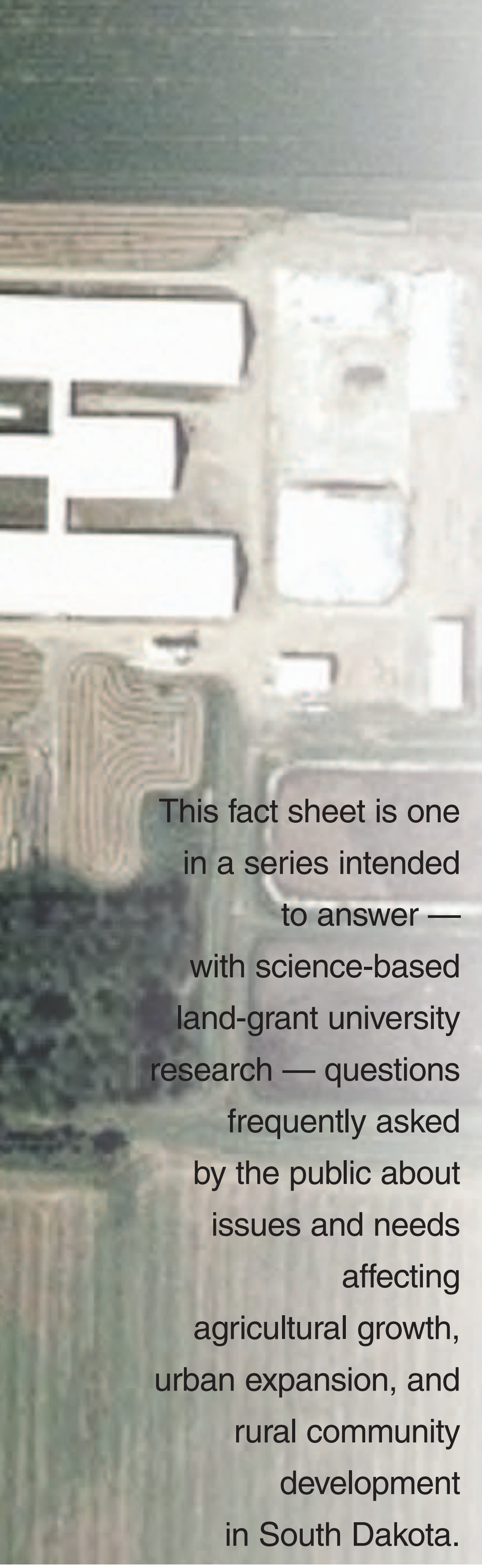

Understanding Livestock Odors

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People don't like an unpleasant smell from something when they derive no direct benefit or have no control, especially when it comes to manure. For producers and their community to be neighborly and good citizens, it is necessary for them to have a basic knowledge of odor control.

Depending on ventilation design, management practices, and the selection and design of the waste management system, each feedlot has a different gas and odor signature.

Microbial decomposition of manure from all poultry and livestock enterprises produces odors and gases as byproducts. Microbes are sensitive to moisture content, temperature, pH, oxygen concentration, and other environmental parameters. Any changes in these parameters will change the emissions. For example, as temperature decreases, microbial activity slows down, which is why odors may decrease in winter months.

As manure decomposes, it produces between 80 and 200 odorous compounds; 168 have been identified in swine manure, for example. Some people are better than others at detecting light concentrations of some gases. Other gases, such as methane, can only be detected at very high concentrations.

Gases and dust are transported via air currents. As wind direction and wind speed change, the odor impact area and intensity change. Depending on specific conditions, odorous gases and dust may travel several miles or several feet.

Gas transmission and the resulting impact area also depend on the specific gas. Heavier gases will move along the ground; lighter gases will be lifted higher.

All these issues make it difficult to predict the impact odorous gases and dust will have on residents in areas surrounding a livestock enterprise.

Producers need to apply basic odor principles to their management and technology to prevent adverse environmental and public health impacts from the odors and gases generated from their livestock and poultry production sites. Regulators, such as feedlot officers and county commissioners, also need to understand the same principles to develop rules and ordinances that protect the public from nuisances and still not hinder economic development.

This fact sheet is one in a series intended to answer — with science-based land-grant university research — questions frequently asked by the public about issues and needs affecting agricultural growth, urban expansion, and rural community development in South Dakota.

South Dakota State University
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Human response to odors

Smells or odors can be minty, floral, ethereal (pear like), musky, resinous, foul, pungent, or a combination of these smells. Odors have the ability to evoke memories that have been suppressed for many years. For example, the smell of freshly baked holiday cookies can carry us backward to childhood memories. Other odors may recall memories that we associate with sadness or unpleasant situations.

Response to an odor is not always caused by high concentration or intensity but rather by a strong memory or an impression instilled many years ago. Humans have evolved with a natural and strong aversion to odors from manure and decomposing organic matter.

The olfactory organ between the nasal cavity and brain is responsible for the detection of odors. It is so powerful that it can detect different odors in concentrations lower than those detectable by the most sophisticated gas chromatographs.

The olfactory organ is covered by a thin film of watery mucus, approximately 5 to 10 microns thick. When we inhale odorous molecules, they float into our nasal cavities and are absorbed by the mucus, reaching receptor cells and cilia. This “smell center” is made up of more than 5 million receptor cells that trigger impulses to the olfactory bulb in the brain. An irritating, tickling, or burning sensation occurs when odors stimulate nerves in the mucus and olfactory epithelium.

The strong connection between odors and memories is based on how our brains receive information from the olfactory organ. During normal breathing, only a small portion of the air that enters our noses flows across the olfactory organ. But if we sniff, the majority of airflow is routed over it. Chemicals in the air, intercepted by the mucus and cilia, trigger nerves, and the resulting signal is sent directly to the olfactory bulb in the brain. This direct connection or hard-wire effect is believed to explain how our exposure can have such an impact on our memories and/or our behavior.

Everyone does not have the same sense of smell and thus will respond differently to an odor. A percentage of the population has a very sensitive sense of smell and is able to detect odors at very low concentrations. They are hypersensitive to odors. Another percentage has a very poor sense of smell, requiring very high concentrations in order to detect an odor. They are referred to as anosmic. The majority of the population is in the “normal” range.

Very little information is available on the impact of odor on human physical health.

Most studies address the impact of a particular gas or dust particles. For example, it has been established that there is a dose-response relationship for ammonia, hydrogen sulfide, and dust on human health (i.e., a particular concentration of gas or dust for a particular amount of time will elicit a certain human response). These relationships have yet to be determined for odor intensity. Much of the research to date has been conducted indoors, where gas or dust concentrations are considerably higher than in open, natural conditions.

The dose-response relationship for most of the gases given off during manure decomposition has not been documented due to a lack of complaints in the past. Recently, however, there have been human health complaints based on odor. Schiffman showed in 1995 that odors can adversely affect the moods of neighbors of swine farms. Some people felt anger, frustration, and similar emotions due to chronic exposure, especially when they derived no benefit from or had no control over the livestock operation.

It appears that long-term exposure to odors can affect people’s moods and possibly their psychological health. In such cases, a person’s psychological well-being may be just as important as his or her physical health. Since some neighbors of a livestock operation may be negatively affected by odors, it is clear that odor reductions would benefit both community and livestock industry.

Odor measurement parameters

Just as the quality of water can be evaluated for several different criteria, odors too may be evaluated according to different parameters. Familiarity with these parameters will help farmers, regulators, and land managers understand the source of odors, plan projects, and interpret odor evaluation data.

An odor sample can be evaluated in terms of its concentration, intensity, persistence, hedonic tone, and character (Table 1). Odor threshold, intensity, and persistence are the most common parameters measured. The other two—hedonic tone and character descriptors—are more subjective measurements and are not typically used for regulatory purposes.

Table 1. Descriptions of odor parameters

Odor parameter	Description
Threshold	Minimum detectable concentration
Intensity	Strength of odor
Persistence	Rate of change
Hedonic Tone	Degree of acceptability or offensiveness
Character	What an odor smells like

Threshold

There are two odor thresholds that can be measured -—detection threshold and recognition threshold. They are usually reported as odor units (OU), defined as the volume of dilution (non-odorous) air divided by the volume of odorous sample air at either detection or recognition.

The **detection threshold** concentration is the volume of non-odorous air needed to dilute a unit volume of odorous sample air to the point where trained panelists can correctly detect a difference compared to non-odorous air. At the detection threshold concentration, the panelists just begin to detect the difference between the odorous and non-odorous air mixture and two other non-odorous air streams. This is the most common threshold determined and reported.

The dilution of odor is the physical process that occurs in the atmosphere downwind of the odor-generating source. The receptor (citizen in the community) sniffs the diluted odor. The dilution ratio is an estimate of the number of dilutions needed to make the odor nondetectable (below the recognition threshold). If the receptor detects the odor, then the odor in the atmosphere is above the threshold level (suprathreshold).

The **recognition threshold** concentration is the volume of non-odorous air needed to dilute a unit volume of odorous sample air to the point where trained panelists can correctly recognize the odorous air.

The difference between detection and recognition thresholds can be illustrated using the analogy of sound. For example if, in a quiet room, you turn down a radio so low that it can not be heard, the radio is said to be below the detection threshold. If you increase the volume in very small steps, it will increase to a level where you will detect a sound. This volume corresponds to the detection threshold. You won’t be able to recognize the sound, i.e. whether it is music or people talking. If you increase the volume more in small steps, the volume of the sound will increase to a point where you will be able to recognize that it is either music or people talking. The volume corresponds to the recognition threshold.

Odor intensity

Odor intensity is the relative strength of the odor above the detection threshold (suprathreshold). The intensity of the sample (odorous or foul air), is compared to a series of concentrations of reference odorant, which is normally n-butanol mixed with water. Trained panelists sniff containers of n-butanol at different concentrations in water to learn the scale (Table 2).

Table 2. Odor intensity reference scale based on n-butanol.

Intensity category		Equivalent head space concentration of n-butanol in air (ppm)	Mixture of n-butanol in water (ppm)
0	No odor	0	0
1	Very light	25	250
2	Light	75	750
3	Moderate	225	2250
4	Strong	675	6750
5	Very strong	2025	20250

Diluted or full-strength (diluted is always presented first) odorous air samples are presented to the panelists who compare the samples to the n-butanol standard scale. Intensity rates the strength of an odor.

The odor intensity of an air sample with n-butanol is expressed in parts per million of butanol. A larger value of n-butanol means a stronger odor, but the relationship of one value to the next is not in a simple numerical proportion.

The scale is a standard method to quantify the intensity of odors for documentation and comparison purposes.

Odor persistence

Persistency is a term used in conjunction with intensity. While the perceived intensity of an odor will change in relation to its concentration, the rate of change of intensity with concentration is not the same for all odors. This rate of change is termed the persistency of the odor.

Persistence is a calculated value based on the full-strength intensity and the detection threshold concentration. The slope of the line connecting these two points on a logarithmic graph is the persistence (Fig 1).

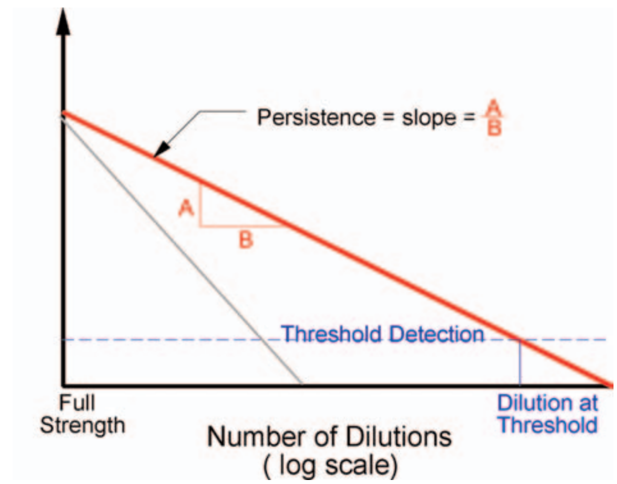
The persistency of an odor can be represented as a dose-response function, which is determined from intensity measurements of an odor at full strength and at several dilution levels above the threshold level. The logarithm of the intensity plotted against the logarithm of the dilution ratio is the dose-response function. The slope illustrates the persistency.

Persistence indicates how easily the full-strength odorous air is diluted to below the detection threshold.

Odorous air that has a low persistence will have a steep slope, which indicates that it does not take much dilution air to dilute the odorous air to below the detection threshold. Odorous air with a higher persistence will have a shallow slope, which means the sample air requires more dilution air to reach the detection threshold. A more persistent odor will be remembered longer.

In Figure 1, the flat slope of Odor X, compared to the steep slope of Odor Y means that Odor X is more persistent than Odor Y even though both odors have near the same full strength intensity. Odor X would have a greater "hang time" in the ambient air.

Fig 1. Odor dose-response relationship.



Hedonic tone

Hedonic tone is a measure of the pleasantness or unpleasantness of an odor sample and is independent of its character.

An arbitrary but common scale for ranking odors by hedonic tone is used. Typically the scale most often used is the 9-point scale that ranges from -4, unpleasant, to +4, pleasant. Unpleasantness may increase with odor intensity. Pleasant odors may increase in pleasantness with odor intensity at low intensities but become less pleasant and even unpleasant at relatively high intensities.

-4	-3	-2	-1	0	+1	+2	+3	+4
Unpleasant				Neutral				Pleasant

Each odor panelist assigns a subjective hedonic tone value to an odor sample. A panelist uses his or her personal experience and memories of odors as a referencing scale. During training the panelists have become aware of their individual odor experience and memory referencing. The average value of the odor panel is then reported as the hedonic tone for the odor sample.

Because of the lack of standard measurement protocols and differences among individuals, results for hedonic tone cannot be compared among different laboratories. However, using the same laboratory or odor panel, hedonic tone can provide an accurate assessment of odor variation over time.

Odor character

Odor character is also known as odor quality. The character of an odor is reported using odor descriptors, which provide a referencing vocabulary for odor character or odor quality.

Numerous "standard" odor descriptor lists are available. For example, an odor might smell like mint, citrus, earth, or any other select term used by trained panelists. Character descriptors are used on samples at or above the recognition threshold concentration. The odor descriptors most frequently assigned by the evaluating odor panel are reported for referencing purposes.

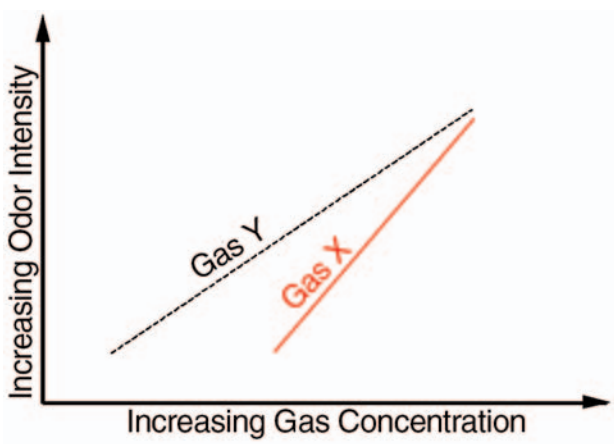
Odor measurement methods

There are two general approaches used to measure odor: either measure individual gas concentrations or use olfactometry. It is also important to understand the distinction between gas concentration and olfactometry because both approaches have strengths and weaknesses.

Olfactometry is a measure of detection sensed by the nose. Gas concentration is the relative amount of gas in the air, often measured by calibrated instrumentation in parts per million (ppm) or parts per billion (ppb).

The relationship between an odor and gas concentration varies between gases (Fig 2). For example, odor intensity is positively correlated with concentrations of ammonia and/or hydrogen sulfide, when no other compounds are present. Hydrogen sulfide has such a deadening effect on the sense of smell that increasing concentrations are not perceived as higher odor intensities. Even when these gas concentrations are reduced, people do not perceive similar reductions in odor intensity, since there are many other compounds in the odors as well.

Fig 2. Relationship between gas concentration and odor intensity.



Gas measurement

Individual gaseous compounds in an air sample can be identified and measured using a variety of techniques that produce fairly accurate results. Regulations can be established to limit exposure to an individual gas concentration.

The gas measurement approach has some weakness when used to measure odors. Currently there is no known relationship between any specific gas concentration in a mixture and its perceived odor. If controls are based on gas concentration, the result may not adequately address the odors sensed by people downwind of a source.

To complicate things even further, some combinations of gases may be more or less odorous than the sum of the individual gases. Also, dust particles can and do transport odorous compounds and can absorb and emit odors. Dust particles can settle on the ground or other surfaces, so the distance the dust travels affects the odor of the impacted air.

An electronic nose is a device that measures several select gas concentrations simultaneously and determines the relationship between the concentrations of each compound. The device uses a variety of methods for measuring the gas concentrations. Researchers continue to evaluate this device for application to livestock odors but to date have not been successful.

Several studies have been conducted to describe the relationship between odor intensity and ammonia concentration. DeBode found that after covering manure storage units, their ammonia emissions were reduced from 75 to 100% while odor intensity was reduced from 28 to 72%. Both odor intensity and gas emissions were reduced but in significantly different amounts. Other studies have shown similar relationships between odor intensity and specific gas concentrations.

Olfactometry measurement

Olfactometry uses trained individuals and standardized procedures to measure odor levels. The main advantage of olfactometry is the direct correlation with odor and its use of the human sensitive sense of smell. Olfactometry also has the advantage that it analyses the complete gas mixture so the contribution of each compound is included.

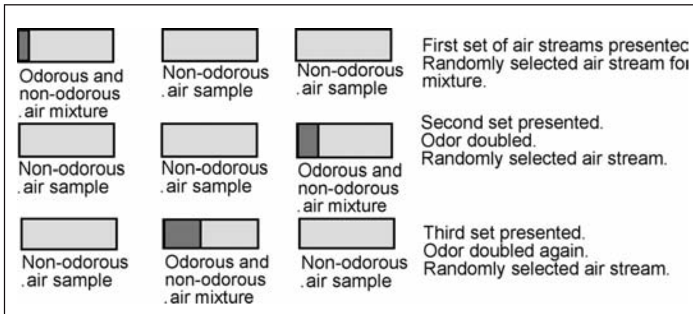
Odors are a combination of gases—some in nearly undetectable concentrations. The human nose can sense these gases and gas combinations at extremely low levels. No instrument can match the sensitivity of the human nose.

Several techniques have been employed to assist the human nose in determining detection threshold and intensity. The most popular method of odor measurement uses an instrument called the dynamic olfactometer and an odor panel.

A dynamic, triangular, forced-choice olfactometer presents three air streams to the trained panelists. One air stream is a mixture of non-odorous air and an extremely small amount of odorous air from a sample. The other two air streams have only non-odorous air. Panelists sniff each air stream and are asked to identify which air stream is different (i.e. has a different odor) than the other two non-odorous air streams. Initially panelists must guess which air stream is different, because the amount of odorous air added is below the detection threshold.

In steps, the amount of odorous air added to one of the air streams is doubled until the panelist correctly detects which air stream is different. The air stream with the odor is randomly changed each time. Figure 3 illustrates the olfactometry measurement process.

Fig 3. Olfactometer dilution sequence example.



The detection threshold is the non-odorous airflow rate divided by the odorous airflow rate when the panelist correctly recognizes which air stream is different. A panel of eight trained people is significant enough to analyze each odor sample. The panel's average concentration is reported and used for analysis. This statistical approach is called triangular forced-choice. The ANSI (American National Standards Institute) and ASTM (American Society for Testing and Materials) have accepted standard practices for olfactometry.

A device known as the scentometer can also be used to determine the number of dilutions-to-threshold (D/T) for measuring ambient odor levels in the field.

The device is a rectangular, clear plastic box with two nasal ports, two chambers of activated carbon with air inlets, and several different size odorous air inlets. Varying proportions of ambient air and air drawn through an activated carbon filter are introduced to an individual's nose. The ratio of ambient air to filtered air at which the individual detects an odor is the dilutions-to-threshold.

Portability and relatively low cost are the main advantages of the scentometer. Disadvantages include poor accuracy and air leakage between the nostril and the device. Since this method requires the individual to be on site, the results may be biased because the individual may anticipate the smell or become desensitized to the odorous air before taking the measurement. This method is also difficult to verify when it involves only one person. Some researchers have improved the accuracy of scentometry by using several persons and scentometers, averaging several measurements for a single observation, and using respirators to avoid odor desensitization.

Another method of odor measurement is to use trained odor detectors—people who have been trained to detect odor intensities. These people have "calibrated" their noses to certain odor intensities. They are trained to go to a site and rate the odor intensity on a numeric scale. Issues of desensitizing and biasing also occur with trained odor detectors.

All odor measurement technologies have their limitations, but each may be useful in certain situations.

Odor measurements are often complicated by the variability in meteorological conditions during the sampling period. Odor emissions change with time and the movement of odorous air. The intensity and location of the odorous air may change with wind speed and direction. At any particular location, the current odor intensity may have little bearing on the odor intensity that was present an hour ago or an hour from now.

Livestock odor sources

Poultry and livestock odors are classified as originating from three major sources: 1) buildings, 2) manure storage and treatment units (lagoons), and 3) land application of manure.

Gas emissions from buildings occur year around and vary by time of day as well as the season. Those from lagoons vary with seasonal temperatures. Odors from land application of manure occur periodically when and immediately after manure or litter is spread. Also, the amount of odors emitted from a livestock operation depends on the amount and type of microbial degradation of the manure.

Technologies to manage odors are available to livestock producers. Applicability, effectiveness, costs, and labor and management requirements vary between technologies and need to be considered before adoption of any system. Odor control technologies fall into three categories that are intended to:

- Prevent odors from being generated.
- Capture and destroy odors before they are released to the atmosphere.
- Disperse or disguise odors so they do not create a nuisance when transported away from the odor source.

Predicting odor movement

The amount of odor emitted from a particular farm is a function of animal species, housing types, manure storage and handling methods, size of the odor sources, and the implementation of odor control technologies. Once the odor is emitted, the following questions require answers:

- How far does the odor travel?
- How much odor control is needed to reduce odor from an existing facility?
- Can the odor impact from a proposed facility be predicted?

To answer these and other questions related to odor, the University of Minnesota has developed a modeling tool "Odor From Feedlots Setback Estimation Tool" (OFFSET). This model has been modified for South Dakota climate conditions for prevailing wind speed and direction. The tool estimates the average odor impact from a variety of types of animal facilities and manure storages at various distant from the source. The model can also adjust the frequency a person is annoyed by an odor by varying the distance.

The next step

Odor measurement, control, and management are all difficult subjects. The research community has made considerable progress the past 10 years in understanding livestock odors and odor control technology.

Odors occasionally create problems for the livestock industry and for some individuals and communities near livestock facilities. Effective livestock odor management will usually involve one or more control practices because most operations have several sources and different manure handling practices.

Technologies that capture and treat odors include manure storage covers, organic mats, and biofilters. Technologies that disperse or mask odors include stacks, chimneys, vegetated windbreaks, windbreak walls, site selection, setback distances, and deodorant or masking agents. SDCES Fact Sheet 925-C, Biofilters, and 925-D, Covers, provide additional information on two of the more effective technologies.

Communities need policies that manage odor problems while preserving the economic integrity of the animal industry. How much odor should a community or individual have to tolerate?

This question must be answered before performance standards or any good odor control program can be developed and enforced. These and other questions are being addressed by the research community.

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