6.0 PREVENTING AND SUPPRESSING FEEDLOT ODOUR

Preventing and suppressing odour from feedlots is a combination of good design, conscientious management and attention to detail. In reality, no feedlot will ever be odour-free, so the management objective is to avoid severe odour events by anticipating the conditions that give rise to extreme emissions.

To a great extent, feedlots are at the mercy of the weather with respect to odour potential, far more so than roofed or enclosed livestock operations. In general, the key to feedlot odour prevention is to keep manure and water separate whenever possible. This can be accomplished through thoughtful site selection, good feedlot design and proper management of corrals, manure storages and runoff catch basins.

Suppressing odour involves taking advantage of favourable weather conditions when performing highly odorous activities, responding quickly to adverse weather conditions and applying corral amendments when appropriate. Understanding that feedlot odour results almost exclusively from anaerobic conditions in manure is central to anticipating and mitigating odour.

The most important principle of odour control is to avoid anaerobic conditions by:

- Keeping manure and other organic materials dry.
- Keeping manure storages and surfaces exposed to oxygen.
- Keeping corral surfaces hard, smooth and free of loose manure.

6.1 Site Selection and Facility Design

Odour management is first and foremost an issue of site selection. Operators that anticipate building or expanding feedlots should avoid locations where neighbours are within one or two kilometres downwind. If expanding an existing operation or building a new feedlot, contact the Natural Resources Conservation Board (NRCB) and review Schedule 1 of the *Agricultural Operations Practices Act* (AOPA), to determine the required minimum distance separation (MDS). This setback distance, from the outside walls of neighbouring residences to the point closest to the developing livestock facility, manure storage, runoff catch basin, compost area, feeding pen or barn, is designed to reduce odour nuisance.

6.2 Corral Design

Many existing feedlots already have well designed corral facilities that reduce odour, either directly or indirectly. In preparing an odour management plan, operators should consider the following design criteria:

Slope. The corral slope should be between two and four percent, sloping down away from the feed apron. A slope of two to four percent will shed rainfall more rapidly than a flat corral, reducing the likelihood of puddles that can quickly become anaerobic. Avoid too steep a corral slope, since it may result in soil movement (erosion) in the runoff water.

Drainage. Minimize pen-to-pen drainage of rainfall runoff. Corrals that drain discreetly and directly into a runoff are less likely to detain water behind the manure ridges that develop under fencelines between corrals.

Equipment access. Ensure manure pen cleaning equipment has convenient access to the corrals. Frequent manure removal is vital to ensure rapid, complete drainage. If equipment access is difficult or awkward, the corral surface will be difficult to manage.

Soil. Corral soils should be firm, stable and not easily eroded into rills and gullies. Eroded corrals are prone to water retention.

Fill. Ensure an abundant and convenient supply of fill dirt is available. When gouging or erosion occurs in a corral, rapid maintenance reduces the likelihood of puddles forming from rainfall or spilled drinking water.

Pen shape. Pen shape must be conducive to edge-to-edge manure removal. Pens that are irregularly shaped cannot be maintained in the hard, smooth conditions that are central to effective manure removal.

Drainage channels. The potential for backwater from major drainage channels should be low. In some older feedlots, the downstream edges of the corrals are prone to temporary flooding. Stagnant water in a corral is a major contributor to intense odour. Ensure that runoff channels are well maintained to prevent backwater, especially within corral boundaries.

Diversions. Clean rainfall runoff must be diverted around corrals and manure storages. This relieves pressure on the catch basin and reduces the amount of water that is potentially detained on the corral surface or around the base of manure stockpiles.

Figure 6.1

Pen-to-pen drainage can result in localized wet areas where drainage is incomplete, resulting in significant odour emissions.

Photo credit: Dr. Brent Auvermann, Texas A & M University

Figure 6.2

Fill dirt is frequently needed around concrete pads where water fountains are located.

Photo credit: Dr. Brent Auvermann, Texas A & M University

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6.3 Feedlot Operation and Maintenance

Corral maintenance

No matter how well an open-lot feedlot has been designed, corral maintenance will make or break the yard with respect to odorous emissions. Again, the key is to keep the corral surface hard, smooth and dry, maintaining a firm two to five centimetre base of compacted manure above the mineral soil. Corrals that shed water rapidly and completely have the least potential for odour. The key elements of an odour management plan are:

Frequent, proper manure removal. In feedlots, manure removal typically occurs only after each corral is emptied for slaughter or transfer, an interval of 120 to 180 days. In flat feedlots or where ponding of rain is common, an interval of 120 days or more between manure removal activities will lead to corral conditions that are prone to odour. A few modern, large (capacity greater than 35,000 head) feedlots in Texas have experimented with continuous manure removal in which two or three tractors with box scrapers operate continuously across the yard, even when cattle are present. These corral conditions are excellent, and managers report little to no depression in feed-to-gain performance or increased cattle stress.

"Pull" blade vs. "push" blade. It is physically more difficult for a pushed scraper blade (e.g., front-end loader) to leave an even, smooth surface than a pulled blade (e. g., box scraper). Blades that gouge and scar the corral surface reduce the corral's water-shedding efficiency.

Operator training. Train employees both in the techniques of manure removal and in the justification, motivation and objectives of manure removal. Machinery operators who understand both the "what" and the "why" will be more apt to make sound decisions.

Corral drainage. Frequent inspection for and correction of pits, holes and wallows is necessary. Train and equip bunk readers, feed-truck drivers, pen riders and night security providers to note pits and holes developing in the corrals. Repair corral damage with compacted fill. Assign higher priority to holes and wallows near water troughs and feed aprons, where spilled and excreted water may collect even during dry weather.

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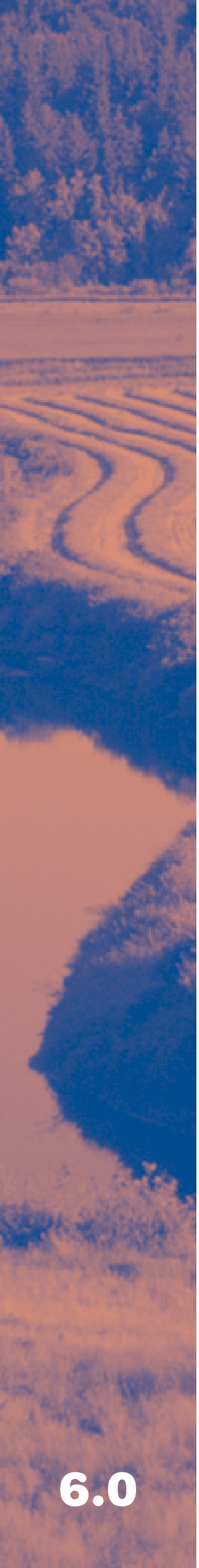


Manure mounds for flat corrals. Construction of manure mounds serves a fourfold purpose:

- Temporary storage of excess manure.
- Cattle refuge from muddy, wet and cold conditions.
- Shade during the summer to reduce heat stress.
- A means to enhance the water-shedding efficiency of corrals with little or no slope.

Waterer maintenance. Pay rigorous attention to overflow waterers, misters and water distribution systems. Water leakage in corrals, near feedbunks and manure storage areas can contribute significantly to odour. Train feedlot employees to look for signs of leaky distribution systems and water troughs.

Inspect fence lines. Ensure frequent inspection of fencelines for manure ridges, especially before rainfall. The moist manure that builds up under fencelines as a result of hoof action is a fertile breeding ground for flies. During rainfall these ridges act as dams, creating puddles and wet spots that generate odours. When rainfall is expected or when flies are becoming a major nuisance, knock down these ridges and spread the manure out to dry.

6.4 Drainage Structures and Runoff Catch Basins

Management of catch basins and other wastewater retention structures has been covered in great detail in Section 3. This simple checklist fills in some gaps concerning runoff control structures.

Open channels. Attend to corrals, settling basins and open channels to prevent clogging, backwater or poor drainage.

Equipment access. Where settling channels are used to reduce solids loading in catch basins, ensure that machinery for solids removal has convenient access under all weather conditions.

Sludge. Consistent monitoring and timely removal of excess sludge will improve catch basin performance and reduce odour potential.

Shallow catch basins. Shallow catch basins less than 1.2 metres (use natural topography where feasible), are less prone to anaerobic activity. This design option is probably not feasible in high-rainfall areas.

Drain water. When weather permits, pump out catch basins soon after storm events.

6.5 Mortality Management

Often overlooked, mortality management is one area in which public awareness has been sharpened by unfortunate, and often uncharacteristic, oversights or neglect.

Remove carcasses. Remove and dispose of carcasses quickly, especially in warm weather (Section 8).

Short-term storage. Locate short-term mortality storage (less than 48 hours) away from the property line and out of sight.

6.6 Manure Stockpiles and Composting Operations

Avoid long-term stockpiling of manure (over six months). Unmanaged stockpiles will eventually exclude oxygen and even if the stockpiles themselves are not odorous, old, stockpiled manure releases more odour when applied to land than manure that has been exposed to oxygen. If stockpiling is necessary, minimize stockpile size.

Avoid overheating. If stockpiling is necessary, ensure manure is dry (less than 45 percent moisture) to avoid overheating. Charred stockpiles release intense and uniquely disagreeable odours during application.

Locate properly. Locate stockpiles and composting operations upwind relative to prevailing winds and the centre of the feedlot. The odour potential of stockpiles and storage areas dictates that they should be situated as far upwind of the principal downwind property line as permitted by topography or other operational considerations. Short-term solid manure must not be stored less than 150 metres from the nearest residence that is not owned or under the control of the feedlot (AOPA).

Provide supplemental carbon for composting. A proper carbon to nitrogen ratio in a compost pile or windrow encourages faster composting and reduces odours over the long term. (Section 4)

Aerate. Aerate compost piles at a frequency appropriate to their moisture content and composition. In general, aerate wet manure at two-day intervals until the moisture content is reduced to 65 percent or less, then aerate weekly or bi-weekly thereafter. High moisture content will reduce the oxygen content of the pore spaces in a compost pile. (Section 4)

Select drier manure for land application. Dry manure spreads more uniformly than moist manure and releases less odour.

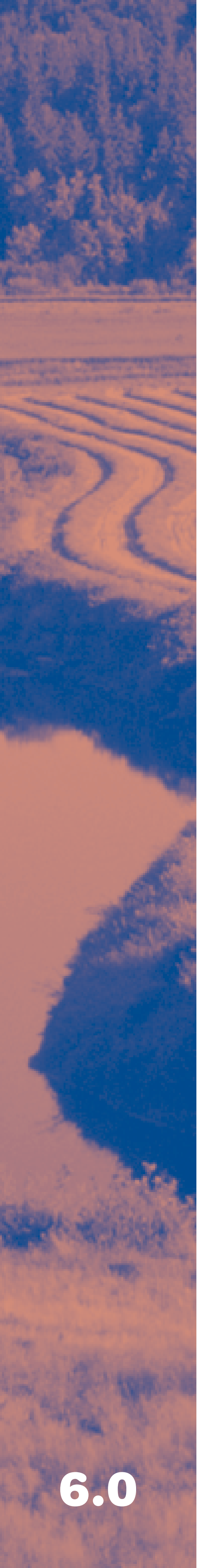
6.7 Feeding Strategies

Recent experimental feeding strategies have been shown to reduce emissions of odorous compounds. With the sheer number of such compounds, it is unlikely that feeding strategies alone will reduce feedlot odour. However, it has several promising components for an overall odour management plan.

Nitrogen balance. Of the more than 170 compounds known to contribute to livestock odour, many contain nitrogen and/or sulphur. Balancing the ration with respect to nitrogen may help to reduce the amount of nitrogen excreted in manure and urine. This will not eliminate odours, but it has economic value and contributes to a conscientious odour-management regime.

Sulphur balance. Avoid overfeeding sulphur and account for dissolved sulphate in drinking water. The same principles apply for sulphur as for nitrogen. In addition to feedstuffs, excess sulphur may unwittingly be “fed” in the form of high-sulphate drinking water. Be aware of high-sulphate water and account for the additional sulphur when formulating rations.

Investigate innovative feeding strategies (cyclical rations, grouping methods). Although these strategies still await conclusive verification with respect to feed-to-gain efficiency, any feeding strategies that result in more efficient nutrient use should also reduce nutrient excretion and may improve overall profitability.



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6.9 Appendix: Health Effects of Odour from the Feedlot

People experience odour continually, even in the absence of livestock. During the course of a day, people are confronted with odour from asphalt during paving activities, perfumes and deodorants used by co-workers or gasoline vapours at the service station. People may use their sense of smell to judge the freshness of produce or meat at the grocery store or to assess danger from bears, skunks or other wildlife during a backcountry expedition. Recurring or persistent odours, especially if intense or disagreeable, may affect an individual's health, mood or sense of well-being.

Although the health effects of emissions from swine and poultry facilities have been studied extensively, not a great deal is known specifically about how feedlot odour affects human health. The primary reason for this species-specific knowledge base appears to be that swine and poultry are most frequently produced in houses or sheds where employees are exposed to unnaturally elevated odour concentrations and where natural ventilation is usually insufficient to reduce indoor concentrations. However, public and occupational health inquiries, along with the increased frequency of nuisance complaints, have increased scrutiny of confined feeding operations (CFOs), irrespective of the species being produced.

Feedlots, with their relatively large surface area, may generate large downwind plumes of odorants having some known association with human health effects. Although the evidence linking these odorants to public health is often circumstantial, evidence of occupational health effects is reasonably compelling and should be considered seriously. Emissions from non-CFO (industrial) sources should also be considered.

Odours vs. odorous compounds

Feedlot odour results from the interaction of a complex mixture of odorous compounds with an array of sensory receptors in the human body. Nearly 200 individual compounds emitted by livestock or livestock manure have been associated with measurable odour responses in humans. The profile of compounds associated with livestock odour is likely to be species-specific because of differences in physiology and diet composition, but these compounds can be broadly classified in a manner that may be generally applied to all livestock species:

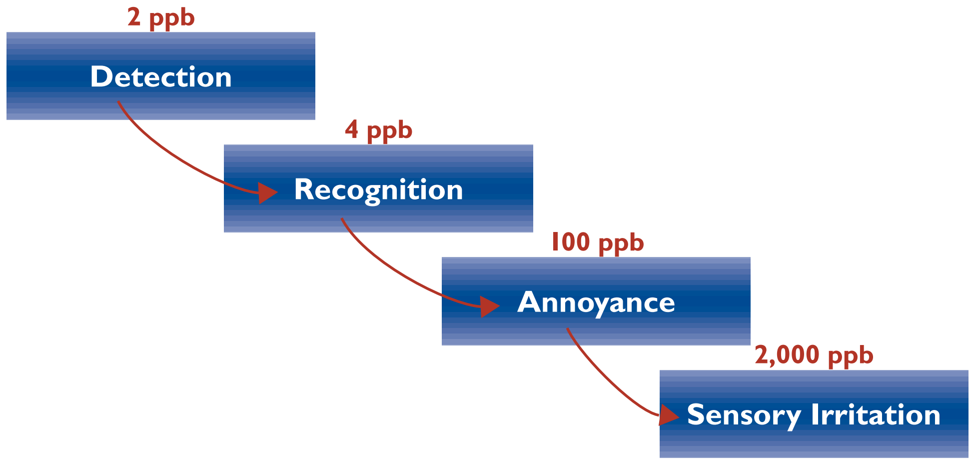
- Volatile organic acids.
- Trace sulphurous compounds.
- Trace nitrogenous compounds.
- Phenolic compounds.
- Alcohols, ketones and aldehydes.

A key distinction exists between the health effects of exposure to feedlot odours and exposure to compounds associated with feedlot odour. In the former case, health effects are principally psychological and relate to the overall sensation of odour, which may depend strongly on conditioning, experience and cultural factors. In the latter case, however, human health effects are more clearly physiological and may frequently be linked to identifiable modes of action (e. g., asphyxiation or bronchoconstriction). Psychologically, significant odour responses often occur at concentrations well below physiologically significant levels. Of course, physiological and psychological effects are not entirely independent and may be mutually reinforcing. In both cases, the combined effects of multiple odorants may be additive, synergistic or antagonistic.

How humans perceive and respond to odours and odorous compounds

Research has described human response to odour and odorants in the context of two primary sensory systems, the *olfactory* and *trigeminal* systems. The dominant system that operates in response to a given compound or mixture of compounds depends on the concentration(s). As concentrations increase, human responses proceed through benchmarks of detection, identification or recognition, annoyance and irritation, as shown in Figure 6.3.

Figure 6.3 **Human Responses to Odorants**



Human responses to odorants are a function of the concentration of exposure. Values listed are for hydrogen sulphide (H_2S). (ppb = parts per billion)

Reference: Dr. Brent Auvermann, Texas A & M University

The detection threshold of an odorant is its concentration in air, at which 50 percent of human panelists in a test are able to detect the presence of the odour correctly without recognizing the odorant specifically. In general, each panelist is presented with two or more streams of air, one of which has the odorant at a known concentration. The other stream(s) is so-called "odour-free" air, which usually has been deodorized by drying the air and passing it through a filter of activated charcoal or other adsorbent media.

The panelist must blindly choose which of the streams of air contains the odorant. The 50 percent (median) response criterion reduces the influence of hypersensitive and hyposensitive panelists (panelists whose ability to detect the presence of odour is consistently well outside the normal range) in determining detection thresholds.

Physiological responses to odorants

With so many different classes of compounds contributing to livestock odour, human physiological responses to odorants are many and varied. Even different compounds within a class of odorants or different isomers of the same compound may produce different physiological (either health or olfactory system) responses. The following section explores the major odorant classes and their most extensively documented dose-response characteristics. For comparison, typical occupational exposures and ambient concentrations are presented where published data is available.

Ammonia and hydrogen sulphide

Although research surveys of gaseous emissions from feedlots are in their infancy, ammonia (NH_3) and hydrogen sulphide (H_2S) are likely to dominate the emissions profile in terms of total mass emitted. The hedonic tones (what the odour smells like) of NH_3 (glass cleaner), and H_2S (rotten eggs), are distinct and widely recognizable. Although these compounds are undeniably odorous, studies show concentrations of NH_3 and H_2S in ambient air to be unreliable predictors of the intensity of livestock odour as perceived by human panelists.

Ammonia (NH_3). Although European researchers have studied NH_3 releases from livestock facilities for some time, only recently has North American attention turned to NH_3 release as it pertains to odour, and secondary particulate matter formed through combination with atmospheric nitrate and sulphate ions.

As an odorant, the public overrates the potency of NH_3, perhaps because it is present almost everywhere and because of its relatively high concentration in air compared to other odorants associated with livestock production. Research demonstrates that at concentrations up to 20 ppm, NH_3 is an eye irritant. Studies have shown that at concentrations between 40 and 200 ppm, exposure symptoms include headache, nausea, appetite suppression and upper respiratory irritation.

The odour detection threshold of NH_3 is approximately 5 ppm, and its one-hour exposure guideline in Alberta, which is clearly not a health-based threshold, is 2 ppm. In 1998-99, Alberta Environment measured one-hour NH_3 concentrations downwind of CFOs ranging from 0.011 ppm to 1.364 ppm (Alberta Environment, 2000). Average one-hour concentrations downwind of the eighteen CFO locations ranged from 0.009 ppm to 1.213 ppm.

Hydrogen sulphide (H_2S). H_2S is among the most well known occupational hazards for individuals working in the confined livestock industry. Denser than air, H_2S accumulates near (or below, in the case of manure pits) the floor in enclosed livestock barns. Workers may encounter lethal concentrations of H_2S when manure pits are agitated and pumped out. It is an irritant at concentrations between 2 and 20 ppm (well above its detection threshold of 2 ppb) and induces nausea between 50 and 100 ppm. At concentrations above 200 ppm, H_2S may cause dizziness, susceptibility to pneumonia and fluid in the lungs. It has been shown that extreme concentrations (greater than 500 ppm) are potentially lethal within seconds. At those concentrations, H_2S may paralyze the nasal nerve cells so that the person is unable to smell the gas and escape danger. Research reports 600 ppm as the H_2S threshold where rapid death is likely.

As an example of typical occupational exposures in mechanically ventilated, deep-pit swine barns, research measured daily average H_2S concentrations between 38 and 536 parts per billion (equivalent to 0.04 to 0.5 ppm), with 12 minute averages up to 1.6 ppm, one-sixth of Alberta's eight hour Occupational Exposure Limit (OEL) of 10 ppm. One hour averaged H_2S concentrations downwind of Alberta feedlots and swine facilities ranged from below the minimum detection limit of 0.6 ppb to 54 ppb; the mean one-hour measurement was 4 ppb. Alberta's one-hour guideline for H_2S, 10 ppb, is based on odour perception, not human health.

Remarkably, among the eighteen CFOs in the Lethbridge area, where downwind H_2S was measured in 1998 and 1999, maximum one hour concentrations exceeding the 10 ppb odour-based guideline were observed at two locations only (26 ppb and 54 ppb). In both cases, these one hour spikes were 0.5 percent or less of the eight hour OEL and were located within 30 metres of the source of the swine facilities.

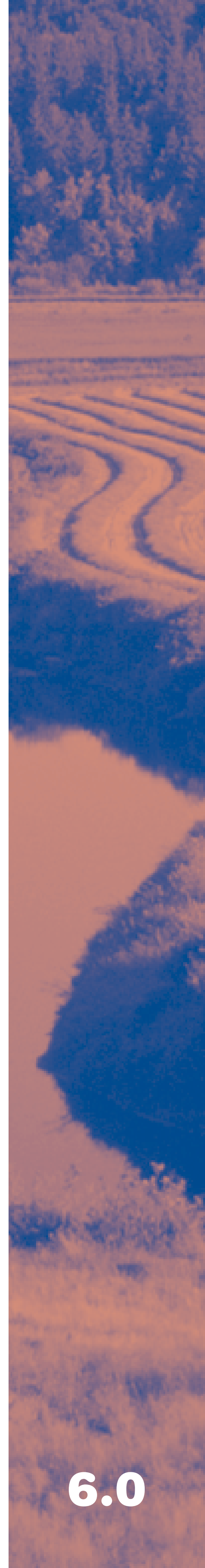
With notable exceptions (associated mainly with agitation and pumping of stored, liquid manure), livestock production does not appear to elevate environmental H_2S or NH_3 concentrations as individual compounds to levels that would compromise occupational or public health in the strict physiological sense. The synergistic or antagonistic effects on human health that these two compounds may have with trace gases are unknown.

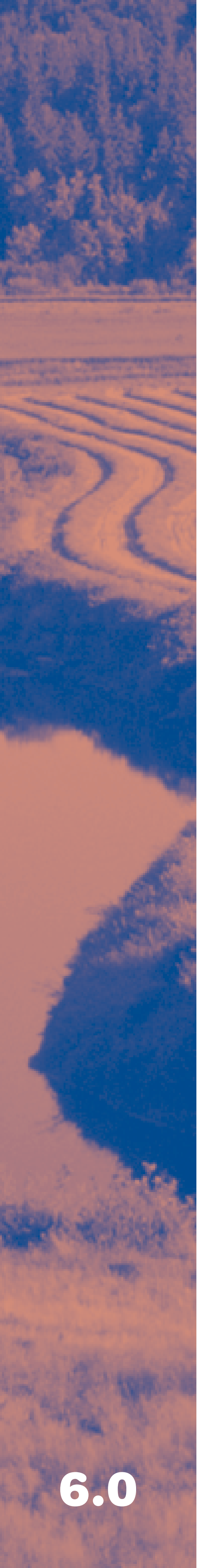
Trace gases

Other than H_2S and NH_3, the other gases and vapours typically associated with odour from manure decomposition are *trace gases*; that is, when detected in livestock odour, they occur in quantities too low to be considered serious physiological threats to human health. At high concentrations (i.e., far beyond the concentrations detected downwind of livestock facilities), many of these compounds are considered extremely hazardous substances for selected regulatory purposes and emergency planning (e.g., spills). These compounds, as well as H_2S and NH_3, are not unique to livestock agriculture and are emitted in significantly greater quantities from heavy and light industry than from CFO.

Trace gases tend to have low odour thresholds so that even when their concentration in air is minute, they may affect the sensation of odour and thereby contribute either indirectly to physiological health effects or directly to psychological effects. The classes of compounds that tend to be trace gases are often characterized by distinct hedonic tones, although individual compounds may differ in hedonic tone from that of the class as a whole.

Volatile organic acids – "Sour." Volatile organic acids (VOAs), including volatile fatty acids (VFAs), occur in trace amounts but appear to serve as reliable indicators of odour intensity. Remarkably, even compounds in this class which are as seemingly harmless as acetic acid (vinegar) are considered hazardous substances in the context of emergency planning regulations.





Phenolic compounds – "Medicinal." As measured by their odour thresholds, phenol, p-cresol and their isomers are among the strongest odorants associated with livestock manure. Like many of the trace odorants, phenolics can be extremely hazardous at high concentrations, but are detectable many orders of magnitude below their hazardous thresholds.

Alcohols, ketones and aldehydes – "Sweet" or "Pungent." This broad class of compounds represents many common by-products of industrial fermentation. Ethanol, for example, is a sweet-smelling alcohol produced by bakeries, breweries and distilleries. N-butanol, another sweet-smelling alcohol, is a standard reference odorant used in olfactometry. These gases are upper respiratory irritants and/or ocular irritants at high concentrations.

Trace sulphurous compounds – "Rotten." Trace sulphurous compounds include assorted mercaptans, sulphides and other by-products of protein metabolism. Butyl mercaptan, for example, is the compound primarily responsible for skunk odour.

Trace nitrogenous compounds – "Fishy or Pungent." These compounds, which include the amines and methylamines, are among the most prominent odorants associated with CFOs. Like the trace sulphur compounds, they are by-products of protein metabolism, and many are considered extremely hazardous at concentrations far higher than those routinely encountered near CFOs.

Odours, psychology and quality of life

Medical scientists have studied the psychological aspects of odour exposure extensively over the past decade. CFOs are not the only source of environmental odours in rural areas. In particular, chemical and petrochemical industries, oil and gas production, agricultural processing facilities and other industrial sources may contribute significantly to rural odour loads. Vehicle traffic on major highways may also contribute in localized areas. Where CFOs are large and/or numerous, however, their contribution to nearby odour loads is difficult to dispute.

Of course, odour is often an excellent advance indicator of an imminent health hazard and can therefore be useful and desirable property. For example, utilities add a trace odorant to odourless methane gas (CH_4) so that homeowners can detect leaks, faulty pilot lights or kitchen appliances that are accidentally left on. Although high concentrations can paralyze the olfactory system, the odour associated with low concentrations of H_2S can provide advance warning that dangerous conditions are possible, imminent or nearby.

Epidemiological literature only vaguely supports the assertion that the psychological impact of odours induces direct significant physiological effects *per se*. Much of the literature focuses on mood disturbance, impaired quality of life, and health surveys based on self-diagnosis and symptom reporting by respondents in the vicinity of CFOs. In many cases, such surveys are not accompanied by direct exposure or ambient air quality data from which intensity/response relationships can be inferred.

Nevertheless, despite a lack of epidemiological data and evidence of direct causality, the association between geographical regions of CFO concentration and mood disturbance, impaired quality of life and increased stress, represents a reasonably compelling, circumstantial case that CFO odour plays an important role in both the psychological health and physical well-being of the surrounding community.

Research has involved a respected survey instrument known as the *Profile of Mood States* (POMS), which has been used frequently and with good reproducibility in a variety of psychological contexts completely unrelated to the sensation of agricultural odours. (For example, the POMS instrument has been applied to athletic performance, post-surgical recovery and pleasant odours.) Briefly, the experimental design consisted of:

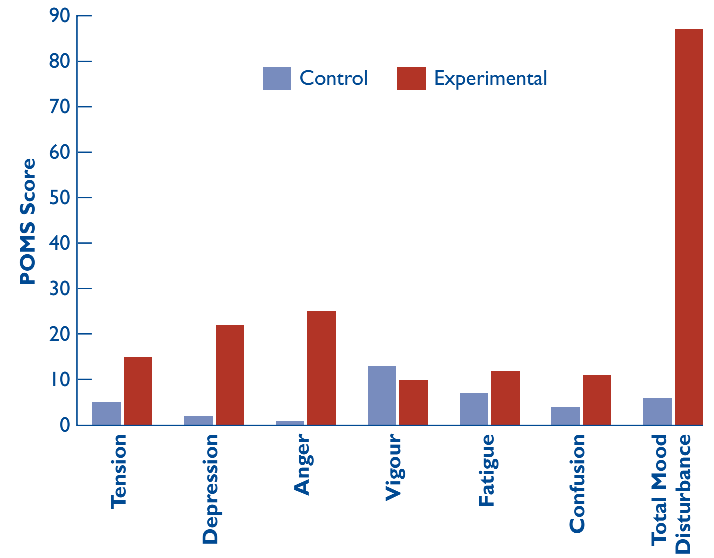
- 44 residents of North Carolina were sampled in each of two groups (control and experimental).
- The majority of respondents were skilled labourers.
- Experimental respondents lived near hog operations.
- Experimental respondents took the POMS on four different occasions when odour was present.
- Control respondents took the POMS on two different occasions.

Respondents answered questions that were linked to six major indicator classes of mood: tension, depression, anger, vigour, fatigue and confusion. Responses within each indicator class were combined to yield a single score for that class as shown in Figure 6.2. Although the six indicator classes do not appear to be purely independent of one another, the authors computed a weighted sum of the individual indicator scores (weighting "vigour" negatively) to yield a Total Mood Disturbance (TMD) score.

All of the indicator scores differed significantly and although the probable correlation of certain indicator pairs renders the TMD score suspect as an aggregate measure of the overall degree of impact, the proximity of CFOs appears to have a measurable effect on overall mood. To the extent that mood or its indicators induce or intensify physiological responses to stress (e.g., hypertension, hormonal responses), CFO odours may be thought to affect human health in a measurable way.

Figure 6.4

Association Between Geographical Regions and Mood Disturbance



POMS data comparing the mood disturbance of residents living near a North Carolina swine facility (experimental group) and residents not affected by swine facilities (control group).

Reference: Schiffman, S., Brain Research Bulletin 1995; 37(4): 369-375.

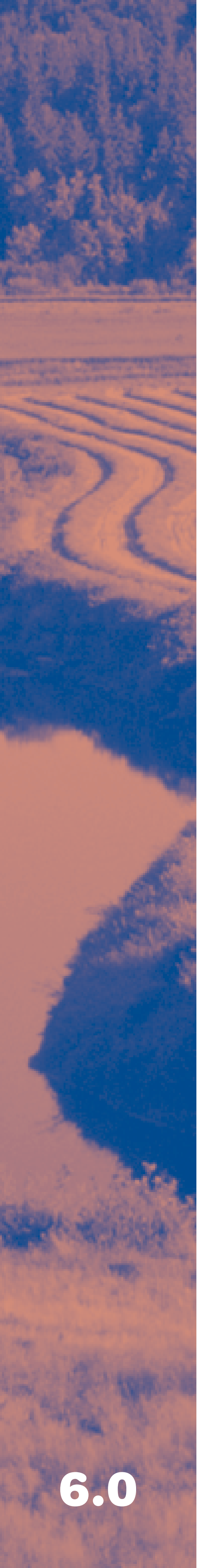
Some research has gone further, suggesting that the use of liquid manure management systems (as compared to a pasture operation) significantly increased the incidence of the following symptoms of reduced quality of life:

- Being reluctant to open the windows or go outside.
- Reports of headache, runny nose and/or sore throat.
- Excessive coughing.
- Burning eyes.

Three North Carolina communities near livestock operations were examined under winter conditions (January-February 1999). The nearby livestock production consisted of:

- One 6,000-head swine finishing facility.
- Two dairies with a total milking herd of 300.
- One unconfined livestock area with no liquid manure management system.

The authors surveyed health symptoms and reduced quality of life in these communities in the context of generic "rural health" and did not identify livestock production as the focal point when recruiting participants. Individuals conducting the surveys did not notice odours on the dates they conducted the surveys, and the authors did not collect environmental exposure data, so no clear association exists between odour *per se*, and the physical and psychological symptoms reported. The nature of the psychological responses could suggest odour as the causative agent(s), but, as is the case with much of the survey data concerning the health effects of livestock odours, the conclusions were not buttressed with monitoring data, olfactometry, scentometry or other exposure measurements. The survey responses were also highly species-specific (i.e., ruminants vs. monogastrics).



In a similar study, eighteen respondents living within 3.2 kilometres of a 4,000-head swine facility and a control group of identical size were surveyed. They concluded that the two groups reported significantly different levels of respiratory symptoms: nausea, weakness, dizziness and fainting; headaches and plugged ears; and burning eyes, runny nose and sore throat. Interestingly, however, they found little evidence to suggest that either anxiety or depression was elevated in the CFO neighbours.

Summary

As the scale and intensity of commercial livestock production increases, odour is among the most contentious issues arising between livestock producers and their neighbours. Perhaps because of the inherent subjectivity involved in odour perception and the difficulty involved in associating measured odour intensity with nuisance odour events, research has yet to confirm consistent causal associations between CFO odour and clearly defined medical syndromes, illnesses or psychological responses. Still, the number of studies that have drawn statistical associations between geographical location and suites of self-reported symptoms will undoubtedly give rise to more detailed research to establish any causation that may exist. Although many of the chemical components of CFO odours are listed worldwide as hazardous to humans, they usually occur at concentrations far below human health thresholds.

Glossary of Terms

Additive, Synergistic and Antagonistic. These terms refer to the ways in which the combined effect of two or more stressors may be expressed, and they are most easily defined by giving an example:

Suppose that pure ammonia gas at 10 ppb in air has an odour threshold of five, and pure hydrogen sulphide gas at 10 ppb in air has an odour threshold of five. Now, prepare a mixture of ammonia, hydrogen sulphide and air so that the ammonia concentration is 10 ppm and the hydrogen sulphide concentration is 10 ppb. The odour threshold of the mixture defines whether the effect of mixing the two is additive, synergistic or antagonistic.

- If the odour threshold of the mixture is 20, the effect is said to be additive; the effect of the mixture is equal to the sum of the effects of the individual, pure components.
- If the odour threshold of the mixture is, for example, three, the effect is said to be antagonistic; the effect of the mixture is less than the sum of the effects of the individual components.
- If the odour threshold of the mixture is, for example, 30, the effect is said to be synergistic; the effect of the mixture is greater than the sum of the effects of the individual components.

Asphyxiation. A potentially lethal medical condition in which the lungs are deprived of oxygen.

Bronchoconstriction. A medical condition in which the air passages (bronchial passages) in the lungs shrink or are squeezed, leading to partial or full asphyxiation.

Isomers. Two or more chemical compounds having the same chemical formula but whose physical structures are different. For example, ethanol (CH_3CH_2OH) and dimethyl ether (CH_3OCH_3) have the same total number of carbon, hydrogen and oxygen atoms in their molecular formulas, but differ in the way the atoms are joined together in their molecules. Isomers nearly always have different properties.