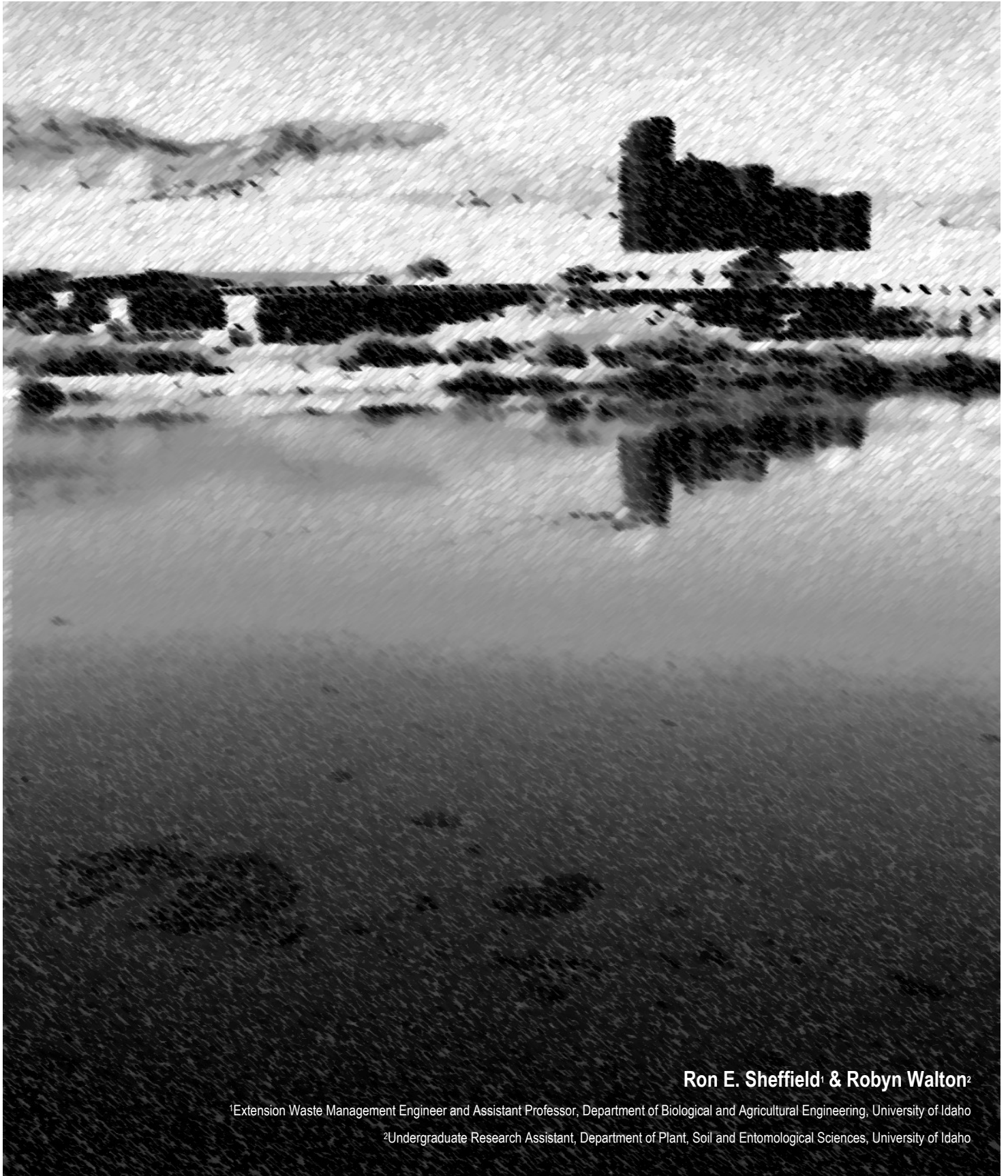


Dairy Odor Management & Control Practices



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Introduction

Over the past several years there have been an increasing number of large confined animal feeding operations being built. Large animal farms produce huge quantities of odor causing manure. The ever-increasing rural population is causing many conflicts especially with dairy farmers. People living in close proximity to these feeding operations have the most problem with the odors produced by the farms.

There is very little information available on the impact of odor and airborne contaminants from livestock operations on human health. Gases like ammonia (NH_3) and hydrogen sulfide (H_2S) at high concentrations have shown negative effects on humans. However, little data is available to show definitive effects on health at low level exposure to these gases. Some states have even put air quality standards into affect to control the amounts of ammonia and hydrogen sulfide released into the atmosphere.

However, there are various ways to prevent or even eliminate odors produced from dairies and other similar operations. A livestock farm will need to consider the size of the farm, its proximity to non-farming neighbors, the location of existing farm buildings, topography, weather conditions, and governmental regulations to apply the proper odor management plan. General information on odors and how they are perceived, the source of odors, the importance of dairy farm site selection, and good management practices are also items needed to help with the odor problem. Methods of removal will be discussed; for example, mechanical, chemical, and biological control of odors. Understanding airborne contaminants' movement and odor intensity is a must in evaluating and minimizing the effects of odor emissions.

This chapter will focus on four key issues: understanding odors, selecting odor control technology and practices, developing an odor management plan and responding to complaints from neighbors. Additionally, Table 1 is a comprehensive list of odor practices and technologies that may be considered on dairies in the Pacific Northwest. The table is a list of suggestions or a tool box on which to refer to and should not be used as a list of required practices for any or all dairies. The selection of odor control practices should be made in conjunction with production goals, inventory of existing infrastructure, regulatory requirements, the intensity of the odor problem and the farm's nutrient management plan.

Odors – Detection, Perception, Characteristics, and Measurement

The Sense of Smell

Odor perception is different for every person, almost as different as personalities. Our memories of odors play a role in how we perceive them. An odor has the ability to bring back memories that have been suppressed for many years. This could be why odors are the best-remembered sensory stimuli for most people. Odors can be good, bad, or neutral depending on the memories surrounding the odors. It can be very difficult to change a person's opinion of an odor once it has been labeled. Over time, small doses of that odor may be all that is required to trigger a response. The olfactory receptors in humans are high up in the sinuses and connect onto the most primitive parts of the brain. The olfactory organ is so powerful that it can detect minute concentrations of odors that are undetected by many of today's most advanced gas chromatographers.

People get accustomed to different odors. This will explain why the odors do not have the same affect on producers that it might have on someone who has little exposure to livestock farming. The human nose has receptors that become saturated with long-term exposure to strong odors. When the receptor site becomes over-whelmed with an odor, it becomes odor fatigued. This is a condition that prevents the olfactory organ from perceiving that odor. It may take one-half hour or more for the receptor site to recover from odor fatigue. This explains why people with long exposure periods to a strong smell are not as responsive to the smell.

Description of Odors

The feeling that humans have about different odors was imprinted in our minds early on. Odors can have a value put on them other than good, bad, or neutral. Odors are measured by using their concentration, character, intensity, persistence, frequency, and duration (Table 2).

- **Concentration** – There are two ways the threshold of odors can be measured: detection threshold and recognition threshold. Odor concentrations are called odor units (ou). Odor units are defined as the volume of diluted air divided by the volume of odorous sample air at either detection or recognition. Detection threshold is how much an odor is diluted before it is undetectable by trained panelists. Recognition threshold is how much an odor must be diluted to a point where trained panelists can still recognize the odor.
- **Character** – Also known as odor quality. This is a process of using odor or character descriptors to provide a verbal description to odor quality. There is a standard odor descriptor available for use. It is known as the Flavor Wheel published by the International Association on Water Pollution Research and Control (IAWPRC). Similar wheels exist for beer, wine, and perfumes.
- **Intensity** – This is the strength of the odor above the threshold of an approved standard gas. The odor is usually compared to known concentrations of butanol to give a specific intensity value. The threshold can also be determined with an olfactometer to give odor units. Odor units represent the number of times the air needs to be diluted before the odor is no longer detectable. Odor intensity decreases with dilution.
- **Persistence** – A term used in conjunction with intensity. The intensity of an odor will change in relation to its concentration, while the rate of change of intensity

with concentration is not the same for all odors. The rate of change is the persistency. The persistency of an odor can be shown by a dose-response function. The dose-response function describes how long it can take to dilute an odor below detection threshold. The more air it takes to dilute an odor the higher the persistence.

- **Frequency and Duration** – This can also be described as hedonic tone. These terms are used to describe odoriferous events that can significantly affect people. Mathematical models have been developed to estimate the concentration of specific gases downwind from a source. Odors are rated using a scale for –10, being unpleasant, to +10, being very pleasant. A neutral odor is given a zero. This method accounts for breakdown of gases and dispersion during different weather conditions. These parameters are also called concentration or threshold, or hedonic tone.

Odor Measurement

Odors are a combination of many different gases in extremely low concentrations. The slightest difference in composition can alter the way some one would perceive the odor. In order to distinguish between different odors, the concentrations of gases must be measured. Determining the exact make up of an odor is very difficult, very expensive and very time consuming.

There are two common approaches used to measure odors: gas measurement and odor measurement. Both methods have pros and cons. The main difficulty associated with these methods is poor correlation between odor and the combination and concentration of different gases that are present in the air.

Gas Measurement and Methods

The method of measurement is used to determine the concentrations of individual gases in the air. When taking gas measurements, it is vital to understand that the data the instruments relay is an average and will constantly vary with time. The person analyzing the data may also have an influence on the readings. Sampling devices must be calibrated and maintained frequently to assure accurate readings. The following will describe several methods of gas measurement listed in order of least expensive to most expensive.

Patches

The patches are single-use indicators that are made of cardboard or plastic. When exposed to a specific gas, the chemical indicator will change color. The reading patches given are not very precise, and it shows the average value. Patches cost approximately \$1.00 per sample.

Indicator and Diffusion Tubes

Indicator tubes are tubes made of glass that have both ends sealed. To take a reading, remove the seals at both ends and attach to a hand-held air pump. The pump will pull air into the tube and allow it to react with chemicals in the tube. A color change is used to determine the presence and relative concentration of a particular gas. This type of sample is known as a grab sample. Diffusion tubes are also used to take gas samples. The diffusion tube method takes an average sample of the gases in the air. To take a sample, one end of the tube must be opened to allow air to enter. Then hang the tube in place where it can be monitored. Six to eight hours later, note the

amount of color change in the tube. Using these methods, you are only able to sample one gas at a time, and they are only available for a few gases. Both of these methods are moderately inexpensive, costing between \$0.50 and \$1.50 per sample.

Jerome® Meter

The Jerome meter is a portable instrument used to measure concentrations of reduced sulfur compounds in the air. This machine is run electronically. When this machine takes a sample, it will sample for several seconds. During this time, it is measuring the sulfur concentrations by the electric resistance of a gold-leaf metal strip, which is being exposed to the outside air. This device is fairly expensive and requires calibration. Jerome meters cost approximately \$12,000 and require an annual calibration (additional \$1,000).

MDA Single-Point Monitor

The MDA monitor is a commercial device that is used to identify concentrations of individual compounds in the air for a long period of time. This machine runs a tape that chemically reacts with the air causing a color change. The tapes typically last 2900 samples, or a month when sampling on a 15-minute interval. Different tapes can be purchased for varying concentrations and gas compounds. Recent studies in Idaho have shown MDAs to be relatively precise but lack the accuracy needed to be used for research or regulatory purposes. MDAs cost over \$15,000 for the unit and tapes cost \$75 to \$100 each.

Electronic Sensors

Electronic sensors vary greatly in the method they take a sample and the precision. This type of device is often used to measure single gas concentrations over a relatively small sample area. Sensors are useful for monitoring known odor sources as close to the emission as possible; from man-hole, mixing chambers or edges of storage ponds. Sensors may be equipped with data loggers for long term monitoring or with alarms to if concentrations get too high. Electronic sensors cost between \$1,000 and \$2,000 depending on the chemical and features desired.

Gas Chromatograph/Mass Spectrometer

The gas chromatograph/mass spectrometer is most often used in laboratory research. This machine can measure gas concentrations in very small samples. The sample is injected into a gas stream passing through a GC/MS column. The column absorbs and desorbs the chemicals in the air at different rates to separate them. The gas then passes through a detector that identifies the amount of chemicals in the sample. Portable models are now available. This is the most expensive machine to use.

Odor Measurement and Techniques

Measuring and evaluating odors is very difficult but researchers have found some methods that can be reliable. The following is a list of common methods used to measure odor.

Electronic Nose

There is a wide variety of this type of device available commercially for non-agricultural odors. This device measures odor by selecting and measuring select chemical compounds. Electronic Noses currently are used in several industrial quality control applications for the processing of perfumes, fish, silicone chips and food products where only a handful of odorous compounds are likely to be

present. Because of the complexity related to the gases and odorous compounds related to livestock manure, an electronic nose has not been developed.

Scentometer

The scentometer is a hand-held portable devices that measures odor levels in the air or the number of dilutions-to-thresholds. It is a rectangular, clear plastic box with two nasal ports, two chambers of activated carbon with air inlets, and several differently sized odorous aid inlets. Air is drawn in through the activated carbon and into the panelist's nose. The ratio of ambient air to filtered air at which the individual detects an odor is the dilutions-to-threshold. Panelists using the scentometers have noted some disadvantages. First, panelists often note leaking and poor sealing of the glass nasal inserts when using the scentometer. Secondly, the devices does not control or monitor the flow or amount of air that is inhaled by each panelist when a sample is taken. However, even with these limitations, several states use the scentometer as regulatory tool for monitoring excessive industrial and agricultural odors. Scentometers cost approximately \$550.

Facial Mask Field Olfactometer

Facial mask field olfactometers are functionally similar to scentometers, but rely on a full-face charcoal filtered respirator to prolong odor fatigue. These low-cost (\$100) devices are modifications of conventional partial face respirators use the same whole diameters and D/T as the scentometers.

Nasal Ranger

The "Nasal Ranger" is a new field olfactometer developed by St. Croix Sensory, Inc. of St. Paul Minnesota. The "Nasal Ranger" and is designed to combine the portability and relatively low-cost (\$1500) of a scentometer with the sampling control of a more expensive laboratory olfactometer. The device uses readily available charcoal filters to clean the ambient air. Flow control is maintained by a static pressure sensory and LED's which provide feedback to the person sniffing to inform them if they should increase or decrease their sniffing. The static pressure target range is equivalent to 14-18 LPM sniffing rate enabling the unit to be attached to a pump and directly calibrate the dilution ratios. The sniffing mask on the "Nasal Ranger" is equipped with inlet and outlet with check valves, allowing the assessor to keep the unit over their nose during an entire test.

Dynamic, Triangular Forced-Choice Olfactometer

Olfactometers as sophisticated machines that dilute and deliver field collected air samples to panelists in a laboratory. Typically a team of eight panelists sniff three ports or samples of air and try to determine the one that contains the sample odor. The odor sample starts out very diluted and continues to get stronger with each set. If the panelists are not able to identify the odor, they will move to the next set of three until the odor is detected or recognized. Olfactometers cost approximately \$50,000 for the unit and associated software and established lab typically charge \$1,000 per sample.

Field Sniffers or Odor Detectors

This is a method of evaluating odors at the source or at the point of a complaint using trained panelists. Field sniffers need to "calibrate" their noses in order to be consistent as an individual and in a group situation. Panelists travel to the site and evaluate the odor on a numerical scale.

Sniffers should charcoal masks or respirators and only remove them to sniff the air when taking a reading. This is done to prevent odor fatigue and desensitizing.

Other Methods

Dust concentrations in the air surrounding an animal facility can be measured by using gravimetical methods. To measure the dust in the air, a known amount of air is allowed to pass through a filter that was weighed first. After the air has passed through the filter, it is weighed again. This will show you the amount of dust in the air usually calculated in units of milligrams of dust per cubic meter of air (mg/m^3). There are many different types of devices that measure dust on the market today. There are three basic types used: electronic particle counters, total dust concentration counters, and machines that only measure the dust particles small enough to enter the respiratory system.

Pathogen measurements are used to report the amount of airborne bacteria. A petri dish filled with agar and exposed to air that may contain pathogens. After a period of incubation the colonies are counted to determine the units per volume of air.

Sources of Odor Emissions

Livestock odors arise from many different sources. There are more than 160 odorous compounds that have been identified coming from dairy, beef, swine, and poultry manure. Some of these gases are said to contribute to global warming and the production of acid rain. There are four primary sources of odor from animal facilities: livestock operations with buildings or open lots, manure treatment/storage facilities, manure transport systems, and areas of land application.

Livestock Operations

There are many variables that can cause odor that are almost impossible to eliminate. A combination of manure solids, dander, hair, bedding, and feed are the cause of the majority of the dust problems in animal feeding operations. Some larger factors are animal activity, temperature, relative humidity, ventilation rate, stocking density and feeding methods. Dust harbors gases and odors. Dust reduction can significantly reduce problem odors.

There are tools that can be used to aid in the reduction of dust. Mechanical ventilation is very effective in removing gases and dust from production barns but emit these compounds into narrow highly concentrated plumes. Windbreak walls, biomass filters, and biofilters will help reduce the amount of dust that will travel downwind from a mechanically ventilated facility. Frequent cleaning and sprinkler installation are also effective methods used in open lot production. Sprinklers and cleaning are most helpful in the evenings when the animals become more active. There is some concern using this method, because under wet conditions, odors are released.

Manure Treatment/Storage Facilities

Manure waste can be stored as a liquid or a solid. Liquid waste is stored in liquid storage basins while solid waste may be stockpiled or composted. The majority of the odors from dairies can be blamed on the storage of waste. There are two common types of manure treatment/storage facilities: liquid manure storage and solid manure storage.

There are two common ways to store liquid manure: earthen storage ponds and formed tanks or settling basins. Formed tanks are constructed of steel or concrete. They are located below the floor or possibly in another building above or below ground. Unlike lagoons, liquid manure has no extra water added to enhance microbial activity. The surface area of these tanks is smaller than that of storage ponds or anaerobic treatment lagoons. These tanks produce a concentrated form of odor because the manure is more concentrated. Odor control covers can be placed over the top of tanks or basins to prevent the odor from escaping.

Odors from solid waste storage are usually considered to be less offensive than those from liquid storage. The liquid is removed from the solid waste and can be stored using two different methods. The two types of systems are stacking and composting. Stacking is for storage only, while composting is treatment and storage. In order for the solid manure to break down, it has the appropriate ratio of carbon, nitrogen, porosity, and has the appropriate moisture level. By frequent mixing, non-composted material is mixed with composted material increasing the treatment efficiency and reducing the time in which the material is stabilized. Solid manure can be stored indoors to prevent exposure to wind, blown soil, and rain.

Land Application Areas

Typically, more than 50% of all odor complaints filed nationwide are a result of applying manure. When the manure is applied to land, it enlarges the surface area and allows a large odor plume to form. One way to solve this dilemma is to directly rapidly incorporate or inject the manure into the soil. Odors can also be caused if concentrated liquid manure is pumped through the irrigation systems at high pressures or without dilution.

Other Emission Sources

Dead animals have potential to be a source of odor. Proper disposal of dead animals is a must. Animals should never be disposed of in manure basins, or storage pits. Truck and tractor activity can cause large amounts of dust. Heavily traveled roads should be graveled or watered regularly to keep the dust down.

Physical Factors Affecting Odors

The physical environment can have a great affect on the emissions of odors on or off the farm. Little can be done to change the weather, but there are some management strategies that can be used to reduce odors before they spread. Some of these factors that can be managed are oxygen, temperature, moisture content, time, dilution, air stability, and dust.

Oxygen

The presence or absence of oxygen in a material can affect the odor it emits. Situations where oxygen is not present, an anaerobic environment, produce the strongest odors. When oxygen is present, an aerobic environment, odors can be reduced greatly.

Temperature

The greater the temperature of the atmosphere the more reactions occur causing odors. For every 20°-Fahrenheit increase in ambient temperature doubles the speed of biological reactions.

Moisture Content

Moisture content can affect the reactions that occur in decomposing material. The higher the water content, the less oxygen is present, again causing more intense odors. Water in decomposing material can also become volatile and produce odors that mix with the air. Lower levels of moisture can slow the number of reactions occurring that produce odors.

Time

The longer a substance is allowed to decompose, odors produced will become more offensive. The majority of offensive odors are produced in the first three to five days of decomposition. If a long enough time period has passed, the odors will decrease, because the breakdown reactions have slowed.

Dilution

The intensity of an odor is reduced as the dilution ratio is increased. High concentrations of organic material and poor ventilation will be the perfect foundation to produce highly concentrated odors.

Air Stability

Air stability can be affected by wind speed, air temperature, and topography. These factors are very hard to manipulate and change; however, management tools can be used to reduce the spread of odors by these factors.

Dust

Odor compounds can easily attach themselves to dust particles. Dust reduction around an animal operation is a very important factor in dropping the level of odors traveling long distances.

Open Lot Facilities

Environment and short-term weather patterns are the primary cause of dust and odor emissions from confined animal facilities. During low moisture conditions dust is the primary problem of open lots. Under high moisture conditions odor is the primary problem. Water management is very important to controlling odors produced by open lot facilities. Keeping both dust and odor at their minimum levels by moisture management is impossible, but when the moisture content of an open-lot surface is 25 to 40%, both dust and odor are at manageable levels. When a manageable moisture content is obtained, the other manure properties such as depth, bulk density, and texture become more important factors in controlling dust and odor.

Managing Open Lot Odor

The two most important ways to control odor are avoiding anaerobic conditions by keeping (a) manure and other organic materials as dry as is practicable, (b) manure storages and surfaces exposed to oxygen, and (c) corral surfaces hard, smooth, and free of uncompacted manure.

Open Lot Design

New facilities and expanding operations have the best opportunity to implement odor reduction designs. Existing lots can also be modified to use new designs to help reduce the amount of odor produced.

1. Open lot surfaces should have a slope of 3% to 5% down and away from feed apron to move rainwater away and reduce the likelihood of producing puddles that can turn anaerobic. Mounds can be used to enhance the drainage of the lots. In some situations, mounds may not be practical because of impaired livestock performance.
2. Slopes should also minimize pen-to-pen runoff. This will help prevent water from puddling behind manure ridges that develop under fence lines between corrals.
3. Providing convenient access to corrals. Frequent removal of manure will ensure proper drainage.
4. Use corral soils that are firm, stable, and not easily eroded into rills and gullies. Eroded corrals are prone to detain water.
5. A supply of fill soil may be helpful in maintaining lots. Use the soil to fill areas where erosion and gouging occurs. This will help fill areas where puddles may form.

6. Design pens to have an edge-to-edge manure removal. Odd-shaped pens are harder to maintain and remove the manure properly. Hard, smooth, rectangular- shaped pens are the most effective to remove manure.
7. Minimize the potential for backwater from major drainage channels. Temporary flooding in the bottom end of corrals can contribute to many strong odors. Maintain drain channels to ensure there will be no backwater in the corrals.
8. Divert clean rainfall runoff around corrals and manure storages to relieve pressure on the holding pond and reduce the amount of water that is potentially detained on the corral surface or around the base of manure stockpiles.

Mounds

Manure mounds are constructed in flat, open lots for three reasons:

1. Temporary storage for excess manure.
2. Cattle refuge from muddy, wet, and cold conditions.
3. Means to enhance the water-shedding efficiency of corrals with little or no slope.

Mounds should be placed parallel to the slope of the lot. This will prevent the mound from blocking water flow. Round mound tops promote good drainage and avoid creating holes for puddling. A shallow “W” lot cross-sectional shape is preferred to reduce slope lengths, increase drainage, and reduce manure accumulation along fences. Manure mounds require maintenance to work properly.

The upper half of the mound surface mixed with chopping bedding, a soil mix, or by disking in lime will stabilize the mound. Barn lime reacts more quickly than agricultural limestone. Start by adding one pound of limestone per square foot of mound; add more lime until the mound surface is stable. Fly ash produced by power plants can also stabilize the soil, but may be very heavy in cadmium and lead. If the quality of the ash is low, the stabilizing capacity will be low. Some states may also regulate the use of fly ash, so be sure to check state regulations.

Lot Maintenance

Open lots will always need some type of maintenance to keep odor emissions low. Again, the key is to keep the corral surface hard, smooth, and dry as possible, maintaining a firm 1- to 2- inch base of compacted manure above the mineral soil.

Frequent and proper removal of manure will help maintain the open lots. Removal of manure daily when cows are in the milking parlor will keep the corral surface in excellent shape. Manure removal equipment needs to be adjusted to ensure the 1- to 2-inch layer of compacted manure above the mineralized soil. Weekly removal may be a more economical option and a better management tool to use in your operation.

The type of blade used to scrape the corral can affect the efficiency of the removal of water. Scraper blades that are pushed are more difficult to obtain optimum manure depth and smooth surfaces. Push blades often gouge or scar the surface and reduce the ability for the corral to shed runoff water. Blades that are pulled leave a smoother surface.

Training of machinery operators in the proper techniques and methods is important. It is considered to be a good idea to teach justification, motivation, and the objective of manure harvesting to promote sound decision making.

Frequent inspection of corrals for damage like pits, holes, and wallows is important to a sound management program. This could be as simple as having the feed truck driver, night watchman, or pen riders scout for problems in pen maintenance. The sooner the damage is fixed, the fewer problems will result. Holes and wallows near watering troughs and feeding areas should be a high priority.

Water supply maintenance is essential to prevent puddling of overflow water. Leaky water systems like overflow waters, misters, and water distribution areas can make a significant contribution to odors produced. Feedlot employees should be trained to pick out signs of malfunction in watering systems.

Fence lines need to be inspected to remove any ridges of manure that form under them. The ridges will form dams that will back up the flow of water in the corral and produce odors. The water that puddles because of this is also the prime breeding ground for insects.

Open Lot Runoff Control Structures

- Design corrals, settling basins, and open channels to avoid clogging, backwater and poor drainage.
- Where settling channels are used to reduce solids loading in holding ponds, make sure machinery access for solids removal is convenient under all weather conditions.
- Improve lagoon performance and reduce odor potential by monitoring sludge consistently and removing sludge in a timely manner.
- Use natural topography to make shallow holding ponds. This option is less prone to anaerobic conditions but is probably not feasible in high rainfall areas.
- Pump down holding ponds soon after storm events when weather permits.

Dust Management Plan for Open-Lots

There are many things in common between dust control and odor control. Dust is produced when dry manure is crushed into smaller particles from the action of livestock walking on it. When the animals move around through the corral, the manure dust is suspended in the air. The peak time of day for dust accumulation in the air is late afternoon, evening, and into the early morning hours. Dust accumulation is worse at this time because afternoon heat, wind, and solar radiation remove much of the moisture leaving it dryer than any other time of the day. As the temperatures cool in the evening, cattle become more active. They will move to the feed bunk and start social activities. The atmosphere becomes more stable between dusk and midnight than during the afternoon so many manure particles suspended in the air by cattle activity tend to remain near the ground.

The three general approaches to dust control include:

- Remove dry, loose manure from the corral surface;
- Manipulate the moisture regime at the corral surface to achieve optimum moisture content; and
- Attempt to reduce peak cattle activity during the critical late afternoon hours.

Lot Design

The most effective way to manage odor and dust in an open lot situation is to make sure there is no accumulation of moisture in small, localized areas. In semi-arid and arid regions, applying supplemental moisture to maintain optimum moisture content in the corral surface often offsets daily evaporation. Water trucks should have easy access to a water supply throughout the yard. Deadheading or rolling empty should be avoided over long distances.

It has been proven that reduced stock density will reduce the amount of dust in the air by 29%. This works best in areas of moderate annual rainfall. Stocking densities can have an effect on the behavior of the animals. In cases of high density, there is a greater chance of stress and reduced performance. Managers should experiment with stocking density and manipulation very carefully and on a small scale to ensure there will not be a big disaster.

Other Emission Reduction Options

In high-risk areas close to larger populations and more traffic, additional steps may need to be taken in order to reduce emissions. Solid set sprinklers, vegetative barriers, and improved manure removal equipment may increase the effectiveness of the management scheme.

Solid-set Sprinkler Systems

Solid-set sprinkler systems work very well in dryer climates, but they are expensive. Sprinkler systems require a great deal of site-specific design based on seasonal water balance calculations, but in general terms, systems should have the following characteristics:

- Sufficient capacity to deliver 0.25 inches or more of water per day across the entire yard.
- Sprinkler patterns that overlap by 50% of the diameter of throw.
- Sprinklers located so that their throw does not extend all the way to the feed apron.
- Water that is drawn from a holding tank to avoid creating a demand peak on the main water system that may reduce drinking water delivery during the hot afternoons.

The use of holding pond water is an experimental technique. Using this method could amplify the possibility of increased disease transmission between livestock.

Vegetative or Artificial Barriers

For odor control around open lots, vegetative and artificial barriers may be used to increase dispersion around open feedlots by elevating dust-laden air from the ground surface and mixing it with cleaner air above. Fast-growing trees also provide a visual barrier that may indirectly reduce nuisance complaints and improve relations with neighbors and passers-by.

Manure Removal Equipment

All equipment should be operated by skilled employees, to ensure a firm, smooth and evenly graded corral surface. Box scrapers do an excellent job because it is easy to adjust the blade height.

Manure Handling and Storage Systems

Odors can be changed when the manure is stored for as little as three days. The application of stored manure on land can be very detrimental to the environmental quality of the air surrounding the area. When storing manure, all disadvantages and advantages need to be accounted for. Storing manure makes it possible to apply when the nutrients in the manure will benefit the plants the most, reducing water pollution and complying with state and federal regulations. However, long-term storage may produce strong odors. This balance between required containment and odor prevention will continue everyday the dairy is in operation. Having a prepared thoughtful review of how your farm manages its manure is the first step in preventing offsite odors.

The location of the manure storage facility needs to be carefully considered. Anything that can be done to create a larger area of separation between the storage facility and the closest neighbors will be an advantage to the farm. It may benefit the farm to have the storage site near the fields where the manure is to be spread. This will reduce labor costs at spreading time and also reduce the concentration of vehicle traffic between the barn and fields.

Open storage systems can cause seasonal problems with odor. Day-by-day changes in the weather can affect the odors produced. Manure storage is usually the main focus of the sources that cause odors. However, collection pits, separation basins and flushing of recycled pond effluent can also be major sources of odor on the farm. Even though these may be much smaller in surface area, these structures may comprise the majority of a farm's odor emission. The following are methods that may be implemented to provide additional odor control:

- Covers
- Liquid-Solid Separation
- Composting
- Anaerobic Digestion
- Liquid Aerobic Treatment
- Manure Additives

Covers

Odors from open manure storage facilities can be greatly reduced by properly covering the stored liquid. Covers reduce the amount of odor, hydrogen sulfide, ammonia, and volatile organic compounds that are given off from the liquid manure. Such reductions are possible one of three mechanisms: 1) minimizing the amount of surface turbulence in the liquid, 2) by providing a substrate for beneficial bacteria to grow and transform these compounds as they move through the cover, or 3) are collected and oxidized by combustion or aerobic digestion. The main disadvantage to covers is their initial cost and for some covers their maintenance. When selecting the appropriate type of cover, the following need to be considered:

- Type and size of manure storage system.
- Type of manure treatment system (if any).
- Frequency of pumping.
- Amount and quality of labor available.
- Cost of the cover material.

The surface area of the cover is typically how the price is determined. The larger the surface area that needs to be covered the higher the cost. The geometry of the pit may also influence the amount of covering needed but not the ability to cover a pond. Impermeable covers have been constructed and maintained over storage ponds of 25-acre or larger for over 15 years. Ponds and basin with sloping side walls will require more cover if the liquid level is managed to vary greatly.

Rigid and Flexible Covers

Rigid covers are commonly made of concrete, wood, and PVC and are used on small and medium sized pits and settling basins. They can reduce odors from a pit as long as the manure is not agitated. Lightweight roofs can be used to contain odorous gases. They can be made of fiberglass, aluminum, and flexible plastic membranes. This type of cover is usually more expensive but lasts much longer than other methods. On average, the typical rigid cover lasts 10 to 15 years. Non-corroding materials can extend the life of covers. Without the non-corroding materials, the covers will only last a few years.

Flexible covers can be used to contain odors from an outdoor system. The tarp is attached to the systems perimeter as tightly as possible. There is a center support column with radiation straps that supports the outer shell. Air is forced in under the cover with a low-pressure blower. This blower will maintain a constant operating pressure. During agitation the cover is deflated allowing it to lie on the support straps.

Permanent roofs constructed of wood, concrete, or an inflated cover can reduce odors as much as 80%. Rigid roofs prevent the loss of ammonia gas by 80%. In another study, the hydrogen sulfide and ammonia emissions were reduced by 95% when an inflated cover was used.

Floating Covers

Floating covers can be made from numerous different materials. There are natural floating covers and artificial floating materials. Natural covers are usually made from the fibrous material in the manure. Artificial floating organic covers, called bio-covers, are commonly made of straw, chopped cornstalks, sawdust, wood shavings, rice hulls, and many others. Polystyrene foam, plastic mats, and Geotextile fabric are also used as covers.

Covering the surface of liquid manure greatly reduces the gases that are expelled into the atmosphere. Permeable covers, like straw, have shown to reduce odors by 60 – 85%. When an aerobic layer is established on the surface of the liquid, odorous compounds that escape may be broken down aerobically before they are released into the atmosphere. Barley, wheat, and chopped cornstalks are used to form an organic floating cover. The straw is applied to the manure storage systems with a chopping/blowing machine. The cost, labor involved, and the life of the cover may vary considerably for organic covers.

A German study estimated the useful life of a straw cover to be six months. Other studies indicated that a 2- or 3-inch layer of straw would only last for several weeks. Canadian studies found that a layer of straw 6 inches in depth could last three to five months only requiring applications of new straw in small areas. Overall, 8-inch thicknesses may work for odor control, but 12 inches are needed for lasting life. The straw may vary in cost considerably. Special equipment is also required to apply the straw on the manure basin.

Other floating permeable covers, such as Geotextile materials, provide a more permanent long-term solution than straw covers. There has been a significant reduction in the levels of hydrogen sulfide, ammonia and odor when Geotextile is used. Because of the difficulty in lifting the cover, Geotextile covers can be especially suited to facilities where manure is not annually agitated and completely pumped out. After the removal of the manure in the fall, the Geotextile may sink to the bottom of the pit and become partially submerged when new manure is added. In the colder winter months, this is not a problem because biological activity is reduced. When spring comes, it may take several months for the Geotextile to dry out and float again. Supports may need to be placed under the Geotextile to keep the cover from becoming submerged. The average life expectancy of a Geotextile is five to seven years and cost approximately \$0.15 to \$0.17 per square foot.

Floating plastic cover sheets are also used to reduce odor emissions. A plastic cover developed in Canada is an inexpensive and lightweight system. Negative air pressure is created with fans and a perforated pipe system to hold the plastic cover up. Fans are used to produce uniform air pressure. Perimeter sealing may be a problem if the manure needs to be agitated or pumped frequently.

Liquid-Solid Separation

One way to reduce energy costs for an aerobic system or to reduce the loading on an anaerobic lagoon is to remove solids from the manure stream ahead of the storage. By separating solids, biochemical oxygen demand (BOD) and nutrient loading are reduced on liquid systems downstream. Two methods to remove solids from manure include mechanical separation and gravimetric settling.

Mechanical separators

Mechanical separators of animal waste include: inclined screens, vibrating-screens, belt presses, and screw presses. Manure is collected in a sump sized to store the largest combination of flush tank capacities or pit storage accumulations. A submersible or stationary bottom-impeller lift pump mixes the manure and liquids into a slurry and pumps it across the separator where the liquid drains off. These devices are effective in solids while producing a product with a moisture content between 60 and 70 percent (Table 3). Separators with few moving parts, such as inclined screens and vibrating-screens, are more effective when large amounts of water are moved through the devices, such as in flushing systems. Most mechanical separators require daily cleaning and flow adjustments. Screens will need to be replaced periodically when the solids removal is decreased.

Gravity Separation

A gravity settling basin may be less costly while removing 50 percent or more of the solids from liquid manure. Solids can be settled and filtered by a shallow basin (2 to 3 feet deep) with concrete floors and walls and a porous dam or perforated pipe outlet. Basins should allow access by a front-end loader to remove solids every 1 to 2 months.

An alternative is an earthen settling basin for 6 to 12 months storage of solids. The basin top width should be no more than 100 feet with a length-to-width ratio near 3:1 and a liquid depth of 8 to 10 feet. The basin contents should be thoroughly agitated and removed for land spreading either by liquid manure spreader or slurry irrigation. If an earthen basin is used, the operator must make the necessary inspections discussed earlier in this chapter for anaerobic lagoons. The dam structure

and waste level must be constantly monitored, and the dam structure maintained to allow visual inspection for structural deterioration.

A third alternative consists of a large rectangular metallic or concrete settling tank with a 3:1 length-to-width ratio with an 8-foot depth. Tank volume depends on a peak-flow wastewater detention time of 10 to 30 minutes. Most solids in livestock manure settle in about 10 minutes although some additional settling occurs for hours. Tank inlets and outlets are baffled and solids are removed by automated skimmers and scrapers. Unless substantial solids storage is added to the settling tank volume, tank cleaning will need to occur frequently.

Flocculants & Polymers

The use of polymers or other flocculants comes up frequently in discussions about solid separation of animal manure. This is especially true from frequent flush or pit recharge swine houses due to the liquid nature of swine manure and the dilution by flush water. Chemical treatment of wastewater involves the addition of chemical flocculents and polymers to alter the physical state of dissolved and suspended manure solids to increase the percent removed by solid separation equipment. Chemicals can be added to wastewater to react with phosphorus and other metals to coagulate dissolved particles into small visible floc. Flocculation then further adheres the coagulated floc upon the addition of a polyelectrolyte that adheres the particles into larger separatable particles. Many natural polymers, such as starches and chitosan, a product from shellfish, and synthetic polymers, such as those derived from polyacrylamide (PAM), are commercially available as flocculants. Solid separation of manure prior to entering the lagoon can provide significant reductions in lagoon nutrient concentrations. This benefit can be enhanced by the use of various polymers. Decisions about whether to use a polymer should consider the cost of the polymer and additional equipment requirements, such as mixing devices and metering pumps that may be needed for polymer addition.

Bench-scale separation evaluations of flushed swine manure over an inclined bed screen separator indicated that a 1/32" screen would be a more efficient choice, than a 1/16" screen, for situations either with or without polymer additions. Some questions that producers may want to consider include: Why is polymer use being considered? Will solids separation alone suffice? Do the costs of the polymer and the additional equipment outweigh the anticipated benefit?

In summary a solid/liquid separator may accomplish the following:

- reduce the volume of manure storage needed
- improve anaerobic digestion
- reduce concentrations of phosphorus, copper, and zinc in sludge and effluents
- reduce pipe clogging problems
- produce value-added by-products
- allow the use of irrigation or direct soil injection equipment
- reduce pumping horsepower needed and increase pumping distances
- allow a greater hauling distance for the solids versus liquid slurry

Composting

Composting is a biological process where microorganisms convert organic material into a soil-like material called compost. The process of composting can be accelerated when managed as a

treatment rather than allow nature to take its course. This is an aerobic process used to reduce the amount of solid waste. The volume of material can be reduced as much as 50%. Composting will also kill all weed seeds and pathogens that are in the manure.

Composting is not typically recommended to be used as an odor control method for solid manure; however, if managed properly, odors should not be a problem. Depending on the type of management, composting can produce many odors or none at all. In order to efficiently compost, the following are required for proper microbial growth: An efficient supply of oxygen (5 - 15%), a moisture content of 50 to 60%, pH between 6.5 and 8.0, and a blend of material that meets a desired ratio of carbon to nitrogen, ideally between 30:1 and 40:1.

Details on the proper method for composting can be found in NRAES 54, *On Farm Composting Handbook*. Management is the key factor to producing a quality product with minimal odor emissions. Ignoring these recommendations will almost certainly guarantee odor problems.

Anaerobic Digesters

Digesters are designed and managed to optimize the bacterial decomposition of organic matter under controlled conditions converting carbon material into methane (CH₄). This process takes between 15 and 21 days to treat animal waste to reduce the odor potential and stabilize the organic material. This process forms odorless by-products primarily methane and carbon dioxide.

Anaerobic digesters are very expensive (\$400/cow) and may only be effective in certain situations. The conversion of methane to electrical power via a generator or producing hot water via a boiler allows the digester to be one of the few manure systems that will help pay for themselves. Economics and management requirements typically limit these systems to operations larger than 500-head and areas where either grant programs or energy contracts greater than \$0.05/kW.

In the 1970's many digesters were installed following government grant programs focuses on reducing our nation's reliance on foreign energy sources. Many of these digesters failed, resulting in a poor "track record" for these systems. These failures relate to issues of low gas yield, low quality gas; poor and inexperienced design and installation; high management requirements; and poor quality equipment and materials selection.

Aerobic Treatment

Aerobic treatment of manure adds dissolved oxygen to the manure, converting carbon to carbon dioxide and microbial biomass. Aeration of the manure can be accomplished by rigorous agitation (surface aeration), blowing air into pumped liquid manure (saturation), or by bubbling air up from the bottom of a tank or pond (micro-bubble aeration). The amount of oxygen required is directly related to the goal of treatment. Odor control has been shown to be effectively reduced when the redox potential of the liquid is above -50mv, approximately 50% of the BOD demand. If BOD reduction is the goal then the aeration system must supply 100% of the oxygen requirement of the microorganisms to stabilize the material. For the conversion of nitrogen and ammonia to nitrate, nearly twice the BOD demand will be required.

Aeration systems have been very well studied because for low strength industrial and municipal waste systems work. Livestock wastes and manure contain much more organic material and non-biologically available than most industrial and municipal waste systems. Therefore, the proper size

of lagoon, equipment and the type of liquid are all very important aspects in designing and operating a livestock aerobic lagoon. System providers should be able to demonstrate how these issues have been addressed in their design.

Loading of Manure Storage Basins

Excessive odors and hydrogen sulfide has been found to several storage basins in the Northwest. The exact “cause and effect” of these odor is not known, however several factors have been found the increase the likelihood of excessive odors being produced in manure basins where both parlor wastewater and manure is stored:

- large amounts of water being used in milk parlor, either for flushing or chiller wastewater
- construction of basin greater than 180-day storage requirement and the pond level is maintained near capacity
- solids accumulation comprises over 15% of the pond storage volume.

Lagoon loading is the mass of volatile solids per unit of lagoon liquid volume that is waiting to be treated. Excessive loading tends to cause odors. Ponds which are loaded at a low rate have been found to support beneficial bacteria.

Pink, red, or purple ponds are associated with low odor. These colors are from naturally occurring sulfur reducing bacteria. This bacterium utilizes sulfide under anaerobic conditions through a process similar to photosynthesis and thus reduces the odor potential of the stored liquid. The organism can also reduce the levels of chemical oxygen demand, ammonium, nitrogen, and soluble phosphorus. Effluent from a purple lagoon can be used to seed a non-purple pond.

High concentrations of several factors can limit the growth of sulfur reducing bacteria:

- arsenic
- copper
- antibiotics

Checking the pH, the electrical conductivity (EC), and oxidation-reduction potential (ORP) can be used to monitor the potential to produce odors. If the pH is too low, hydrated lime or caustic soda can be added. Fresh water can be added if the electrical conductivity is above 2000mv. ORP levels should be between -50mv and 0mv.

Manure Additives

There are many manure additives on the market today that are used in pits, ponds, animals feed, and in the air to reduce odors. Only under appropriate management and favorable environmental conditions will additives work to reduce odors from animal manure. However, research has shown little promise with the effectiveness of additives as a single cure to a farm's odor problem. Field tests showed that some worked well on one farm while being completely ineffective on others.

Microbiological additives

Microbiological additives, or digestive deodorants, generally contain mixed cultures of enzymes or microorganisms designed to enhance the degradation of solids and reduce the volatilization of

ammonia and/or hydrogen sulfide. The microorganisms metabolize the manure. Digestive deodorants need to be added frequently to select for certain bacteria.

Many different studies and research have concluded that there is a wide variability in the results from digestive deodorants. The supplemental organisms may not be suited for the type of environmental conditions the microbes are being introduced into. There are large amounts of different species in manure and that is why it is questionable if adding a small amount of specific microbes will be helpful.

Masking agents

Masking agents only cover one smell with another. Masking agents are a mixture of compounds that have a strong odor of their own. In theory the desirable odor will mask the undesirable odor. This is usually only a short-term solution to an odor problem.

Masking agents are made from vaporized material usually consisting of organic aromatic compounds. Vaporized agents are sprayed directly over the manure. Non-vaporized agents are added directly to the manure. The effects of masking are very difficult to predict because of changing environmental conditions. The main advantages to masking agents are their low costs, and they are non-hazardous to the environment.

Counteractants

Counteractants neutralize odors and do not react chemically with the odors but reduce the perceived odor level. Counteractants are usually neutral and are very safe to handle. Counteractants are more expensive than masking agents, but they usually lower or maintain odor levels. Their effectiveness has been found to not always be predictable.

Adsorbents and absorbents

Adsorbents and absorbents are biological or chemical materials that can collect odorous compounds in their surfaces (adsorb) or interiors (absorb). Examples of materials include sphagnum peat moss, sawdust, rice straw, sodium bentonite, charcoal, and certain natural zeolites.

Chemical additives

Chemical additives chemically alter odorous compounds or enzymes. Chemical additives can be used to kill bacteria that produce volatile organic compounds. Long-term use of chemical additives can be time consuming, costly and require specialized product delivery systems.

When dosing chemicals into manure, side reactions will occur in addition to the desired reactions. When calculating dosing rates, make sure to account for safety and consider all side reactions that may occur. Testing before adding a chemical additive to the whole lagoon or pit is recommended.

Chemical additives are classified by their mode of action:

- Oxidizing agents: Chlorine (as gas or sodium hypochlorite), potassium permanganate, and hydrogen peroxide will oxidize sulfides and inhibit sulfide production. Ozone also has been used as an oxidizing agent.

- Precipitants: Iron and zinc salts will react with sulfides to form insoluble compounds. Ferrous and ferric chloride have been used for that purpose.
- pH control: Sodium Hydroxide or lime can be added to manure to raise the pH, inhibiting sulfide production and preventing hydrogen sulfide off-gassing.
- Electron acceptors: Electron acceptors are taken up preferentially to the sulfate ion, and thus prevent sulfide formation. Sodium nitrate can be used for this purpose.

Land Application

Land application of manure can be a major source of odor. The odors from applied manure can last for a few hours up to weeks. There are several factors that can affect the intensity and duration the odor is present. Surface area is one of the major contributors to the odor. If manure is spread over a large area, a greater amount of manure is exposed to the air. This allows more odor molecules to enter the atmosphere. A smaller area of manure causes odors to be emitted into the air. Solid and liquid manures can also have very different odors. Liquid manure odors are much stronger than solid manure odors. The conditions the manure was stored in and the method of application can also have a great affect on the intensity of the odors emitted when the manure is applied to the land.

Manure Characteristics

It is logical that fresh manure has a different odor than stored manure. Manure with a low liquid content, like bedding, will smell different than manure that has a high liquid content like a lagoon or slurry. In most cases, manure that is stored for long periods of time under anaerobic conditions will have a more intense odor than manure that has been treated in an aerobic lagoon. The aerobic manure will have fewer odors and cause less odor problems when being spread on the land.

Manure that is stored in piles or stacks generally contains fewer odor-causing materials. However, the moisture content of the material will have a great impact on the amount of odor that is being emitted when the piles are disturbed and land applied.

Large amounts of odors can be produced when slurry and liquid manure is being pumped from ponds or tanks. There is a great amount of agitation when pumping liquid manure that causes odors to be released. The method used to apply the liquid manure will determine the odor generated during and after application. Typically, the finer the droplet of liquid manure produced during application, the amount of odor increases. Smaller droplets will also be carried by the wind and odors may spread for over a mile downwind, even under low-wind conditions.

Land Characteristics

The location of the land that is being used will be an important factor in the problems that could arise from manure application. Applicators should take into consideration the distance of the field to the nearest house and where it sets compared to the application site. The closeness of houses may help determine the method of application. For example, direct injection may be considered close to houses and sprinkler irrigation used in area downwind of neighbors..

Injection and Incorporation

Untreated liquid manure can be directly injected into the soil. This method greatly reduces the amount of odor produced from land applications of manure (Table 4). Another common way to apply liquid manure is simply spread it on the soil surface. In order to reduce odor, the liquid manure should be incorporated into the soil as soon as possible. Incorporation of the manure does reduce odors but not near as much as direct injection into the soil.

Speedy incorporation or direct injection also helps the soil retain nitrogen in the form of ammonia. This triples the amount of nitrogen available in the soil that was produced by the manure. It is a

good idea to apply manure to crops that require high levels of nitrogen. The amounts of phosphorus and potassium will also need to be considered in your nutrient management plan.

Many different types of equipment can be used with the injectors. Narrow tines, sweeps, disk injectors and covers (Figure 1), and even the conventional chisel plows can be used when injecting manure into the soil. It is a very important decision when choosing the type of equipment used with the injectors. You will need crop residue left on the soil surface to prevent erosion in wet weather. Concentrated manure or separated manure solids placed on the soil surface should be incorporated with conventional tillage equipment immediately following application to prevent odors.

Drag Hose Injectors

Drag hoses are used for direct injection of liquid manure into the soil from a storage tank. A 4- to 6-inch diameter hose is dragged across a field behind the tractor. This hose delivers the manure to the injector of the low-mounted distribution manifold. If the low-mounted distribution manifold is used, some type of tillage must be performed to incorporate the manure into the soil. Drag-hose injector systems are capable of applying nearly 1 million gallons in a day while dramatically reducing the cost and time of application compared to applying the material in a slurry tank.

Wastewater Irrigation

The use of irrigation equipment is a very efficient way to apply liquid manure onto ground used in a cropping situation. However, this method produces extreme amounts of odor. If managed properly, the odor released from this method can be reduced. Reducing irrigation system odors can be done by:

1. Using nozzles and pressures that produce large-sized droplets.
2. Installing drop nozzles on center pivot systems.
3. Adding dilution water to the liquid manure before applying.

Droplet size plays a very significant part in the amount of odor that is emitted by the manure. Small droplets have a higher potential to be carried by the wind. This will cause the area of drift to be much larger than if a small droplet size was produced. Droplet sizes are determined by the nozzle size and the pressure the system uses. The larger the nozzle and the less pressure a system uses the larger the droplet size and the less likely the drops will drift in the wind. Aerosol drift from irrigation systems is also a public relations issue when the droplets cover a windshield or a drying set of clothes in your neighbor's back yard.

When using center pivots, drop lines can be used to reduce the odors produced during a sprinkler application. Drop lines can extend the nozzles 2 or 3 feet from the pipe to even as much as 8 feet. This will reduce the amount of water that evaporates from the manure before it hits the ground and reduce the length the droplets fall through the air. Consult with your irrigation dealer to ensure that your system is properly designed to prevent erosion or excessive ponding.

Solid Manure

When applying fresh or stockpile solid manure onto fields it should be incorporated into the soil immediately following application. Loading and transferring of solid manure also creates odors. If the solid waste needs to be stored, consider covering it with fresh straw or a finished compost to reduce the amount of odor released into the atmosphere.

Timing and Location of Applications

Choosing the right time and location to make your applications could influence the amount of complaints received from neighbors. Apply on days when the wind is not blowing towards homes of neighbors. Try to spread on weekdays because people are more likely to be away from their homes. Avoid weekends and holidays. It may be a good idea to talk with neighbors to make sure they do not have a social event planned for that day. Letting your neighbor know when you are going to spread large quantities of manure can also be an effective tool. People usually object less if they know ahead of time.

10.7 Odor Management Plans

Manure Management Plans have become a practice for dairies. These plans document the proper handling and application of manure and wastewater onto cropland. Likewise, Odor Management Plans (OMP) systematically identifies potential odor sources, determine odor control practices to reduce these odors, and establish criteria for implementing these strategies (Table 5). A successful OMP can lead to easier and more enjoyable public relations.

The development of an OMP consists of the following five steps:

1. Fully describe the farm and the manure handling, storage and application systems (Table 6)
2. Create a list of potential odor sources on the farm
3. Determine which of the odor sources are the most likely to bring about odor complaints
4. List one or two odor control practices for each of the significant odor sources
5. Develop a protocol to respond to odor complaints

Facility Odor Sources

Nuisance odors can be the result of a single odor event, a single odor source, or the combination of several sources and events. Therefore, it is important to conduct a thorough inventory of all odor sources on the farm (Table 7). This inventory should be conducted on-site in a systematic way to ensure that all odor sources are included. Be specific; include all collection basins and manure storages and stockpiles.

Odors from dairy originate from three primary sources: manure storage structures (including collection and mixing pits, settling basins and stockpiled solids); barns and open lots; and , during the land application of manure. Feed storage, mortality disposal and collection sites, and silage bunkers may also be odor sources.

Develop a bulleted list of odor sources on the facility. Provide a brief description of each odor source, including the size of the odor source (physical area) and its distance from the roadways, neighbors, property boundaries, etc.

The OMP must also identify which of the many on-farm odor sources are likely to have the highest potential to cause nuisance odors. Rank each odor source as low, moderate, or high. Also include an explanation of the ranking and why it is listed as an odor source. Any sources with low odor production should also be listed with an explanation of how current, positive management practices are affecting them. Several factors should be evaluated when ranking odor sources:

- Surface area – more SA, more emission surface
- Frequency
- Duration
- Intensity
- Organic Loading (BOD) – High BOD, high microbial activity, more gas production
- Moisture content – High moisture, more aerobic
- Nutrient levels – High N, more ammonia release
- Chemical compounds (H₂S, NH₃, VFAs, VOCs)

Usually the human nose will work for determining odor problem areas, but everyone's olfactory senses vary in their ability to detect different compounds. Several methods are currently being used to determine odors although many have not been sufficiently researched yet. Include any test results in your explanation for ranking of sources.

These are a few of the devices used:

- Measuring for reduction in BOD – indicates the system is becoming more aerobic
- Olfactometry – collecting air samples and presenting them before a panel of trained/ calibrated individuals to measure intensity. Typically done by specific laboratories
- Nasal Ranger, Mask Olfactometer or Scentometer – devices used in the field to evaluate odor intensity
- N- butanol scale – different dilutions of N – butanol used to compare odor intensity

When ranking sources consider the proximity of the sources to public areas or neighbors. Dilution of odors is caused through the mixing of odor with ambient air. The dilution is a function of distance, topography, and meteorological conditions. Farther distances between odor sources and the public will result in fewer odor complaints. Topographical features can either enhance or reduce dilution depending on the particular feature. Wind breaks or tree lines will encourage mixing of odorous air with clean air, whereas valleys, draws or low areas may concentrate odors. Maximum dilution occurs when the cool air near the ground is heating and rising, especially during the mid-day in full sun. Conversely, during the late evening, the odorous air is trapped near the ground and it will flow downhill in a concentrated plume. Of these three factors – distance, topography and meteorology – separation distance is typically the largest factor leading to nuisance complaints.

Tiered Implementation of Odor Control Practices

Three steps or tiers are typically taken when evaluating solutions to an odor problem. During each tier the level of odor control becomes increasingly more stringent and potentially the cost of control practice becomes more expensive. The tiered process allows facilities to target odor sources with concentrated effective efforts while minimizing cost. The tiered process is a means to achieving the goal of reducing odor emissions and not a mechanism for farms to avoid making necessary changes or capital investments in order to reduce odor emissions. An economic and technical evaluation should be included with each tier.

Tier #1

Pertains to management changes and low cost Odor Control Practice (OCP). It should include a bulleted list of primary OCPs to be implemented. Each bulleted item should address these topics:

- How and when it will be implemented
- Estimate of cost to implement and benefit
- Sources it will impact (reduce odor emission)
- How it will be monitored to demonstrate reduction
- General quantitative and/or qualitative reduction goals

Tier #2

Pertains to more intense management changes and mid cost OCPs. This bulleted list will include secondary OCPs to be implemented. The bullets should contain the information from tier #1.

Tier #3

Pertains to intense management changes and mid-high cost OCPs. Contains the same information as the previous tiers.

Public Involvement

One of the most important pieces of an Odor Management Plan is how the farm will respond to complaints. First, it is sometimes difficult to separate serious odor complaints resulting from excessive odor emissions for complaints registered by disgruntled neighbors during non-odorous events. Second, it is difficult to determine how many valid complaints are needed to trigger the implementation of an odor control technology or a major review of your OMP. And third, there must be some method for monitoring the effectiveness of an odor control technology. The complaint response protocol will set up an OMP and set guidelines for an acceptable number of odor events and some method to evaluate the effectiveness of odor control practices. For this, it is critical to foster and maintain a good relationship with neighbors and other community members.

Avoid Odor Complaints

Avoid odor complaints by making an effort to control odor emissions, including peak odor events such as manure agitation or land application of concentrated manure. These efforts and their perceived effect on odors should be documented.

Establish a Relationship with Neighbors and Community Leaders

An effective complaint response plan requires the input of neighbors and community leaders such as environmental service specialists, regulatory agencies, and county commissioners. These individuals provide an honest evaluation of farm odor impacts. They could be listed on the OMP and help in the development of the complaint response plan. A team approach fosters communication and a flow of information what is critical to responding to complaints.

Monitor Odor Events

Monitoring odor events will help verify odor complaints and identify odor sources. Monitoring might include scheduled drives around the farm perimeter with a notebook recording the date, time, and location of monitoring and recording the relative strength of odors detected. Other monitoring might include record keeping of odor events by neighbors. The strength of odors can be recorded on a three point intensity scale, where 1 = detectable odors, 2 = recognizable odors, and 3 = very distinct and annoying odors.

Set Acceptable Intensity and Frequency Limits

Since odors are a part of all dairy, livestock and poultry operations, it is impossible to expect 100% odor free air around the farm. However, frequent odor events of high intensity are unacceptable. Therefore, some reasonable frequency of odor events should be established. This frequency could include a given number of odor events per month or per year that are acceptable. Above this frequency, the OMP would be implemented. Establishing the acceptable frequency and intensity (how often and how strong) of odor

events should be done with input from your neighbors and community leaders so everyone is familiar with the goals of the farm.

Evaluate Odor Control Practices

After an odor control practice has been implemented, an honest evaluation of its effectiveness is needed. A complaint response plan should outline the evaluation methods and techniques. This evaluation should consist of a mixture of laboratory analysis, field odor assessments and relative odor evaluations as described above.

Your OMP should describe how the public will be involved in the process. Dairies should keep the public aware of actions underway and how the process is going (ex. phone contact, small public meetings, newsletters, newspaper interviews, etc). These actions are at the discretion of the producer. Remember that if the public isn't impacted by the changes in odor then why develop an OMP.

Reviewing your OMP

Periodically the Plan will need to be assessed. The Plan should state who is going to assess it and when in each tier the Plan. Special provisions should also be made if significant changes are made to the manure handling system, Nutrient Management Plan or if there is a dramatic change in odor resulting in odor complaints. Remember that the OMP is a working document that should be flexible and allow for modifications if needed.

Good Neighbor Relations

Being friendly and courteous to people who neighbor the facility can go a long way to help improve the image of the operation. The appearance of the farming operation also helps. A clean atmosphere is much more pleasing to look at than a dirty and unclean one. The way a manager handles complaints and concerns is also a vital part in keeping good relations with neighbors.

Be caring to neighbors. Give advanced notice when you are planning to spread manure that may cause offensive odors. Talk with your neighbors to avoid spreading manure around outdoor weddings, barbecues, picnics, and other social events that may potentially be ruined. Let your neighbors know that you are willing to talk about odor problems and you care. Ask your neighbors if they would like some compost or separated solids for their garden.

A system of communication may also need to be set up. This will help solve any problems before they get out of hand. Some people feel more comfortable talking to someone other than the person with the problem. Give concerned members of the community a contact person to talk to. Lastly, work with community leaders and regulatory agencies before complaints get out of hand. Today, in most parts of the country, community leaders set and enforce the regulations on farming operations. A dairy farmer working with community leaders may lessen the demand for regulations against odor. If dairy farmers do not work with neighbors and community leaders, it could mean losing profits or even your farm.

However, there are things that can be done to help prevent or reduce the amount of odors that are being caused by your facility:

- Develop an Odor Management Plan
- Use of odor-control technology
- Clean-up old manure and feed stockpiles
- Start a dialogue with neighbors, community leaders and regulators

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TABLE 1. Odor Control Technologies and Recommended Management Practices: Dairy

Prepared by: Ron Sheffield, University of Idaho Extension, Twin Falls Research & Extension Center

Location	Technology	Type of Practice T = Technology M = Management	Mode of Practice I = Intensity D = Duration F = Frequency O = Offensiveness	Description	Cost (if available)	Status ID = Installed on Dairy Farm IS = Installed on Swine Farm RA = Re-Application of Technology T = Theoretical - not tested	3rd Party Evaluation
Animal Feed	Ration Manipulation	M	O, I, D	Reduce protein requirement and increase feed conversion: increase dry mater, synthetic amino acids and more digestible supplements (limit feeding corn silage, blood meal and distillers grain).		ID	some
Drinking Water	Chemical Treatment	T	O, I, D	Removal of potential odorants source elements (S, Se) from process and drinking water that will ultimately end up in manure storage.		RA, T	NO
Farmstead	Manure and Feed Cleanup	M	F, I	Aggressive and comprehensive management and clean-up of excess manure and spilt feed on the farm. Additional benefit of reduced dust and flies.		ID, IS	--
	Natural Windbreaks	T	I	Plant hybrid Poplars or other fast growing trees to break wind flow and aerial mixing. Increased aesthetics. Will require irrigation and several years to be effective as windbreak.		IS, RA	some
Feed Storage: Feed	Feed Cleanup	M	F, I	Aggressive and comprehensive management and clean-up of excess manure and spilt feed on the farm. Additional benefit of reduced dust and flies.		ID, IS	--
	Feed Additives	T / M	I, O	Microbial or chemical additives to reduce odors or excreted nitrogen in manure or increase feed efficiency. Effectiveness of odor reduction is highly variable from farm to farm.		T, ID	NO
Feed Storage: Silage Bunkers	Silage Leachate	M / T	F, I, O	Control leachate by minimizing moisture prior to storage following recommendations from NRAES-5 or other professional recommendations. Collect leachate either by adsorption or containment in the liquid manure system. Adsorbed leachate can be diluted and combined with existing compost system. DO NOT compost adsorbed silage leachate material by itself.		ID	--
Feed Storage: Commodity Storage	Grain Concentrates	M	F, I, O	Store grain concentrates under roof and drain all runoff away from feed storage area. Ensure the aggressive and comprehensive management and clean-up of spilt feed between feedings. Additional benefit of reduced dust and flies.		ID	--
Freestall / Open Lot Alley	Automated Scrape Removal Systems	T	I, O	Removal of manure from freestall or outdoor feeding alley via a sidebar and cable/chain. Concentrated, high solid % manure. Frequent manure removal is required.		ID	--
	Vacuum Removal Systems	T	I, O	Removal of manure from freestall or outdoor feeding alley via vacuum tankers. Concentrated, high solid % manure. Frequent manure removal is required.		ID	--
	Flush Systems	T	I, O	Frequent removal of manure from freestall or outdoor alleys via hydraulic conveyance. Dilute, low solid % manure. REQUIRES further treatment in addition to solid separation (maximum TSS of 1%).		ID	--
	Ozonation of Flush Water	T	I, O	Oxidize odorants and VOCs, increase ORP. Must consider the poor effluent quality (High % Solids) and pumping distance when calculating pipeline retention time. Ozone generators have traditionally been very fragile and expensive to operate (high electrical cost).		T, ID	NO
Freestall	Acidification of Freestall Compost Bedding	M	I, D, F, O	Addition of low pH solutions to reduce ammonia emission from freestall bedding (AICI) in granular or concentrated liquid forms.		T, RA	NO
Land Appliation: Pre-plant Application	Manure Incorporation	M	I, D, F, O	Incorporation of broadcasted or irrigated manure immediately following application as possible or within 24-hours (maximum).	~ \$5.00/ac applied	ID, IS, RA	YES
	Manure Injection	M / T	I, D, F, O	Direct incorporation of manure via tank or hose-drag applicators. Injector options include: disc incorporators, sweep, no-till, chisel and rotary aerator.	~ \$0.001/gallon applied	ID, IS, RA	YES
	Manure Injection	M / T	I, D, F, O	Limited inner row incorporation on early growth crops (tankers) or injection into newly harvested alfalfa (tankers or hose-drag).	~ \$0.001/gallon applied	ID, IS, RA	YES
Land Application: Irrigation	Fresh Water Dilution	M	I, D, O	Dilute applied manure with freshwater; side-rolls and low pressure (< 35 psi) drop nozzles: 5 to 10 times; high pressure sprinklers or overhead sprinklers on pivots: 8 to 10 times.		ID, IS	YES
	Low-Pressure Application	T / M	I	Use low pressure (35psi max.) drop nozzles/sprinklers that encourage large droplet production.		IS, T	NO
	End-Gun Prohibition	M	I, F	Cease use of center pivot end-guns		RA, ID, IS	--
	"Dribble" Drop Hoses	T / M	I	Low pressure drop hoses with application bladders or dribble nozzles to apply high volumes directly to soil surface. Must consider lower application uniformity and high precipitation rates. High runoff potential.		RA, ID, IS	??
	Inner-Canopy Applications	M	I	Extended low pressure drop hoses used primarily when crop growth is above sprinkler. Must consider lower application uniformity and high precipitation rates.		RA, IS	YES
	Pre-Application Aeration/Oxidation	T / M	I, D, F, O	Aeration of stored manure/effluent prior to application. Oxidize odorants and VOCs, increase ORP.		T, IS	
	Pre-Application Ozonation/Oxidation	T / M	I, D, F, O	Similar to Pre-Application Aeration. Oxidize odorants and VOCs, increase ORP. Must consider the poor effluent quality and pumping distance when calculating pipeline retention time. Ozone generators have traditionally been very fragile and expensive to operate (high electrical cost).		T, ID, IS	NO

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TABLE 1. Odor Control Technologies and Recommended Management Practices: Dairy (continued)

Prepared by: Ron Sheffield, University of Idaho Extension, Twin Falls Research & Extension Center

Location	Technology	Type of Practice T = Technology M = Management	Mode of Practice I = Intensity D = Duration F = Frequency O = Offensiveness	Description	Cost (if available)	Status ID = Installed on Dairy Farm IS = Installed on Swine Farm RA = Re-Application of Technology T = Theoretical - not tested	3rd Party Evaluation
Manure Solids	Composting	T	I, F, O	Aerobically digest solid manure or separated manure solids. Maintain adequate porosity, MC (50-60%) and C:N (25-30:1). Excessive moisture and low C:N may lead to high NH3 losses and odors.		ID, IS	some
	Manure Separation	T / M	I, O	Reduce solids to liquid storage: reduces BOD load, improved handling. Creates second waste stream and potential odor source. Gravity separation ~ 50% removal, mechanical ~35% maximum (however, efficiency is quite variable between technologies, applications and manufacturers).	varies	ID, IS	some
Outdoor Stockpiles	Permeable Synthetic Biocover	T	F, I	"GorTex" like cover to reduce odor, NH3 emissions.		RA	YES
	Permeable Organic Biocover	T	F, I	Manure stockpiles covered in mature compost		ID, IS, RA	YES
Open Lot	Manure Removal / Dust Suppression	M	F, I	Removal of accumulated manure and bedding from corrals. Dust suppression to maintain ~30% MC on corral surface. MC >40% will cause higher odor emissions.		RA	YES
	Corral Drainage	M	D, F	Maintain surface grade and fill all runoff fills that form following heavy storms.		ID	--
	Acidification of Corral Surface	M	I, D, F, O	Potential application of alum or other acids to reduce ammonia emissions. Winter applications will largely reduce emission during spring cleanouts, summer applications will reduce odor and dust during summer. Research required to determine application rates, application intervals and system cost.		T, RA	NO
Storage Basin / Lagoon	Anaerobic Treatment Lagoon	T / M	I, F, O	Anaerobic treatment and storage lagoon to reduce odors, BOD and TSS. Uncovered anaerobic treatment lagoons will result in the loss of >60% of manure N.		ID, IS	YES
	Anaerobic Digestion	T / M	I, F, O	Anaerobic destruction of organic matter in manure to encourage the production of methane (CH4). Produces relatively odor free liquid. Potential for energy recovery (heated water, electrical co-generation). Works best with concentrated manure handling systems (scrape, automated scrapers and vacuum).	covered lagoon \$400 - 700/cow; complete mix \$450 - 600/cow; plug flow \$400 - 500/cow	ID, IS	YES
	Aerobic Digestion	T / M	I, F, O	Aerobic digestion of organic matter. Produces relatively odor free liquid. Depending on aeration rate - may result in large production of biomass to be land applied or digested. Electrical costs of aeration must be considered.	\$300 - 600/cow plus operating cost	ID, IS	YES
	Lagoon / Manure Additives	T / M	I, O	Microbial or chemical additives to reduce odors from stored manure. Typically either oxidants, microbial colonies, masking agents or microbial inhibitors. Effectiveness of odor reduction is highly variable from farm to farm.		T, ID	NO
	Impermeable Cover	T	F, I	HDPE or similar cover for odor control or methane capture	~\$0.65/sq.ft.	ID, IS	YES
	Geotextile - Permeable Cover	T	F, I	Geotextile cover to reduce odors, VOCs and H2S	~ \$0.18/sq.ft.	IS	YES
	Granular Foam Biocover	T	F, I	Permeable biocover to reduce odor, NH3, VOCs & H2S		RA	NO
	Fixed Foam & Geotextile Cover	T	F, I	Permeable biocover to reduce odor, NH3, VOC & H2S		IS, RA	YES
	Straw Biocover	T	F, I	Barley and wheat straw biocovers for winter storage		IS, RA	YES

Table 2. Methods for describing and analyzing odors.

Odor Test	Definition	Analytical Methods
Intensity (strength)	Strength of an odor sample above the detection threshold.	N-butanol
Duration / Persistence	Measure of how easily the odor can be diluted in air: Full strength intensity divided by threshold concentration.	N-butanol and D/Td
Frequency	Return interval (hours, days) of a detected odor.	No analytical measure.
Offensiveness / Hedonic tone	Measure of unpleasantness of an odor. Typically displayed as a scale: -10 (unpleasant) to +10 (pleasant).	Odor Panel
Character descriptor	Description of an odor. Trained panelists use standardized terms such as sulfide, rancid, putrid, or phenolic.	Odor Panel
Threshold Concentration (D/Td) - Detection	Volume of non-odorous air needed to dilute a unit volume of air to the point where panelist begin to detect an odor.	Olfactometry; field olfactometer; scentometer,
Threshold Concentration (D/Tr) - Recognition	Volume of non-odorous air needed to dilute a unit volume of air to the point where panelist begin to recognize an odor. $D/Tr \geq D/Td$	Olfactometry

Table 3. Performance of Mechanical Separators. Adapted from: Zhang, R.H. and P.W. Westerman. 1997.

Separator - Animal	Screen Size (mm)	Total Solids in Raw Manure (%)	Separation Efficiency (%)			
			Total Solids	COD	Total Kjeldhal Nitrogen	Total Phosphorus
Stationary Screen						
Swine	1.5	0.2 – 0.7	9	24	-	-
	1.0	0.2 – 0.7	35	69	-	-
	1.0	1.0 – 4.5	6 – 31	0 – 32	3 – 6	2 – 12
Dairy	1.68	4.6	49	-	-	
Vibrating Screen						
Swine	1.7	1.5	3	6	-	-
	0.841	1.5 – 2.9	10	1 – 14	-	-
	0.516	1.8	27	24	-	-
	0.516	3.6	21 – 52	17 – 49	5 – 32	17 – 34
	0.39	0.2 – 0.7	22	16	-	-
	0.44	1 – 4.5	15 – 25	13 – 26	2 – 5	1 – 15
	0.104	3.6	50 – 67	48 – 59	33 – 51	34 – 59
Dairy	1.7	0.9 – 1.9	8 – 12	-	-	-
	0.841	1 – 1.8	12 – 13	-	-	-
	0.6	1 – 1.7	10 – 16	-	-	-
Rotating Screen						
Swine	0.75	2.5 – 4.12	4 – 8	4	-	-
	0.8	1 – 4.5	5 – 24	2 – 19	5 – 11	3 – 9
Belt Press						
Swine	0.1	3 – 8	47 – 59	39 – 40	32 – 35	18 – 21
Centrifuge						
Swine	-	1 – 7.5	15 – 61	7.8 – 44	3.4 – 32	58 – 68

Table 4. Odor reduction using various Land Application Methods.

Application Method	Odor Threshold
Broadcast	2818
Plow	200
Harrow	131
Inject	32
Unmanured	50

Table 5. Typical Contents of an Odor Management Plan (OMP).

- 1. Cover Sheet**
- 2. Facility Information**
- 3. Facility Description & Vicinity Map**
- 4. Description Manure Management System & Site Map**
- 5. Description of Land Application System**
- 6. Climatic Data**
- 7. Facility Odor Sources and Rankings**
- 8. Tiered Implementation of Odor Control Practice**
- 9. Public Involvement**
- 10. OMP Review Process**

Table 6. Farm and Manure Systems Information Needed in Odor Management Plans.

Cover Sheet

- The facility for which the plan was prepared
- Who prepared the plan
- Whom they are associated with (i.e. consulting firm, engineering firm, university, etc.)
- Primary contact phone number
- Signature line for reviewer to sign and date

Facility Information

- Facility Name
- Physical address of the facility
- County
- Owner and Operator
- Other contacts associated with implementation of OMP
- Phone numbers- facility and primary numbers for listed contacts

General

- Type of facility
- Number of animals present and future, include: age ranges, breeds(feedlots note the majority breed)
- Type of housing used related to age groups
- General description of nearby residential and public use areas, etc.
- Scaled Vicinity Map
 - Potential areas for odor movement
 - All Residences
 - Public use areas (parks, recreational areas, schools, etc.)
 - Roads general topography, etc.
 - Other CAFO facilities within a 2-mile radius of the facility

Climatic Data

Typical climate conditions for the area as well as conditions when odor is most prevalent. Requires minimum of two years data(recommend five years). Weather information can be obtained from local area weather stations and on several web pages.

- Odorous conditions – decomposition of organics
- Amount of gas released and where it travels
- Wind Speed and direction(s)
- Temperature ranges during seasons
- Relative humidity
- Precipitation

Manure Management System

Very detailed description of current manure handling system:

- Cleaning systems and management
- Transfer systems and management
- Separation systems and management
- Include descriptions of:
 - Timing
 - Frequency
 - Duration
 - Volumes
 - Dimensions
 - Flow Rates
 - Location of bypasses, etc.
- Scaled Site Plan (if not on file with the ISDA)
 - Visual for manure management system
 - Detail: housing, transfer mechanisms (direction of movement), separation systems, storage areas.

Land Application Systems


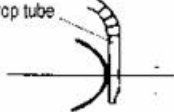
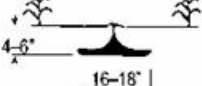




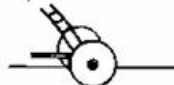
Present management practices used to land apply both solid and liquid manure:

- Type of equipment used
- Delivery systems
- Timing, frequency, and duration of practices
- Proximity of residential and public use areas to land application sites
- Land Application Site Plan (optional)- ISDA may already have one on file in a Nutrient Management Plan

Table 7. Potential odor sources on a dairy.

Process	Location	Information needed in OMP
Manure Storage & Processing	Liquid storage ponds	Size, depth, storage period
	Separation Systems	Type, screen size, removal frequency, size & depth of gravity basins
	Solids storage areas	Size, removal frequency, runoff collection
	Pumping stations	Size, operation cycles
Manure Removal	Scraping	Removal frequency
	Flushing	Removal frequency, flush volume
Feed Management	Feed storage areas	Feed description, runoff collection
	Feed Alleys	Feeding and cleaning frequency
Animal Housing	Barns	Size
	Open Lots	Size, lot maintenance, runoff collection
Animal Mortalities	Collection Areas	Size, fly and vector control, removal frequency
	Disposal Area	Size, fly and vector control, removal frequency
Land Application	Liquid Manure	Method, locations, frequency, pressure, incorporation method
	Solid Manure	Method, locations, frequency, incorporation method

Figure 1. Manure Placement by Manure Injectors.

Row Crop Application Method	Placement of Manure (not to scale)	Application Implement (side views)
a) Injection: vertical knife/chisel		
b) Injection: horizontal sweep		
c) Shallow incorporation: s-tine cultivator (staggered)		
d) Shallow incorporation: concave disks		

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