Odour Emissions From Confined Swine Production Facilities

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Summary

Odour from livestock operations contains many odorous compounds resulting mainly from anaerobic decomposition of manure. The formation and characterization of livestock odours are briefly discussed in this presentation. Commonly used methods of odour measurement are reviewed. Odour levels measured on 10 swine farms in Manitoba are presented and discussed. Some odour control strategies are briefly discussed.

Odour formation and description

Livestock manure contains organic matter and nutrients that are readily utilized by naturally existing microorganisms as energy sources. Microbial decomposition of livestock manure produces various gases and volatile compounds. These gases and compounds may be odorous if the decomposition occurs anaerobically. On the other hand, aerobic decomposition of manure produces mainly carbon dioxide, water, and small amounts of ammonia.

Organic matter in livestock manure mainly consists of protein, carbohydrates and fat. Anaerobic decomposition of protein results in ammonia and volatile organic acids (Powers-Schilling, 1995). Sulfur-containing amino acids are further broken down to sulfides and mercaptans, which are offensive to humans. Carbohydrates are catabolized to alcohols, aldehydes, ketones, and organic acids. Breakdown of fats produces fatty acids, alcohols, and acetate. Nearly 200 compounds have been identified in livestock odours (O'Neil and Philips, 1992). The most frequently reported odorous compounds are 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. These individual odorous compounds are commonly referred as odorants. Odour is the sensation that occurs when a complex mixture of odorants stimulate receptors in the nasal cavity (Schiffman et al., 2000). In other words, odour is a complex physiological variable, not a simple physical or chemical variable. There is no particular consensus as to what compounds contribute in what fashion to the overall odour sensations because these compounds are interactive. High concentrations of odorous compounds can cause irritation or other toxicological effects to humans. However, the concentrations of these compounds in the odorous air from livestock operations are generally below levels that are considered to be acutely toxic to humans. At these concentrations, odour compounds cause unpleasant odours, not irritation.

The parameters that are frequently used to describe odours include the odour concentration (detectability), intensity, quality (character), and hedonic tone. In North America the odour concentration is determined as the number of dilutions to bring the odour to the level that can be detected by 50% of a population. The concentration is often expressed as D/T (dilution to detection) or OU (Odor Unit). These two notations of odour concentration have caused much confusion in the research community because their format is different from the traditional ways of describing concentrations, i.e., mass per volume (kg/m^3) or volume per volume (ppm). In the European Standard (prEn 13725, Draft), the odour concentration is defined as the number of European Odour Units (OU_E) in one cubic meter of gas at standard conditions (CEN, 1999). This allows the odour concentration to be expressed as OU_E/m^3, which is similar to the traditional format of mass per unit volume. Here, the European Odour Unit (OU_E) acts an “equivalent” odorant mass. By definition, 1 OU_E is the amount of odorant(s) that, when evaporated in to 1 m^3 of neutral gas at standard conditions, elicits a physiological response from a human panel equivalent to that elicited by 123 μg of n-butanol evaporated in 1 m^3 gas at standard conditions.

The odor intensity is the perceived strength of odour sensations. The dour intensity increases with odour concentration and the relationship can be described by the power (Stevens) law:

$$I = kC^n \quad (1)$$

where:

I = odour intensity
C = odour concentration
k = constant
n = Stevens exponent

Equation 1 indicates that the odour intensity decreases as the odour is diluted. The rate of decrease is not the same for all odours. This rate of change is termed the persistency of the odour (St. Croix Sensory, www.fivesenses.com). When equation 1 is plotted in a log scale, the slope illustrates the persistency (fig. 1). The lower the rate of decrease, the more “persistent” the odour; and the more persistent the odour, the longer it “hangs” in the air. This means that a more persistent odour would have a greater downwind impact (fig. 1).

The odour intensity may be “quantified” by using referencing scales (eg., ASTM E544-99). This is accomplished by comparing the field odour to the odour intensity of a series of concentrations of the reference odorant (n-butanol).

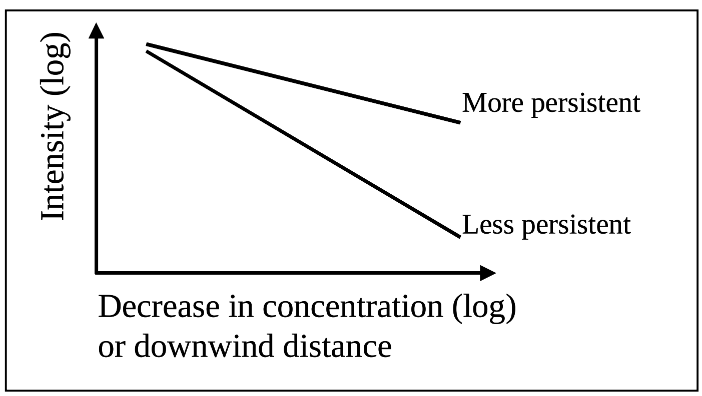

Figure 1 – Variation of odour intensity with concentration

The odour quality (character) is described by “descriptors,” i.e., what the odour smells like. Numerous standard odour descriptor lists are available to use as a referencing vocabulary (St. Croix Sensory, www.fivesenses.com).

Hedonic tone is a subjective judgment of the relative pleasantness or unpleasantness of the odour. The hedonic tone is independent of the odour quality, and both the hedonic tone and odour quality influence the odour intensity. An arbitrary but common scale for ranking odours by hedonic tone is the use of a 20-point scale (St. Croix Sensory, www.fivesenses.com):

+10	Pleasant
0	Neutral
-10	Unpleasant

Methods for odour measurement

While ***odorants*** can be measured by analytical methods (eg., instrument and wet chemistry), the most reliable means of measuring ***odour*** is using human sensory panels. Analytical methods are based on the measurements of individual chemical compounds. Commonly used techniques include gas chromatography (GC), mass spectrometry (MS), and colorimetric detector tubes. Since livestock odour relates to the physiological responses of humans to a mixture of odorants, individual odorants may not be indicators of odour sensations. Sensory evaluations using the human nose are currently considered to the most valid procedure for odour measurement. Two commonly used types of instrument for olfactometric measurement of odour are the dynamic-dilution olfactometer and the scentometer. The working principles of both types of instrument are similar: the odorous air is diluted with fresh air to the detection threshold and the number of dilutions is recorded. A scentometer is a hand-held device suitable for on-site measurement of odour. The odorous air is diluted with filtered air (charcoal filter) and delivered to the sniffer's nose. The dilution level is controlled by changing the sizes of a hole, through which odorous air flows to the sniffer. Scentometers have limited levels of dilution and usually one sniffer operates the instrument. They are, therefore, less accurate than dynamic-dilution olfactometers.

An olfactometer is a dilution apparatus which mixes odorous air in specific ratios with odour-free air for the presentation to a panel of human assessors (fig. 2). In operating a typical dynamic-dilution olfactometer (eg., AC'SCENT Olfactometer of St. Croix Sensory, Stillwater, MN), trained odour assessors sniff the diluted odour sample as it is discharged from one of three sniffing ports and must select one of the three different from the other two. Each assessor declares to the operator (panel leader) if the selection was a "guess," or "detection" (or "recognition" if recognition threshold is to be measured). The assessor then sniffs the next set of three sniffing ports, one of which also contains the diluted odor sample. However, this next set presents the odour at a higher concentration. The assessor continues to additional sets of three sniffing ports until he/she correctly detects the odour at two consecutive dilution levels. For each assessor, the individual BET (Best Estimated Threshold) is determined from the dilution ratio at which he/she has first detected the odour (the first of the two consecutive correct detections) and the D/T is then determined from BETs of the panel.

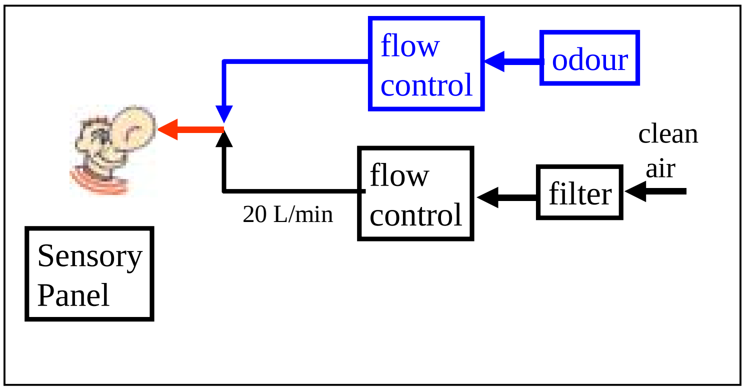

Figure 2 – Working principle of olfactometer

The electronic nose (sensors) has drawn considerable attention recently for livestock odour measurement. An electronic nose contains an array of sensors (eg., conducting polymers) that respond to the various chemical compounds contained in the odorous air. The accompanying software examines changing patterns of the responses to "recognize" odorants. The electronic nose holds promise for simulating human responses to odour as the technology improves (Shiffman et al., 2000).

Measured odour emissions from swine operations in Manitoba

Odour emissions from livestock operations are affected by many factors. Our ability to make informed decisions regarding odour is currently hampered by the lack of knowledge of the relationship between odour emissions and these influencing factors. A study was conducted in Manitoba to measure odour emissions from various types and sizes of swine operations and to examine the correlations between the measured odour levels and the general characteristics of swine operations.

Odour emissions were measured on 10 swine farms in Manitoba in 1999 and 2000. Five of the 10 farms were farrow-to-finish operations (size ranging from 130 to 800 sows), two nursery operations (5,000 and 10,000 hogs), two farrow-nursery operations (2,500 and 3,000 sows), and one grow/finish operation (4,000 hogs). Seven of the 10 operations included in this study were less than five years old, and the other three were 10, 35 and 40 years old, respectively. On each selected farm, odour samples were taken from (i) barn exhaust, (ii) manure storage, and (iii) downwind (50 m to 3.5 km). A flux hood was used to collect odour samples from land application of manure on three farms. Odour levels (concentrations) of collected samples were determined by using a dynamic-dilution olfactometer (AC'SCENT, St. Croix Sensory, Inc., Stillwater, MN) with six screened human assessors. A Jerome meter (JEROME 631- X, Arizona Instrument Corporation, Phoenix, AZ) was used to measure hydrogen sulfide (H_2S) levels of odour samples taken from six farms in 2000.

Measured farm-average odour levels from barn exhaust ranged from 131 to 1842 OU on 10 farms. The farms could be divided into three groups according to their odour levels: four in a low odour level group (131 to 252 OU), four in a medium level group (641 to 750 OU), and two in a high level group (1765 to 1842 OU). No apparent correlations were found between the odour level and the general farm characteristics, such as the age and type of operation, ventilation system, and manure handling system.

The amount of odour emitted from facilities was quantified by the odour emission rate, which was calculated as the product of the odour concentration and the airflow (ventilation) rate. Both odour and H_2S emission rates were determined for six farms. Farm-average odour emission rates ranged from 12 to 39 $OU*m^3/s.m^2$, and the H_2S emission rates from 6 to 25 $\mu g/s.m^2$.

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

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

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

Injection of manure into soil caused little odour emission from soil. The emission rate measured from the soil with no manure applied was almost the same as that from the manured soil (3.6 vs. 4.0 OU*m^3/s.m^2). Downwind air samples collected at the ends (or sides) of the fields on which manure was being applied showed very low odour levels (average odour and H_2S levels were 60 OU and 4 ppb, respectively).

Odour control strategies

Odour problems are results of a three-step process: (1) formation of odorous compounds, (2) release of the compounds into the air, and (3) transport (dispersion) of odorous gases in the atmosphere from the source to the receptor (residences) (fig. 3). Therefore, odour control should be focused on the three critical control points: CP1 – control of odour formation; CP2 - control of odour release to the air; and CP3 – manipulation of dispersion.

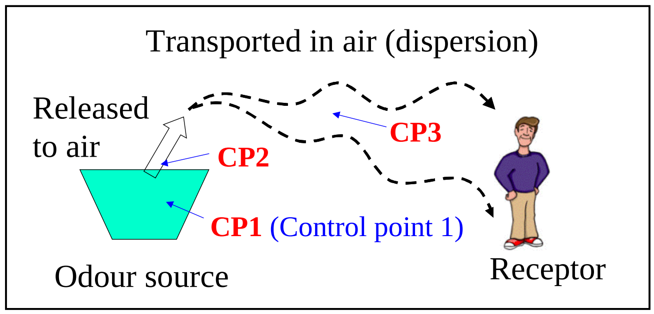

Figure 3 – Odour formation, release and transport

<u>Control of odour formation (CP1)</u>
Typical odour sources in livestock operations are: buildings (barns), manure storage, feedlots, land application, and mortality disposal. Following are some strategies for minimizing odour formation:

- Good housekeeping
  - ✓ Keep floors clean and dry
  - ✓ Keep manure and feed dry
  - ✓ Keep animals clean
  - ✓ Prevent water leakage and feed spillage
  - ✓ Frequent flush/wash/scrape
  - ✓ Maintain adequate environment for animals
  - ✓ Minimize dust
  - ✓ Keep manure pits recharged properly (2-3 in. of water in shallow pits)
- Using pit additives (more research is needed)
  - ✓ Masking agents
  - ✓ Counteractants
  - ✓ Digestive deodorants
  - ✓ Absorbents
  - ✓ Oxidants

- Using feed additives (more research is needed)
  - ✓ Reducing excretion of odour producing compounds
- Treating manure, eg., aeration, solid separation, changing pH
- Alternative housing, eg., dry-pit system

Control of odour release (CP2)

- Covering manure storage
  - ✓ Concrete or steel tanks (reducing odour by 95%-98%)
  - ✓ Straw cover (reducing odour by 70%-75% if used properly)
  - ✓ Plastic cover (eg., negative air pressure system)
  - ✓ Manure crust
- Reducing surface area of manure storage
- Surface aeration
- Manure injection
- Biofiltration

Odour control and dispersion (CP3)

Odour is diluted by dispersion as it is transported in the atmosphere. The further it travels, the more it is diluted. Therefore, adequate setback distances are a key in preventing odour complaints. The important factors that influence odour dispersion are wind, atmospheric stability, and topography. Odour is carried by wind from the source to the receptor. Therefore, the prevailing wind direction should be considered when choosing sites for livestock facilities. The wind direction should be checked before agitating and spreading manure to avoid odour being carried to neighboring residences by the wind.

The atmospheric stability is commonly described by the Pasquill stability classes: A - strongly unstable; B - moderately unstable, C - slightly unstable; E - slightly stable, F - moderately stable, and D - neutral (overcast). Odour is diluted quickly when the atmosphere is unstable. Therefore, it is a good practice to spread manure when the atmosphere is unstable so that odour is diluted to an acceptable level before it reaches the receptor (residences).

Table 1. Pasquill stability classes (Wark et al., 1998)

Surface wind speed, m/s (at10 m)	Day Solar radiation, W/m^2			Night	
	Strong	Moderate	Slight	Thinly overcast	Clear
	>600	300-600	<300	>4/8 clouds	<3/8
0-2	A	A-B	B	-	-
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

If possible, livestock facilities should be built on relatively flat topography for good dispersion. It should be avoided to build facilities near hills to prevent the effect of aerodynamic downwash. Windbreaks (walls, trees and shrubs) may be used to trap odour and dust, and to create more air turbulences for stronger dispersion.

The dispersion theories (eg., Gaussian dispersion model) indicate that increasing the odour release height reduces odour intensity at the ground level. Exhaust stacks (chimneys) may be used to raise the release points of the ventilation air, thus to reduce odour complaints originated from animal buildings.

References

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