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Odor Control Practices for Northwest Dairies

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Introduction

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

Little information is 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 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 effect to control the amounts of ammonia and hydrogen sulfide released into the atmosphere.

There are various ways to prevent or even eliminate odors produced from dairies and other similar operations. A livestock farm operator 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 draw an effective 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. Understanding airborne contaminants' movement and odor intensity is a must in evaluating and minimizing the effects of odor emissions.

This publication will focus on four key issues: understanding odors, selecting odor control technologies and practices, developing odor management plans, and responding to complaints from neighbors. Methods of mitigating odors will be discussed; for example, mechanical, chemical, and biological control of odors. Additionally, Table 6 is a comprehensive list of odor practices and technologies that may be considered for control of odors on dairies in the Pacific Northwest. The table is a list of suggestions for reference 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 along with production goals, inventory of existing infrastructure, regulatory requirements, the intensity of the odor problem, and the farm's nutrient management plan.

Sources of odor emissions

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

Livestock stations—importance of dust reduction. Dust harbors gases, odors

Many variables cause odors 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. Other factors include animal activity, temperature, relative humidity, ventilation rate, stocking density, and feeding methods. Dust harbors gases and odors and, therefore, dust reduction can significantly reduce problem odors.

Tools can aid in the reduction of dust. Mechanical ventilation is very effective in removing gases and dust from production barns, but it emits 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 evenings when animals become more active. However, there is some concern using this method because wet conditions may exacerbate odor release.

Manure treatment/storage facilities—source of most odors

Most of the odors from dairies come from manure storage. There are two common types of manure treatment/storage facilities: liquid manure storage and solid manure storage. Liquid waste is stored in storage basins while solid waste may be stockpiled or composted.

Liquid manure: Two common ways to store liquid manure are storage ponds and formed tanks (settling basins). Formed tanks are constructed of steel or concrete and located below the floor or possibly in another building above or below ground. Unlike in lagoons, liquid manure in these structures 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 stronger odors than lagoons because the manure is more concentrated. Impermeable covers can be placed over the top of tanks or basins to prevent odor from escaping.

Solid waste: Odors from solid waste storage are usually considered to be less offensive than those from liquid storage. The solids removed from the liquid after a solid-liquid separation can be either stockpiled or composted. Stacking is for storage only, while composting is for both treatment and storage. For the solid manure to break down (biodegrade), the appropriate ratio of carbon to nitrogen, porosity, and moisture level must be provided. Frequent mixing or turning of non-composted material increases the treatment efficiency, thus 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 of manure areas—biggest source of complaints

Typically, more than 50 percent of all odor complaints filed nationwide occur during manure applications. When manure is applied to land, its exposed surface increases allowing 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 are potential sources 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 affects emissions of odors on or off the farm. Although little can be done to change the weather, management strategies can be used to reduce odors before they escalate. Some 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 limited or not present create anaerobic environments and produce more odors than situations with plenty of oxygen (aerobic environments).

Temperature: The greater the temperature the faster biological reactions occur. Every 20°F increase in ambient temperature doubles the speed of biological reactions. Anaerobic conditions speed the production of odors but shorten the duration of odor production. Aerobic conditions speed bio-stabilization of the waste resulting in reduced odor production.

Moisture content (MC): Moisture content affects 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 biological reactions that produce odors.

Time: The longer a substance is allowed to decompose, the more the odors produced will become more offensive. However, the majority of odors are produced in the first three to five days of decomposition. Odor production or release decreases with time because organic material breakdown rates also decrease with time.

Dilution: The intensity of an odor is reduced as the dilution ratio is increased. High concentrations of organic material and poor ventilation are a 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 or 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, therefore, an effective method of reducing odor dispersion from the source.

Open lot facilities—importance of water management

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 in 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 percent, both dust and odor are at manageable levels. When optimal moisture content is reached, other manure properties such as depth, bulk density, and texture become more important factors in controlling dust and odor.

Managing open lot odor

The three 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—eight suggestions

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. Here are eight suggestions.

1. **Slopes**: Open lot surfaces should have a slope of 3 to 5 percent down and away from the feed apron to move rainwater away and reduce the likelihood of pro-

ducing puddles that can turn anaerobic. Mounds can be used to enhance drainage of the lots. In some situations, mounds may not be practical because of impaired livestock performance.

2. **Runoff**: 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. **Corral access**: Provide convenient access to corrals. Frequent removal of manure will ensure proper drainage.
4. **Firm soils**: Use corral soils that are firm, stable, and not easily eroded into rills and gullies. Eroded corrals are prone to detain water.
5. **Fill soil**: 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**: Design pens to have an edge-to-edge manure removal. Odd-shaped pens are harder to maintain. They make it more difficult to remove the manure properly. Hard, smooth, rectangular-shaped pens are the most effective for manure removal.
7. **Drain channels**: Minimize the potential for backwater from major drainage channels. Temporary flooding in the bottom end of corrals can be a source of strong odors. Maintain drain channels to ensure there will be no backwater in the corrals.
8. **Divert rainfall**: 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: 3 reasons for them

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.

Stabilize the mound by mixing the upper half of the mound surface with chopping bedding, a soil mix, or by disking in lime. Barn lime or hydrated 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 toxic 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 helps limit odor emissions

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 as 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 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. If manure is not removed daily, lots should be harrowed to break up manure droppings and to help dry urine spots.

The type of blade used to scrape the corral can affect the efficiency of water removal. Scraper blades that are pushed make it 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.

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 waterers, misters, and lot sprinklers can make a significant contribution to odors produced. Feedlot employees should be trained to watch for malfunctions 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

- **Corrals**: Design corrals, settling basins, and open channels to avoid clogging, backwater, and poor drainage.
- **Settling channels**: 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.
- **Lagoons**: Improve lagoon performance and reduce odor potential by monitoring sludge consistently and removing sludge in a timely manner.
- **Holding ponds**: 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.
- **Holding ponds**: Pump down holding ponds as soon after storm events as 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 activity of livestock. When the animals move around the corral, manure dust is suspended in the air. The peak times of day for dust accumulation in the air are late afternoon, evening, and early morning hours because afternoon heat, wind, and solar radiation remove much of the moisture leaving it dryer than any other times 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 more 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;
- Maintain moisture regime at the corral surface to within 25 to 40 percent moisture content; and
- Attempt to reduce peak cattle activity during the critical late afternoon hours.

Lot design: avoid dust, moisture accumulation

The most effective way to manage odor and dust in an open lot 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 percent. 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 carefully with stocking density on a small scale to avoid disaster. Research is not clear on what the limit is. This relationship has yet to be fully understood.

Other emission reduction options

In high-risk areas close to larger populations and more traffic, additional steps may need to be taken 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 evenly across the entire yard
- Sprinkler patterns that overlap by 50 percent 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 hot afternoons

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

Noxious odors can be generated when manure is stored for as little as three days. Application of stored manure on land can be detrimental to the air quality in the surrounding area. 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. A 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 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 methods 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 significantly reduced by properly covering the stored liquid. Covers reduce the amount of odor, hydrogen sulfide, ammonia, and volatile organic compounds that are emitted from stored liquid manure. Such reductions are made possible by: 1) minimizing the amount of surface turbulence in the liquid, 2) providing a media for beneficial bacteria to grow and transform these compounds as they move through the cover, and 3) containing odorous gases until they are treated via a biofilter. The main disadvantages of covers are their initial cost and/or maintenance. When selecting the appropriate type of cover, consider:

- 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 covering cost. Impermeable covers have been constructed and maintained over storage ponds of 25-acres or larger for more than 15 years.

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 made of fiberglass, aluminum, and flexible plastic membranes, can be used to contain odorous gases. These types of covers are usually more expensive but last much longer than other types of covers. On average, the typical rigid cover lasts 10 to 15 years. Non-corroding materials can extend the life of covers. Without non-corroding materials, 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 percent. Rigid roofs prevent the loss of ammonia gas by 80 percent. In one study, hydrogen sulfide and ammonia emissions were reduced by 95 percent when an inflated cover was used.

Floating covers

Floating covers can be made from natural and artificial floating materials. Natural covers are usually formed from fibrous materials in the manure and appear as floating crusts. Artificial floating organic covers, called bio-covers, are commonly made of straw, chopped cornstalks, sawdust, wood shavings, rice hulls, and many other similar materials. Polystyrene foam, plastic mats, and geotextile fabric are also used as covers.

Covering the surface of liquid manure greatly reduces gases that are emitted into the atmosphere. Permeable covers, like straw, reduce odors by as much as 60 to 85 percent. When an aerobic layer is established on the surface of the liquid, odorous compounds that escape are broken down aerobically before they are released into the atmosphere. Barley, wheat, and chopped cornstalks are used to form an organic floating cover. 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.

Researchers in Germany have 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. Studies conducted in Canada indicated 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 extended life. 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 fabric, 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 covers are used. Because of the difficulty in lifting the covers, geotextile covers are especially suited to facilities where manure is not frequently agitated and/or 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 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 cover is five to seven years. It costs approximately $0.25 to $0.32 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. Air pressure under the plastic 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 gravity settling.

Mechanical separators

Mechanical separators of animal waste include: inclined screens, vibrating-screens, belt presses, and screw presses. Manure is collected in a pit sized to store all the flush water to be used until separation is done. 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 to storage as the solids accumulate below the separator. These devices are modestly effective in removing solids producing a product with a moisture content of between 60 and 70 percent (Table 1).

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 rate decreases.

Gravity separation

A gravity settling basin is cheaper and can remove 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 when necessary.

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. Basin contents should be

Table 1. Performance of mechanical separators (Source: Zhang, R.H. and P.W. Westerman, 1997)

Separator	Animal	Screen Size (mm)	Total Solids in Raw Manure (%)	Separation Efficiency (%) Total Solids	COD	Total Kjedhal 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

thoroughly agitated and removed for land spreading either by liquid manure spreader or slurry irrigation. If an earthen basin is used, producers may be required to make regular inspections as required by their permit. 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 and polymers

Chemical treatment of wastewater involves the addition of chemical flocculants and polymers to alter the physical state of dissolved and suspended manure solids. This increases the percent of suspended manure solids removed by solid separation equipment. Chemicals can be added to wastewater to coagulate dissolved particles into larger clumps called "flocs." These larger particles can be separated more readily. Decisions about whether to use a chemically enhanced separator system should consider the cost of the chemicals and additional equipment requirements, such as mixing devices and metering pumps that may be needed for chemical addition.

Bench-scale separation evaluations of flushed swine manure over an inclined screen separator indicate that a 1/32" screen is a more efficient choice than a 1/16" screen, 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 allowing nature to take its course. This is an aerobic process used to bio-stabilized solid waste. During the process, the volume of material can be reduced by as much as 50 percent. Composting will also kill all weed seeds and pathogens that are in the manure.

Composting is not typically recommended as an odor control method for solid manure; however, if managed properly, odors should not be a problem. On the other hand, if poorly managed, composting can produce odors. To efficiently compost, the following are required for proper microbial growth: An efficient supply of oxygen (5 to 15 percent), a moisture content of 50 to 60 percent, pH between 6.5 and 8.0, and a blend of material that meets a desired ratio of carbon to nitrogen, ideally between 20:1 and 30:1. (Optimal C:N ratio is 25)

Details on the proper method for composting can be found in NRAES 54, *On Farm Composting Handbook*. See www.nraes.org/. Management is the key factor to producing a quality product with minimal odor emissions.

Anaerobic digesters can generate income from methane

Anaerobic digesters are designed and managed to optimize the bacterial decomposition of organic matter under controlled conditions converting carbon material into methane (CH_4). The process time for treating animal waste to reduce the odor potential and stabilize the organic material varies depending on the system design. The end products of this process are primarily odorless methane and carbon dioxide.

Anaerobic digesters are very expensive ($400/cow) and are only effective if properly managed. 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 can generate income. Economics and management requirements typically limit these systems to operations larger than 500-head and areas where either subsidized programs offset construction or operational costs or where energy costs are greater than $0.05/kW, a unit of power equal to 1,000 watts.

In the 1970s, many digesters were installed following government grant programs focusing 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. A lot of research has been done and is still on-going on anaerobic digestion, and the systems are now better understood. The designs and control of today's anaerobic digesters are much better, and the technology is more promising in controlling odor from animal facilities.

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. If BOD reduction is the goal then the aeration system must supply 100 percent 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 for treatment of low strength industrial and municipal wastes. Livestock wastes and manure contain much more organic material and non-biologically available material than most industrial and municipal waste systems. Therefore, proper sizing of lagoon and equipment selection are very important aspects in the design and operation of 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 have been observed in several storage basins in the Northwest. The exact "cause and effect" of these odors is not known, however several factors have been identified that would 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 a basin greater than 180-day storage requirement, and the pond level is maintained near capacity
- Solids accumulation exceeding 15 percent of the pond storage volume.

Lagoon loading is the amount of volatile solids allowed to be introduced into the lagoon liquid volume each day for treatment. Excessive loading hinders proper treatment of the waste and results in unacceptable odors. Ponds loaded at correct rates provide adequate treatment and have fewer odor problems.

Pink-, red-, or purple-colored ponds are from naturally occurring sulfur-reducing bacteria and are associated with fewer odor problems. The microbe also reduces chemical oxygen demand, ammonium, nitrogen, and soluble phosphorus in the pond liquid. Effluent from a purple lagoon can be used to seed a non-purple pond as long as conditions in the non-colored pond will support growth of this microbe.

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

- Arsenic
- Copper
- Antibiotics

Checking the acidity (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 (millivolt). ORP levels should be between -50mV and 0mV.

Manure additives

Many manure additives on the market today are used in pits, ponds, animal feed, and in the air to reduce odors. Additives work only under appropriate management and favorable environmental conditions. Research has shown little effectiveness of additives as a single cure to a farm's odor problem. Field tests show that some worked well on one farm while being completely ineffective on other farms.

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 and stabilize manure. Digestive deodorants need to be added frequently to select for certain bacteria.

Many different studies and research conclude there is a wide variability in the results from digestive deodorants. The supplemental organisms may not be suited for the environmental conditions in manure storages. Manure already has many different species of organisms so it is questionable whether 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 aromatic organic compounds. Vaporized agents are sprayed directly over the manure. Non-vaporized agents are added directly to the manure. The effects of masking are difficult to predict because of changing environmental conditions. The main advantages to masking agents are their low costs, and they are generally non-hazardous to the environment.

Counteractant

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 is also not always 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.
- **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 odors can last hours to days

Land application of manure can be a major source of odor. The odors from applied manure can last from a few hours up to several days. 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. Solid and liquid manures 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

Fresh manure has a different odor than does stored manure. 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, and it will cause more odor problems when being spread on the land. Solid manure is less odorous than liquid manure or slurry. Manure that is stored in piles or stacks generally contains fewer odor-causing substances. However, the moisture content of the material will have a great impact on the amount of odor that is being emitted when piles are stirred during land application.

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

Land characteristics

Applicators should take into consideration the location and distance of the application site relative to the nearest residence. This information will help determine the method of application. For example, direct injection may be considered close to residences, while sprinkler irrigation may be used in areas far 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 2). Another common way to apply liquid manure is simply spread it on the soil surface. To reduce odor, the liquid manure should be incorporated into the soil as soon as possible. Incorporation of manure reduces odors, but not as much as direct injection into the soil. Speedy incorporation or direct injection also helps the soil retain nitrogen. This can triple the amount of nitrogen available in the soil from the manure

Table 2. Odor reduction using various land application methods

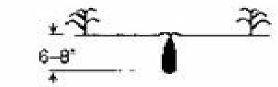
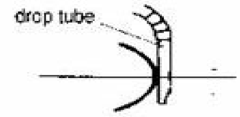
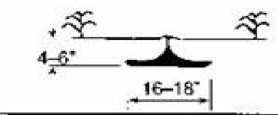
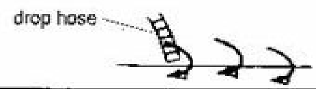
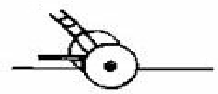
Application Method	Odor Threshold
Broadcast	2818
Plow	200
Harrow	131
Inject	32
Unmanured	50

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. Choosing the type of equipment used with the injectors is an important decision. 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—up to 1 million gal. a day

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 drug across a field behind the tractor. This hose delivers the manure to the injector or a low-mounted distribution manifold. If the low-mounted distribution manifold is used, some type of tillage must

Figure 1. Manure placement 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		

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 using a slurry tank.

Wastewater irrigation—efficient but potentially odorous

The use of irrigation equipment is an efficient way to apply liquid manure when a crop is growing. However, this method may produce 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 rather than spray nozzles on center pivot systems.
3. Adding dilution water to the liquid manure before applying.

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 large 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 systems 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 backyard.

Drop lines can extend the nozzles 2 to 8 feet from the pipe closer to the ground. This will reduce evaporation from the liquid manure before it hits the ground and reduce the length of time 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

Fresh or stockpiled solid manure applied onto the fields should be incorporated into the soil immediately following application. Loading 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: Communicate with 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. Talk with neighbors to make sure they do not have a social event planned during the day of application. 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 you're concerned.

Manure and odor management plans can improve PR

Manure Management Plans (MMP) have become a common practice for dairies. These plans document the proper handling and application of manure and wastewater onto cropland to protect water quality. Similarly, Odor Management Plans (OMP) are emerging to document proper handling of manure and wastewater to protect air quality. Similar to MMP, an OMP systematically identifies potential odor sources, determines odor control practices to reduce these odors, and establishes criteria for implementing these strategies (Table 3). A successful OMP can lead to better public relations.

Five steps for developing an Odor Management Plan (OMP)

1. Fully describe the farm and the manure handling, storage, and application systems (Table 4).
2. Create a list of potential odor sources on the farm.
3. Determine which of the odor sources are most likely to bring about odor complaints and/or rank them in their order of odor generation potential.
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, odor source, or a combination of several sources and events. Therefore, it is important to inventory all odor sources on the farm (Table 5). This inventory should be systematically conducted on-site to ensure that all odor sources are included. Be specific; include all collection basins and manure storages and stockpiles.

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

Table 3. Typical contents of an odor management plan

1. Cover sheet
2. Facility information
3. Facility description & vicinity map
4. Description of 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 4. Farm and manure systems information needed in odor management plans (OMPs)

1. Cover sheet
- The facility for which the plan was prepared
- Who prepared the plan
- Preparer's association or affiliation (i.e. consulting firm, engineering firm, university, etc.)
- Primary contact phone number
- Signature line for reviewer to sign and date

2. 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

3. General
- Type of facility
- Number of animals present and future plans, include: age ranges, breeds (feedlots note the majority breed)
- Type of housing used related to age groups
- General description of nearby residential and public amenities, 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

4. Climate data

List typical climate conditions for the area as well as conditions when odor is most prevalent.
Requires minimum of two years data (recommend five years).
Obtain weather information from local area weather stations and on several Web sites. Also list:
- 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

Continued on p.15

Table 4. Farm and manure systems information needed in odor management plans (OMP) *(continued)*

5. 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.

6. 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)- Idaho State Department of Agriculture may already have one on file in a nutrient management plan

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 the many on-farm odor sources 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 surface area, more odor emission
- Odor frequency
- Odor duration
- Odor intensity
- Organic loading biochemical oxygen demand or BOD—high BOD, high microbial activity, more gas production
- Moisture content—high moisture, more anaerobic
- Nutrient levels—high N, more ammonia release
- Chemical compounds hydrogen sulfide (H_2S), ammonia (NH_3), volatile fatty acids (VFAs), volatile organic compounds VOCs)

Table 5. Potential sources of odor on a dairy

Process	Location	Information needed in an odor management plan (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

Usually the human nose will work to determine odor problem areas, but everyone's sense of smell varies in the 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.

Devices used: These are a few of the devices used.

- **Measuring reduction in BOD**—indicates the system is becoming more aerobic
- **Olfactometry**—collecting air samples and presenting them before a panel of trained 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 the sources, consider the distance 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 will result in fewer odor complaints. 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—inadequate separation distance is typically the major 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 odors sources with effective control efforts while minimizing cost. An economic and technical evaluation should be included with each tier.

Tier #1—low cost

This involves little management changes and low-cost odor control practices (OCP). It should include a bulleted list of primary OCPs to be implemented. Each bulleted item should address the following points:

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

Tier #2—moderate cost

This involves moderate management changes and moderate-cost OCPs. This bulleted list will include secondary OCPs to be implemented. The bullets should contain the information from tier #1.

Tier #3—mid to high cost

This involves most management changes and mid-to-high cost OCPs and should contains the same information as the previous tiers.

Public involvement: Responding to complaints

One of the most important pieces of an odor management plan is how the farm will respond to complaints. First, it is difficult to separate serious odor complaints resulting from excessive odor emissions from complaints registered by disgruntled neighbors. 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 neighboring residents 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, which 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 percent 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, odor control practices 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 either through phone contact, small public meetings, newsletters, or newspaper interviews. These actions are at the discretion of the producer.

Odor management plan (OMP) review

Periodically the OMP will need to be assessed. It should be clearly be stated who is going to assess it and when. 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 increase in odor complaints. Remember, 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 farmstead is much more pleasing to look at than an 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 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.

Set up a communications system

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. A dairy farmer working with community leaders may lessen the demand for regulations against odor.

Preventing/reducing odors

There are things that can be done to help prevent or reduce odors that are being caused by your facility:

- Develop an odor management plan
- Use odor-control technologies
- Cleanup old manure and feed stockpiles
- Start a dialogue with neighbors, community leaders and regulators

Table 6 offers a comprehensive list of odor control practices and technologies to consider for control of odors on dairies in the Pacific Northwest. It lists suggestions for reference and should not be used as a list of required practices for dairies. The selection of odor control practices should be made along with production goals, inventory of existing infrastructure, regulatory requirements, the intensity of the odor problem, and the farm's nutrient management plan.

Table 6. Potential sources of odor on a dairy

Application	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 Eval.
Source reduction	Animal feed	Ration manipulation	M	O, I, D	Reduce protein requirement and increase feed conversion: increase dry matter, 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
Dispersion	Farmstead	Natural windbreaks	T	I	Plant hybrid poplars or other fast growing trees to break windflow and arial mixing. Increased aesthetics. Will require irrigation and several years to be effective as windbreak.		IS, RA	SOME
Emissions capture & treatment	Storage basin / lagoon	Impermeable cover	T	F, I	HDPE or similar cover for odor control or methane capture.	~$0.65/sq.ft.	ID, IS	YES
	Storage basin / lagoon	Geotextile—permeable cover	T	F, I	Geotextile cover to reduce odors, VOCs and H_2S.	~ $0.18/sq.ft.	IS	YES
	Storage basin / lagoon	Granular foam biocover	T	F, I	Permeable biocover to reduce odor, NH_3, VOCs. H_2S.		RA	NO
	Storage basin / lagoon	Fixed foam & geotextile cover	T	F, I	Permeable biocover to reduce odor, NH_3. VOC & H_2S.		IS, RA	YES
	Storage basin / lagoon	Straw biocover	T	F, I	Barley and wheat straw biocovers for winter storage.		IS, RA	YES
	Outdoor stockpiles	Permeable synthetic biocover	T	F, I	"GorTex" like cover to reduce odor, NH_3 emissions.		RA	YES
	Outdoor stockpiles	Permeable organic biocover	T	F, I	Manure stockpiles covered in mature compost.		ID, IS, RA	YES

Acronyms used in Table 6
BOD—Biochemical oxygen demand
C:N—Carbon to nitrogen ratio
H_2S—Hydrogen sulfide
HDPE—High density polyethylene
MC—Moisture content
NH_3—Ammonia
OMP—Odor management plan
ORP—Oxidation reduction potential
PSI—Pounds per square inch
S—Sulphur
Se—Selenium
TSS—Total suspended solids
VFA—Volatile fatty acids
VOC—Volatile organic compounds

Table 6. Potential sources of odor on a dairy *(continued)*

Application	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 Eval.
Manure collection & treatment	Farmstead	Manure cleanup	M	F, I	Aggressive and comprehensive management and clean-up of excess manure on farm. Additional benefit of reduced dust and flies.		ID, IS	--
	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 nitrogen (N).		ID, IS	YES
	Storage basin / lagoon	Anaerobic digestion	T/M	I, F, O	Anaerobic destruction of organic matter in manure to encourage the production of methane (CH_4). 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
	Storage basin / lagoon	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 operating cost to be land applied or digested. Electrical costs of aeration must be considered.	#300–600/cow plus	ID, IS	YES
	Manure stabilization, handling & storage	Composting	T	I, F, O	Aerobically digest solid manure or separated manure solids. Maintain adequate porosity, moisture content (50-60%) and C:N (25-30:1). Excessive moisture and low C:N may lead to high NH_3 losses and odors.		ID, IS	SOME
	Freestall / Open lot alley	Automated scrape removal systems	T	I, O	Removal of manure from freestall or outdoor feeding alley via a slidebar and cable/chain. Concentrated, high solid % manure. Frequent manure removal is required.		ID	--
	Freestall / Open lot alley	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	--

Acronyms used in Table 6
BOD—Biochemical oxygen demand
C:N—Carbon to nitrogen ratio
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S—Sulphur
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VFA—Volatile fatty acids
VOC—Volatile organic compounds

Table 6. Potential sources of odor on a dairy *(continued)*

Application	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 Eval.
Manure collection & Treatment *(continued)*								
	Freestall / open lot alley	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 total suspended solids of 1%).		ID	--
	Manure handling & storage basin / lagoon	Manure separation	T / M	I, O	Reduce solids to liquid storage: reduce BOD load, improve 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
	Freestall / open lot alley	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 (AlCl) in granular or concentrated liquid forms.		T, RA	NO
	Open lot	Manure removial / Dust supression	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
	Open lot	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

Acronyms used in Table 6
BOD—Biochemical oxygen demand
C:N—Carbon to nitrogen ratio
H_2S—Hydrogen sulfide
HDPE—High density polyethylene
MC—Moisture content
NH_3—Ammonia
OMP—Odor management plan
ORP—Oxidation reduction potential
PSI—Pounds per square inch
S—Sulphur
Se—Selenium
TSS—Total suspended solids
VFA—Volatile fatty acids
VOC—Volatile organic compounds

Table 6. Potential sources of odor on a dairy *(continued)*

Application	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 Eval.
Land Application	Pre-plant application	Manure incorporation	M	I, D, F, O	Incorporate broadcasted or irrigated manure immediately following application as possible or within 24-hours (maximum).	~ $5.00/acre applied	ID, IS, RA	YES
	Pre-plant application	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
	Post-plant application	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
	Irrigation	Fresh water dilution	M	I, D, O	Dilute applied manure with 5 to 10 times the freshwater.		ID, IS	YES
	Irrigation	Low-pressure application	T / M	I	Use low pressure (35psi max.) drop nozzles with rotating sprinklers that encourage large droplet production.		IS, T	NO
	Irrigation	End-gun prohibition	M	I, F	Cease use of center pivot end-guns.		RA, ID, IS	--
	Irrigation	"Dribble" drop hoses	T / M	I	Use 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	??
	Irrigation	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
	Irrigation	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	
	Irrigation	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 traditionaly been very fragile and expensive to operate (high electrical cost).		T, ID, IS	NO

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