application site 3. (Each entry in *italics* corresponds to the average of ten readings at the corresponding sampling point).

Position (° from downwind direction)	**Location 1 (600 m)**	**Location 2 (480 m)**	**Location 3 (360 m)**	**Location 4 (240 m)**	**Location 5 (120 m)**	**Location 6 (0 m)**
-30	*1.0*	*1.0*	*1.0*	*1.1*	*1.1*	*2.0*
-24	*1.0*	*1.0*	*1.0*	*1.4*	*2.2*	*1.9*
-18	*1.0*	*1.1*	*1.6*	*2.5*	*2.4*	*2.2*
-12	*1.9*	*1.2*	*2.3*	*3.5*	*3.7*	*3.3*
-6	*2.8*	*1.4*	*1.7*	*3.0*	*2.6*	*1.4*
0	*3.0*	*2.8*	*2.6*	*3.2*	*3.8*	*2.7*
average	1.2	1.1	1.5	2.1	2.4	2.4
standard error (%)	36.7	8.9	41.9	51.6	45.4	27.5

Weather conditions: partly to mostly cloudy (solar radiation = slight), temperature 22°C, 39% RH, wind speed average 3 m/s, gusting to 6 m/s. (Stability class C, slightly unstable).

Table 6. Odour intensity and offensiveness data for liquid surface application site 4. (Each entry in *italics* corresponds to the average of ten readings at the corresponding sampling point).The offensiveness values are the average of the 5 assessors at each location.

Position (° from downwind direction)	**Location 1 (460 m)**	**Location 2 (370 m)**	**Location 3 (280 m)**	**Location 4 (190 m)**	**Location 5 (100 m)**	**Location 6 (0 m)**
-12	*0.5*	*0.9*	*0.7*	*0.7*	*3.0*	*3.9*
-6	*1.8*	*1.7*	*1.1*	*0.2*	*1.1*	*3.0*
0	*1.6*	*1.6*	*2.0*	*1.5*	*1.2*	*3.7*
6	*0.1*	*0.8*	*1.3*	*0.5*	*2.2*	*4.9*
12	*0.1*	*0.2*	*0*	*0.4*	*1.3*	*4.5*
average	1.0	0.5	1.3	0.7	1.5	4.0
standard error (%)	82.9	37.2	42.7	76.7	34.9	21.0
offensiveness	4.6	4.2	4.4	4.8	4.6	2.4

Weather conditions: partly cloudy (solar radiation = moderate), wind speed = 1 - 2 m/s, temperature = 20°C, 70% RH (Stability class A-B, very to moderately unstable).

At site 4, the maximum distance downwind of the application site was limited due to physical barriers (trees, mature canola crop). The barn and manure storages were downwind of the assessors at all times and did not contribute to the odour perceived in the field. A significant shift in the wind direction between locations 3 and 4 was corrected by a shift in the assessor's positions. The odour offensiveness was also recorded at this particular site.

The results from sites 3 and 4 compare reasonably well with each other in that the odour intensity at distances greater than 100 m from the application site was low (less than 2.4 at site 3 and less than 1.5 at site 4). However, site 4 recorded a sharp increase in intensity at the edge of the application site that was not observed at site 3. The elevated barrier at site 3 may have contributed to the low intensity recorded at the edge of the application site.

The offensiveness ratings at site 4 appear to be correlated with the intensity values. Low odour intensity values correspond with the neutral or dislike slightly offensiveness ratings. The intensity 4 readings had an offensiveness of 2.4 (dislike very much to dislike moderately).

Field Olfactometer Results

The odour dilution to threshold results obtained with the field olfactometer for the manure application sites are presented in Table 7. Whenever possible, the odour intensity as observed by the trained odour assessors at that location is also listed (values in brackets indicate the standard deviation of the intensity). At site 2, the field olfactometer operator was located in the center of the plume and at site 3, the operator was approximately -18° from the centre of the plume.

Table 7. Odour dilution to threshold (D/T) results.

Site	Date	Treatment	Location	D/T	Manure Info	Intensity
Dixon	Oct 5/05	Liquid injection	Upwind edge	1 (4 readings)	farrow to finish	
			Downwind edge	4 (4 readings)	1 year EMB	
			500 m downwind	1 (4 readings)	tanker truck injection	
Elstow	Oct 22/05	Liquid injection	Downwind edge	15 (4 readings)	farrow to finish	4.08 (0.66)
(site 1)					1 year EMB	
					drag line injection	
St. Denis	May 9/06	Liquid injection, 6 hrs after	Downwind edge	7 (2 readings)	farrow to finish	2.7 (0.48)
					1 year EMB	
					drag line injection (9,000 gal/acre)	
Floral	May 18/06	Liquid injection	800 m downwind	1 (3 readings)	farrow to finish	1.48 (0.22)
(site 2)			640 m	4 (3 readings)	1 year concrete tanks	2.03 (0.46)
			480 m	4 (3 readings)		2.50 (0.38)
			320 m	15, 1, 15, 7	drag line injection (6,000 gal/acre)	3.68 (0.46)
			160 m	15, 15, 15, 7		4.33 (0.49)
			Downwind edge	30 (3 readings)		4.83 (0.15)
Germs	June 2/06	Liquid surface	600 m downwind	1 (3 readings)	grow-finish	1.23 (0.45)
(site 3)			480 m	1 (3 readings)	1 week concrete tank	1.08 (0.10)
			360 m	1 (3 readings)		1.48 (0.62)
			240 m	15, 7, 1, 15, 4, 4	splash plate application	2.13 (1.10)
			120 m	1, 1, 4, 4, 4		2.35 (1.07)
			Downwind edge	15 (3 readings)		2.35 (0.65)
Germs	July 14/06	Liquid surface	165 m downwind	1 (3 readings)	see above	1.45 (0.51)
(site 4)			Downwind edge	60 (3 readings)		4.03 (0.85)

In general, the odour dilution to threshold results agree reasonably well with the odour intensity values. The downwind edge location resulted in higher D/T readings (between 15 and 60) and the D/T values decreased to 1 as the distance from the source increased. One problem with the field olfactometer is that the short sampling period (two 'sniff's every minute or so) may miss any spikes in odour that may occur as the odour plume wafts over the assessor. Increasing the number of readings taken at each location could help account for this. As shown in the results of Table 7, the D/T values at a given location can vary between 1 and 15. The appropriate presentation of this data can be a challenge since only averaging the values does not accurately represent the odour concentration. Listing all the D/T values recorded at each location shows the range and frequency of D/T values encountered, which more accurately represents the odour at that location. Past studies have used only the highest odour dilution to threshold value when analyzing the data obtained with the field olfactometer (Hamel et al. 2004).

Challenges and Potential Changes to the Protocol

As expected, the odour intensity increased with decreasing distance between the assessors and the application site due to the dissipation of odours in the downwind direction. However, it is possible that passing time and changing wind speeds and direction can also affect the intensity at various locations. The strength of the odour from the source can vary with time, particularly with land application, which will cause fluctuations in the downwind odour intensity with time. Therefore, the grid formation for odour assessors described in Zhou et al. (2005) would be better suited to measure the odour intensity at all downwind locations at the same time. Although the number of assessors required for the grid formation can be prohibitive, the data obtained with this method may be more useful in generating odour dispersion maps.

Current protocols for odour assessors are aimed at measuring the odour intensity downwind of buildings and manure storages. Compared to the large, surface area of emissions from manure application, buildings and storages can be considered point sources. Therefore, it may be reasonable to maintain up to 50 m of space between assessors for all locations, including the downwind edge of the application site since the base of the odour plume may be as wide as the application area. This will provide additional information on the variability of the strength of the odour source which will be essential in predicting downwind odour intensities.

Another change in protocol for this study will involve reducing the amount sniffing time from 20 seconds to ten seconds. Since the human olfactory sense is quickly saturated, particularly in intense odours, the highest intensity was generally observed during the first ten seconds of sniffing. Reducing the sniffing time will allow for longer rests between sniffs or allow for more measurements at each location.

Ideally, the odour concentration data should be collected from the full-scale field applications at the same time the trained odour assessors are gathering odour intensity data to assist in the assessment and application of odour dispersion models. However, it is very difficult to coordinate the efforts of the field odour assessors with that of a laboratory odour panel at an olfactometry laboratory, and with that of each individual farmer's or manure applicator's agenda along with the weather. Also, since intensity data collection is dependent on the volunteer participation of the producers and manure applicators, the research team has little control over variables such as manure species or application rates or patterns.

Odour intensity and dispersion measurements are further complicated by changing wind speed and direction, the large, variable odour source, timing and logistics, barn and manure storage effects on odour and the high degree of variability in odour intensity measurements from trained odour assessors. In order to draw valuable conclusions related to the emissions from manure application, every attempt should be made to address and/or minimize these factors.

Summary

Based on the experience gained from this study, trained odour assessors and the field olfactometer appear to be well suited to obtain odour intensity and dispersion measurements downwind of manure application sites. In order to obtain useful data, protocols must be well established and rigorously followed during odour intensity measurements. Future work in this area will be to establish information for a database that can predict odour intensities up to 800 m downwind of manure application sites based on type of manure, application method, application rate and weather stability. Also, by gathering data on the odour emissions from land application of manure, researchers and regulators will be able to more accurately establish the total odour contribution from livestock facilities including the three main sources: buildings, manure storages, and manure application.

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