Odour emission rates from manure treatment/storage systems

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Abstract The effects of agitation, liquid-only manure, depth and time on odour emission rates were investigated. Manure storage tanks were filled to incremental depths every two weeks. At each depth odour samples were collected twice. The second sample was collected seven days after the first. Odour concentration was measured with an olfactometer. Three different pig-manure treatments were investigated. In one treatment, slurry manure in a storage tank was agitated before and during odour sampling. In a second treatment, the settlable solids in manure were removed gravimetrically over 24 hours and liquid manure was pumped to a storage tank. In the third treatment (control), odour samples were collected from unseparated and undisturbed slurry manure. Overall, the odour emission rates in the agitated manure treatment ranged between 0.39 and 1.02 ou s–1 m–2, increased with depth and decreased with time, i.e. after seven days at each depth. In the liquid-only manure treatment, the emission rates ranged between 0.09 and 0.69 ou s–1 m–2, increased with depth but the effect of time was not evident. In the control treatment, the emission rates ranged between 0.20 and 0.66 ou s–1 m–2 and increased with depth on the first odour sampling day but decreased with depth on the second sampling day.

Keywords Agitation; liquid-only manure; manure storage; odour emission rate; olfactometry; pig manure

Introduction Livestock production in North America, Europe and Australia is on the rise following increases in demand for various livestock commodities. As a result, the quantity of manure produced by the animals has increased and triggered concerns for environmental sustainability in relation to air, surface and ground water and land pollution.

Complaints about the nuisance caused by odours from livestock farms have led to the need for alternative manure management and odour control strategies (Jacobson et al., 1999b). At the same time, legislation seeks the development of scientifically based guideline to govern the siting, expansion and operation of livestock farms (MacMillan, 1999b). In Alberta, Canada, one such guidelines establishes a minimum distance of separation between livestock farms and neighbouring residences tagged as odour receptors (MacMillan, 1999a).

Unfortunately, standard methods for scientifically evaluating the effectiveness of various odour control and reduction strategies used by the livestock industry are lacking (Jacobson et al., 1999b; Pain et al., 1991). In one case, the development of such methods will facilitate the determination of actual odour emission rates from various sources on livestock farms (Jacobson et al., 1999b; Smith and Watts, 1994). These data would be useful for validating odour dispersion models (Smith and Watts, 1994), verifying the appropriateness of minimum distances of separation and development of extension material.

Background Odour emission rates from feedlots, manure storages and manure spread on land may be determined by direct or indirect methods (Smith and Watts, 1994; Schmidt et al., 1999).
Direct methods of determining odour emission rates comprise of collecting odour samples at the point of emission (odour sampling) and measuring odour concentration. During odour sampling, a vented-hood or wind tunnel is used to define an enclosed space above manure of known surface area. Odour samples are collected from the enclosure and the concentration is measured by olfactometry (Pain et al., 1991; Smith and Watts, 1994).

Indirect methods of determining odour emission rates include, mass balance, energy balance, theoretical profile shape, and Gaussian plume methods. These methods do not measure the emissions directly at the source but at a set distance from the source, taking into consideration the effects of various meteorological influences, e.g. wind speed, on odour emission rates (Smith and Watts, 1994).

**Objectives**
The objective of this study was to investigate the vented-hood technique as a direct method of determining odour emission rates from pig manure in storage tanks.

**Methodology**
This study was conducted at the Swine Research Centre, Edmonton Research Station, University of Alberta, Edmonton, Alberta, over a two year period.

**Manure collection**
Every week pig manure from two partially slatted floor grower/finisher barns was added to a collection pit located in one of the barns. The manure, with a settleable solid content of about 3%, was constantly mixed with a recirculation pump to keep the solids in suspension. Every two weeks the required volume of manure was pumped from the pit to the storage tanks and discharged below the surface of the manure. The pigs were fed a commercially-available grower diet.

**Autumn.** Three steel storage tanks measuring 3.1 m in diameter × 3.1 m deep were set in the ground at the research centre to simulate manure storages. Two of the tanks were used in this study.

A vented-hood was constructed from a 20.8 × R34 radial tractor tube for each storage. One side of the inflated tube was boarded with 12.5 mm plywood (Figure 1). Each hood enclosed a volume of 0.27 m³ and spanned a manure surface area of 0.78 m². A 12.5 mm plastic tube was used to channel filtered air from an air compressor into the space enclosed by the hood.

**Figure 1** A vented odour hood floating on pig manure in a storage tank
Odour samples were collected from the enclosed space via a 12.5 mm Teflon tube extending from the hood. A pressure relief valve mounted on the hood was used to prevent pressure build-up within the enclosed space. A commercially available rotameter was used to control airflow through the hood at a rate of 1 L s⁻¹.

Odour samples were collected using a “sampling lung”. The sampling lung was constructed from a plastic container, 0.4 m in diameter × 0.5 m high. A battery-operated vacuum pump was mounted on the lid of the sampling lung to create a vacuum and enable odourous air to flow from the space enclosed by the hood, through the Teflon tube into 10 L Tedlar bags (232-08, SKC, Eighty Four, PA, USA). Odour concentration of the samples was measured with the UA olfactometer developed at the University of Alberta (Figure 2).

The effects of agitation, manure depth and time on odour emission rate were explored. Every two weeks manure from the collection pit was added to each tank in incremental depths of 0.9 m and up to a maximum depth of 1.8 m. At each depth, odour sampling was conducted twice on separate days. A first sample was collected 24 hour after each tank had been filled to the desired depth. The second sample was collected seven days after the first. Two bags of odour were collected per sample.

On each odour sampling day, manure in one of the tanks was agitated continuously with a sludge pump for 30 minutes before sampling and during the sampling period. The manure was recirculated at a rate of 27 L s⁻¹ with the discharge point about 0.3 m above the manure surface to simulate surface loading of a manure storage. Manure in the second tank was used in the control treatment and was left undisturbed.

Filtered air was pumped at a flow rate of about 1 L s⁻¹ for 30 minutes through the headspace created by the vented-hood floating on the manure surface. Odour samples were collected at the end of 30 minutes without disrupting the airflow through the vented-hood airspace. Odour concentration of each sample was measured in duplicate with the UA olfactometer within 4 hours of sampling.

Odour emission rates, $E_{cf}$ (ou s⁻¹ m⁻²), from the manure in the two treatments were determined by the following (Smith and Watts, 1994):

$$E_{cf} = \frac{C_o Q}{A_h}$$

where $C_o$ (ou m⁻³) is the concentration of the odour samples; $Q$ (m³ s⁻¹), is the flowrate of the flushing air and $A_h$ (m²), is the cross-sectional area of the surface enclosed by the hood.

Figure 2  University of Alberta 8-station olfactometer being used to measure odour concentration
Note that Smith and Watts (1994) expressed the odour units as “OU m s⁻¹” because the odour concentration was expressed only as “OU” and not “OU m⁻³” (CEN, 1998).

Summer 2000. Again, the effects of agitation, manure depth and time on odour emission rate were explored. In the third tank, the effect of liquid manure, i.e. manure with little or no settleable solids, on odour emission rate was studied. Approximately 0.6 m of manure was added to each tank every two weeks to a maximum depth of 2.4 m. At each depth, odour sampling was conducted twice on separate days. The second sample was collected seven days after the first. Two bags of odour were collected per sample.

Three replicated treatments were conducted. The first treatment was a control in which slurry manure in one of the storage tanks was not agitated during odour sampling. The first odour sample was collected 48 hours after the tank had been filled to the desired depth.

In the second treatment, recirculation in the collection pit was stopped and solids in the manure were removed gravimetrically over a 24 hour settling period. Liquid manure was pumped to a second storage tank from a depth of 0.9 m beneath the surface of the manure in the pit. The liquid manure was not agitated during odour sampling. The first odour sample was collected 24 hour after the tank had been filled to the desired depth.

In the third treatment, slurry manure in a storage tank was agitated continuously for 30 minutes with a sludge pump (18T 2003, Midland, Connecticut, MO, USA) before and during odour sampling. The manure was recirculated at a rate of 27 L s⁻¹ (421 gpm) with the discharge point about 0.3 m above the manure surface to simulate surface loading of a manure storage. The first odour sample was collected 48 hours after each tank had been filled to the desired depth.

Three odour “sampling lungs” were used to collect samples simultaneously from the three manure storage tanks. Odour concentration of each sample was measured in triplicate with the UA olfactometer within 4 hours of sampling.

Results

Autumn 1999. The effects of agitation, manure depth and age on odour emission rates are presented in Table 1. This was an explorative study and, as such, no statistical analysis was performed on the data. Changes in odour emission rates in the control and agitated manure treatments at the manure depth of 1.8 m, followed a similar pattern to the rates obtained when the manure depth in the tanks was 0.9 m on both odour sampling days, i.e. day 0 and day 7. At both depths, the odour emission rates in the control treatment increased with time (after 7 days).

A comparison between the odour emission rate under the agitated and control treatments shows that the emission rates were greater in the former at both depths. A week later, the rates were in the same range as the control.

Table 1 Odour emission rates from swine manure storages under different treatments in Autumn 1999

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Time (day)</th>
<th>Control (OU s⁻¹ m⁻²)</th>
<th>Agitation (OU s⁻¹ m⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9</td>
<td>0</td>
<td>0.26</td>
<td>0.74</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>0.63</td>
<td>0.55</td>
</tr>
<tr>
<td>1.8</td>
<td>0</td>
<td>0.49</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>0.66</td>
<td>0.75</td>
</tr>
<tr>
<td>Mean*</td>
<td></td>
<td>0.48</td>
<td>0.70</td>
</tr>
</tbody>
</table>

*Geometric mean of odour emission rates
The results appear to suggest that manure agitation increases odour emission rate probably by fostering the release of odourous gases trapped in the manure. The results also appear to indicate that when the volume of manure is low the emission rate in agitated manure drops with time but does not change at the higher volumes. In the former, the decrease in emission rate in time may have occurred following a rapid breakdown of biodegradable material after the first sampling day. Probably, agitation enhances the bio-degradation rate in manure by exposing an increased volume of material to atmospheric oxygen. On the other hand, at the higher manure volume no changes in emission rate may have occurred in the seven days between sampling because of the presence of a larger quantity of biodegradable material.

Jacobson et al. (1999a) published odour emission rates obtained from swine manure stored in tanks set in the ground. A 290 head gestation and farrowing unit produced odour emission rates of 12.8 OU s⁻¹ m⁻² while a 160 head gestation, farrowing and nursery unit produced odour emission rates of 51.3 OU s⁻¹ m⁻². These emission rates vary significantly from the rates presented in Table 1 and may be attributed to several factors including, depth, age, physiochemical properties of the manure, odour sampling method, airflow rates, olfactometer measurements, etc. Thus, it is not only pertinent for standard odour sampling methods to be developed but, odour emission rates from livestock sources should be reported along with details describing the state of the manure at the time of sampling and conditions under which the sampling and measurement were conducted.

Summer 2000. The effects of agitation, the liquid-only manure, depth and time on odour emission rates are presented in Table 2. This was an explorative study and, as such no statistical analysis was performed on these data.

Similar to the results obtained in Autumn 1999, Table 2 shows that the odour emission rates at all four depths were higher in the agitated manure treatment (0.66 OU s⁻¹ m⁻²) compared with the control (0.30 OU s⁻¹ m⁻²). Furthermore, in the former, the emission rates increased with depth but decreased with time.

Probably, the increases in emission rates with depth are proportional to increases in the volume of bio-material available for degradation. On the other hand, the decreases in emission rates with time may relate to an increase in the bio-degradation rate after agitation on day 0 of odour sampling. Thus, by day 7 the volume of bio-material available for breakdown in the manure may have decreased, resulting in the production of a smaller volume of odourous gases.

In the liquid-only manure treatment, the odour emission rate on day 0 of odour sampling increased with depth, except at a depth of 2.4 m. There does not appear to be any apparent

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Time (day)</th>
<th>Control</th>
<th>Agitation</th>
<th>Liquid fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6</td>
<td>0</td>
<td>0.20</td>
<td>0.54</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>0.35</td>
<td>0.39</td>
<td>0.13</td>
</tr>
<tr>
<td>1.2</td>
<td>0</td>
<td>0.30</td>
<td>0.69</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>0.32</td>
<td>0.59</td>
<td>0.36</td>
</tr>
<tr>
<td>1.8</td>
<td>0</td>
<td>0.31</td>
<td>0.85</td>
<td>0.69</td>
</tr>
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<td></td>
<td>7</td>
<td>0.29</td>
<td>0.62</td>
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</tr>
<tr>
<td>2.4</td>
<td>0</td>
<td>0.47</td>
<td>1.02</td>
<td>0.40</td>
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<td></td>
<td>7</td>
<td>0.28</td>
<td>0.73</td>
<td>0.44</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>0.30</td>
<td>0.66</td>
<td>0.30</td>
</tr>
</tbody>
</table>

* Geometric mean of odour emission rates
reason for the drop in emission rate from 0.69 OU s\(^{-1}\) m\(^{-2}\) at a depth of 1.8 m to 0.40 OU s\(^{-1}\) m\(^{-2}\) at a depth of 2.4 m.

Unlike the agitated manure treatment, the odour emission rate at a depth of 0.6 m in the liquid-only manure treatment increased slightly between the two odour sampling days. At a depth of 1.8 m, a decrease in odour emission rate occurred on day 7 of odour sampling but was again in the same range at a manure depth of 2.4 m.

Compared with the control treatment, the odour emission rates in the liquid-only manure treatment were generally higher, except at a depth of 0.6 m where the emission rate in the control treatment was noticeably higher on both odour sampling days. Overall, the geometric means of the emission rates showed no differences between the two treatments. The odour emission rates at the four depths in the control treatment were anticipated to remain higher than the rates in the liquid-only manure treatment because of the larger volume of biodegradable matter in the slurry manure. However, an observation made during the study indicated that in the control treatment a crust formed on the surface of the manure at depths greater than 0.6 m. It appears that the crust reduced the rate at which odourous gases were released from the manure surface resulting in lower odour emission rates in the control treatment compared with the liquid-only manure treatment. In the control treatment, the odour emission rate increased with depth on day 0 of odour sampling but decreased with depth on day 7. At this depth, the slurry was disturbed as bottom loading took place. It appears that crust formation and crust thickness influenced the changes in emission rate on the two odour sampling days. During the trial, the existing crusts were observed to disintegrate to some degree when manure was added to the bottom of the tank in the control treatment. Typically, a new crust had just begun to form on day 0 of odour sampling and had thickened by day 7 of sampling. Another observation made was that the crust thickness on day 7 appeared to increase with increasing manure depth. Thus, it seems that the emission of odourous gases from the surface of the manure in the control treatment decreased as the crust thickness on day 7 increased with increasing depth.

Conclusions
The following conclusions were drawn from this study.
1. Initially, the odour emission rate from agitated manure is high but the rate has a tendency to decrease with time.
2. The odour emission rate from agitated manure increases with manure volume.
3. Over short time periods, the removal of solids from manure does not necessarily result in lower odour emission rates from the liquid-fraction of the manure, but as the volume of manure increases.
4. Crust formation and crust thickness decrease the odour emission rate in undisturbed slurry manure.
5. Emission rates vary significantly in the literature and this may be attributed to several factors including, depth, age, physiochemical properties of the manure, odour sampling method, airflow rates, olfactometer measurements, etc. Thus, it is not only pertinent for standard odour sampling methods to be developed, but odour emission rates from livestock sources should be reported along with details describing the state of the manure at the time of sampling and conditions under which the sampling and measurement were conducted.

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