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NEW MEXICO ENVIRONMENT TECHNICAL NOTE NO. 10

SUBJECT: ECS – AIR QUALITY LPES EMISSION, DUST AND ODOR CONTROL STRATEGIES

Purpose: To distribute Environment Technical Note 10.

Effective Date: When received.

Filing Instructions: Maintained on web page.

Attached is Environment Technical Note 10. This provides three Livestock Poultry Environmental Stewardship (LPES) lessons on air quality considerations for animal feeding operations: Controlling Dust and Odor from Open Lot Livestock Facilities, Emission Control Strategies for Manure Storage Facilities, and Emission Control Strategies for Land Application.

GEORGE CHAVEZ
State Resource Conservationist

Attachments

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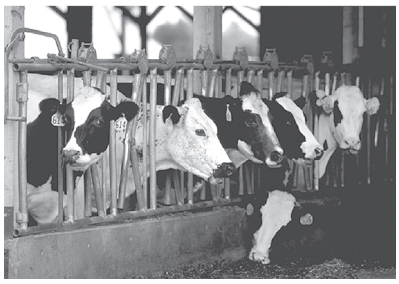
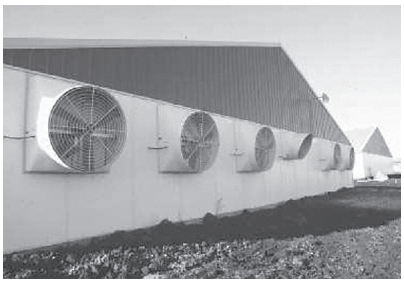
Lesson 44

Emission Control Strategies for Land Application

By Larry Jacobson, University of Minnesota; Jeff Lorimor, Iowa State University; Jose Bicudo, University of Kentucky; and David Schmidt, University of Minnesota

Adapted, with permission, from the proceedings of *Livestock and Poultry Odor Workshop I: Emissions, Measurement, Control and Regulation*, by K. Janni, L.D. Jacobson, J.R. Bicudo, D.R. Schmidt, H. Guo, and R. Koehler, University of Minnesota, St. Paul, copyright 2000.





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Intended Outcomes

The participants will

- Develop or continue odor management plan.
- Determine appropriate or best control technology for their farm.

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Activities

- Give lecture with slides and video.
- Show products.
- Prepare checklist of technologies.

PROJECT STATEMENT

This educational program, Livestock and Poultry Environmental Stewardship, consists of lessons arranged into the following six modules:

- Introduction
- Animal Dietary Strategies
- Manure Storage and Treatment
- Land Application and Nutrient Management
- Outdoor Air Quality
- Related Issues

Note: Page numbers highlighted in green are linked to corresponding text.

Introduction

The land application of manure from livestock and poultry facilities is the most frequent source of odor complaints from the public (Pain 1995, Hardwick 1985). Fortunately, injecting or incorporating liquid manure and incorporating solid manure will significantly reduce odor emissions during land application. To better understand the odor risks associated with your land application practices, a Land Application self-assessment tool (see Appendix A) is provided to assist you.

Description

Land application of manure to cropland is an important component to the long-term sustainability of animal agriculture. Manure application returns nutrients and organic matter to the soil, keeping it healthy and productive. Unfortunately, manure application to cropland does present some environmental risk. Over application of manure can lead to nitrate leaching into groundwater, phosphorus runoff into surface water, and a variety of other pollution problems. Proper manure application requires knowledge of the nutrient content of manure, the nutrient requirements for the crops, the availability of the manure nutrients, the physical limitations of the application equipment, and some understanding of the critical environmental hazards associated with manure application.

Along with water quality problems are nuisance odor concerns. Odor from manure is, in general, offensive to most people. One of the key factors in odor control is the surface area of the emitting source. The larger the surface area, the more odors are emitted. As such, manure applied on the surface of cropland presents one of the most significant sources of odor for any livestock or poultry operation. Applying manure at low rates to avoid over applying nutrients may in fact exacerbate odor problems since the manure must be spread on larger land areas.

Odor may last for a few hours to as much as two weeks, depending on weather conditions and the manure source. Applying manure beneath the soil surface (injected) or covering it immediately after spreading (incorporation) eliminates most of the odor because the odorous gases must then travel up through a soil layer before being emitted into the atmosphere. The soil layer acts as both a trap for odorous gases and an aerobic treatment system, changing odorous gases into less odorous gases through microbial processes. Manure injection or incorporation also reduces manure nitrogen losses to the atmosphere by reducing ammonia volatilization. Field research suggests that odor and ammonia emission reductions of 90% are attainable using shallow or deep injector manure systems versus surface application (Phillips et al. 1988).

Liquid Manure Odor Control Techniques

The odor potential of land applied manure is directly related to the degree of odor generated by the manure storage system. All manure storages are not equal in their odor potential. Anaerobic processes are excellent odor control processes if allowed to proceed to completion. Anaerobic lagoons (Figure 44-1) have substantially lower odor potential due to a lower volatile organic compound (VOC) emission rate (a primary source of odor) as compared to other storage facilities. Spray irrigation of effluent from a purple

The land application of manure from livestock and poultry facilities is the most frequent source of odor complaints from the public... .

...odor and ammonia emission reductions of 90% are attainable using shallow or deep [injection]... .

The odor potential of anaerobic lagoons is affected by time, temperature, and other factors related to the biological processes.

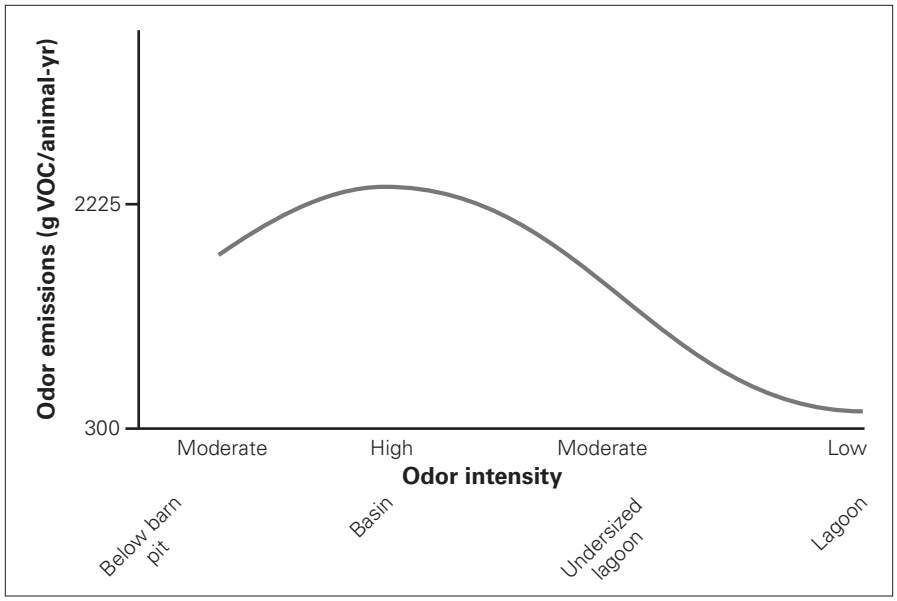

Figure 44-1. Relative odor emissions from different manure storage systems.

lagoon or oversized anaerobic lagoon can be accomplished with less odor than spray irrigation from an earthen basin, below barn pit, or undersized lagoon, which each have very high odor potentials. Manure storage systems that allow anaerobic processes to proceed to completion can be coupled with pivot application of effluents with modest odor risk.

The odor potential of anaerobic lagoons is affected by time, temperature, and other factors related to the biological processes. Thus, management of the facility is a critical factor in defining odor emission from the storage or potential odor emissions during land application. For example, spray irrigation from an anaerobic lagoon in July will have much less odor than spray irrigation from the same lagoon in March.

Some anaerobic lagoon design considerations for minimizing odors are as follows:

- Design anaerobic lagoons with a large permanent pool since it (often 50% of lagoon volume or more) ensures a stable bacteria population for processing odorous compounds and satisfactory dilution of new manure additions. Designing lagoons for light loading rates significantly helps minimize odors.
- Consider time of application. June through fall application of anaerobic lagoon effluent has the least odor. Active biological processes during warm periods better stabilize odors. Winter and spring applications produce the greatest odors due to limited biological activity to stabilize odors during this period.
- Maintain a permanent pool in the lagoon. Clearly mark the top of the permanent pool to avoid over pumping and regularly record the lagoon level.
- Test electrical conductivity and ammonia levels yearly. Salt and ammonia buildup indicates conditions that can be toxic to anaerobic bacteria. Electrical conductivity and ammonium concentration should also be checked yearly. A conductivity reading greater than 10,000 µmho/cm and 670 mg of ammonium/liter (150 lbs of ammonia/acre-inch) indicate a poorly functioning and potentially odorous lagoon.

- To limit salt buildup, pump liquids yearly.
- Add dilution water liberally. When evaporation or low rainfall limits the need for pumping, pump out part of the permanent pool and refill it with fresh water to dilute salts and ammonium. Also liberally use dilution water for barn cleaning, pit recharging, and other housing maintenance activities.
- Establish purple sulfur bacteria population or purple lagoon. Effluent from a purple lagoon can be used to seed a non-purple lagoon. Salt and ammonium concentrations must be acceptable for purple sulfur bacteria to thrive.
- Stop lagoon feeding for two weeks before pumping effluent (allows bacteria to process odorous compounds).

Several methods of reducing odor from liquid manure land applications include incorporating the manure into the soil either during or shortly after it is spread, placing the liquid manure on the soil surface but below the crop canopy, or treating the manure in the storage unit before it is spread on land.

Manure injection into the soil is the most effective way to reduce odor during the land application of untreated liquid manure.

Injection and incorporation

Manure injection into the soil is the most effective way to reduce odor during the land application of untreated liquid manure (Figure 44-2). Table 44-1 shows odor dilution thresholds for various land application methods. One can see that the injection and the unmanured (control) methods have essentially the same odor units. The other common option is to simply spread liquid manure on the surface (Figure 44-3) and immediately incorporate (plow or harrow methods in Table 44-1) into the soil. This method also reduces the odors considerably compared to the broadcast method. However, incorporation after spreading on the surface does not result in as great a reduction of odors as direct injection since some manure remains on the soil surface. Another study (Berglund and Hall 1987) found the odor intensity (measure of odor's strength) from surface application at 400 meters (1,300 ft) downwind was perceived to be equal to that from injection at only

...incorporation after spreading on the surface does not result in as great a reduction of odors as direct injection since some manure remains on the soil surface.

Figure 44-2. Injection of liquid manure into the soil.

Figure 44-3. Surface application of liquid manure on cropland.

Table 44-1. Odor thresholds for various land application methods.

Application Method	Odor Detection Threshold[a]
Broadcast	2818
Plow	200
Harrow	131
Inject	32
Unmanured	50

[a]Ratio of fresh air to odorous air (fresh: odorous) to dilute the odor to where it is just detectable.

Besides their ability to achieve complete manure coverage for odor control, it is...important that these injectors leave crop residue on the surface... .

50 meters (165 ft). A more recent study at Iowa State University showed odor reductions from 20% to 90% by immediate incorporation of manure into the soil. This study looked at five different types of incorporation or injection devices, with all resulting in significant odor and hydrogen sulfide reductions compared to broadcast manure left on the surface (Hanna et al. 1999).

The types of injectors used today include narrow tines, sweeps, disk injectors and covers, and conventional chisel plows. Besides their ability to achieve complete manure coverage for odor control, it is also important that these injectors leave crop residue on the surface to minimize erosion and limit energy (tractor horsepower) requirements. Sweeps require more horsepower than simple tines for a given depth, but the sweeps more than compensate for this by permitting complete coverage while operating at a shallower depth. The disk covers, when set properly, require the least horsepower while still providing complete coverage, but they may also cover more crop residue. When the manure is placed on top of the soil surface and a conventional chisel plow is used for incorporation, complete coverage cannot be achieved. Thus a high level of odor control may be at the expense of higher energy requirements and the potential for greater erosion. The

additional cost of manure incorporation or injection for odor control is offset somewhat by the savings in manure nitrogen. An Iowa study suggests that injecting the manure from a storage system increases costs $0.49 per year per breeding sow and $0.17 per finish hog while injecting the manure from a lagoon system increases costs $1.39 per year per breeding sow and $0.68 per finish hog (Fleming et al. 1998). However, these cost increases did not consider reduced nitrogen losses with the injection system. An Iowa survey of commercial manure applicators showed an average difference of 1/10 of a cent per gallon more for injection versus broadcast (see <http://www.ae.iastate.edu/manurdir99.htm>).

The additional cost of manure incorporation or injection for odor control is offset somewhat by the savings in manure nitrogen.

Drop hoses

Another method of application, used in northern European countries, is to simply place liquid manure on the surface through a series of drop hoses much like a sprayer hose or boom (Figure 44-4). This technique has been used to spread manure slurry (liquid manure from under barn pits) on tilled cropland and on growing crops (especially small grains), producing minimum odor and minimum potential runoff and/or erosion. The system has been used with manure tanks but could be adapted to drag hose technology on pastures or some crops such as forages. Adoption of this technology may be limited in the United States because of the prevalence of row crops and the difficulty of matching tanker tire size with rows and wheel spacing.

Pretreated manure

Treated liquid manure may be less offensive than raw or untreated manure, although this depends on the degree of treatment. Liquid manure can be treated either aerobically or anaerobically (anaerobic digestion) to significantly reduce odors. Research indicates odor reductions of 80% or more during anaerobic treatment of manure (Pain et al. 1990). In such cases, manure can be surface applied or even irrigated with very little odor emissions. The same can be said for solid manure that is applied frequently (hauled daily), dried, or composted since it will generate less odor during land application.

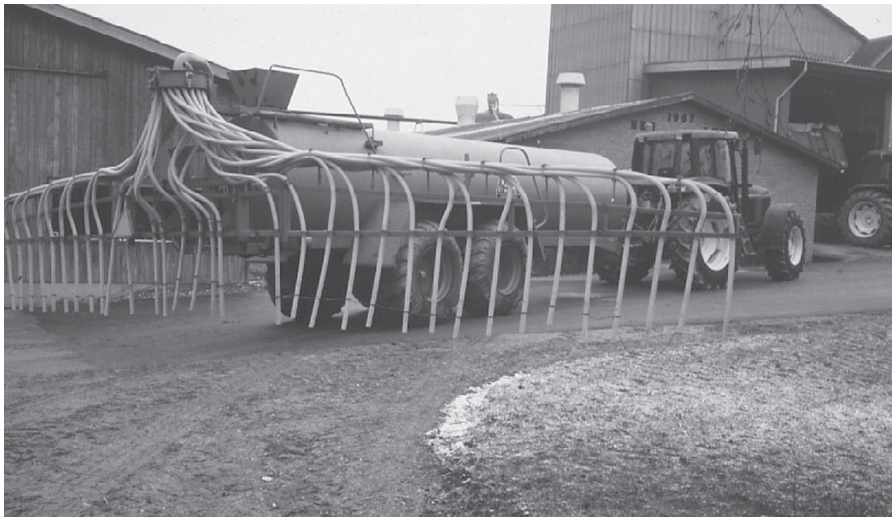

Figure 44-4. Drop hose liquid manure applicator.

Agitation or mixing of the manure before and during pumping contributes to odor and gas emissions… .

Figure 44-5. Agitation and pumping equipment for the deep pit manure storage under a pig-finishing barn.

Treating manure in pits

Agitation or mixing of the manure before and during pumping (Figure 44-5) contributes to odor and gas emission during manure application. This mixing is necessary to suspend the solids that have built up in the bottom of the storage and to distribute the nutrients evenly throughout the manure. Odor and gas emissions during agitation and pumping are difficult to control. The best method for reducing the impact of these odor emissions is to agitate during times when the outside air is heating (sunny clear mornings), causing the odorous air to rise and disperse.

Other techniques to reduce these emissions, such as the addition of chemical additives to the manure, are also being evaluated. Research has shown reductions in hydrogen sulfide emissions of over 90% with additions of calcium hydroxide, ferric chloride, ferrous chloride, ferrous sulfate, hydrogen peroxide, potassium permanganate, or sodium chlorite (Clanton et al. 1999). Although these reductions in emissions do not guarantee reductions in odor emissions, odor reductions are likely.

Characteristics of irrigation systems that reduce odor include using nozzles and pressures that produce large droplet sizes, installing drop nozzles on center pivot systems, and adding dilution water to the liquid manure before applying.

Surface application by irrigation

Applying liquid manure with irrigation (both surface and spray) systems (Figure 44-6) remains a popular and efficient method to distribute manure nutrients onto cropland in some sections of the United States. As mentioned previously, it can produce considerable odors if not managed properly and/or the liquid manure is untreated or has a high nutrient content. Characteristics of irrigation systems that reduce odor include using nozzles and pressures that produce large droplet sizes, installing drop nozzles on center pivot systems, and adding dilution water to the liquid manure before applying.

Droplet size is of importance because of the much higher surface area per unit volume associated with smaller droplets as well as the potential for greater drift of smaller droplets. In general, larger droplets are better for odor control. Droplet size is determined by a combination of nozzle size and pressure. To overcome their tendency to drift, droplets generally must be greater than 150 microns in size, depending on wind speed. Traveling guns must operate at high pressures, but the nozzle size is large, resulting in primarily large droplets.

Figure 44-6. Spreading liquid manure with a traveling gun irrigation system.

Fresh water dilution can also be used to reduce manure odors and nitrogen loss during irrigation applications. One Midwestern state (Iowa) requires a 15:1 dilution with fresh water if untreated slurry manure is to be irrigated. Burton (1997) reported that 3:1 fresh water additions to manure slurry reduced ammonia losses from 20% to 90%. Lagoon liquid is often mixed into irrigation water in states that commonly use irrigation for crop production. The lagoon effluent is then spread in a very dilute and greatly odor reduced manner.

Center pivot irrigation systems are unique because they are permanently established on a specific parcel of land. They are appropriate only for lagoon effluents. If producers select pivot applications, they need to consider the odor risk associated with this method and identify practices that minimize this risk. The following list provides some design and management considerations to keep in mind when selecting a pivot irrigation system:

- Center pivots have wide latitude for nozzle size and pressure combinations. Use low-pressure drop nozzles to maximize droplet size and minimize droplet suspension time.
- Dilute effluent with fresh water (2 parts fresh water to 1 part effluent or greater dilution. Corn is most sensitive to salt and to ammonia prior to the 6-8 leaf stage. Greater dilution may be necessary during this stage of growth). Mixing fresh water and effluent requires a back flow protection system to prevent manure from contaminating a fresh water well.
- Select pivot application sites that (1) maximize the setback distance between the pivot and receptors and (2) do not place a pivot downwind of neighbors based upon prevailing winds during the time of the year that manure application is most likely.
- Install a weather station that (1) constantly monitors wind direction and speed and (2) automatically shuts the system down if the wind blows toward the neighboring residences.
- Monitor the wind speed. Shut down the pivot when the wind speed is likely to remain less than 5 mph for an extended period. Low wind speeds produce more stable air and less dilution of odorous air.

Center pivot irrigation systems are…appropriate only for lagoon effluents.

Odor plumes extend much further during stable atmospheric conditions such as low wind speeds.

- Irrigate during morning and afternoon hours only (odors disperse more quickly when the temperature is rising).
- Maintain records about the timing of applications and associated weather conditions. This practice will provide documentation of your operating procedures that may be helpful if neighbors complain.

Solid Manure Odor Control Techniques

Technologies that reduce the odors released during land application of solid manure parallel those of liquid manure, namely, treating solid manure before it is spread and incorporating surface-applied solid manure into the soil as soon as possible after it is applied.

Incorporation

Solid manure cannot be injected, because unlike liquid manure, it will not flow through the pipes and tubes common to injectors. It therefore requires another pass with a disk or other tillage equipment before being incorporated into the soil. The simple recommendation is to use a tandem disk or field cultivator as soon as possible after the solid manure is spread. New equipment needs to be designed that will both apply and incorporate solid manure with a single piece of equipment or spread solid manure on grasslands.

The loading or transfer of solid manure from buildings, stacks, or storage areas can produce odor emissions. This can be a problem when solid manure is temporarily stored near cropland and then applied after the crop is removed in the fall or before the crop is planted in the spring. One way of minimizing odors from stacked manure, however, is by covering it with plastic. Using black plastic may also help minimize fly production due to the high temperatures that occur beneath the cover.

As with liquid manure, treating solid manure… can reduce odors.

Treatment

As with liquid manure, treating solid manure (such as composting, Figure 44-7) can reduce odors. Some chemical treatments can reduce gas emissions.

Figure 44-7. Mechanical turner used in composting solid manure.

For example, alum has been shown to significantly reduce ammonia volatilization from poultry litter (Moore et al. 1995).

Time and location constraints

When applying manure, always consider wind direction, especially if you are broadcasting. Select days when the wind is blowing away from neighbors and dwellings. If feasible, spread manure on weekdays when neighbors are likely to be away from their home; avoid weekends, especially Sundays and holidays. Before spreading manure, check with neighbors to be sure that they do not have a social event planned for the same day that you are planning to spread. If they do, change your plans. Finally, one of the most effective practices is simply to tell your neighbors or those who may be affected that you plan to apply manure to your farmland. Typically, people will object less if they know ahead of time and feel that they have some control or at least some input into what is happening around them.

...tell your neighbors or those who may be affected that you plan to apply manure to your farmland. Typically, people will object less if they know ahead of time... .

Summary

Manure application can cause significant odor emissions. Several methods of reducing odor from both liquid and solid manure land applications include incorporating the manure into the soil either during or shortly after it is spread, placing manure on the surface but beneath the crop canopy, or treating the manure before it is spread on land. The agitation and/or loading of manure from long- or short-term storage facilities will also create odors that need to be managed to avoid complaints during the application process.

APPENDIX A

Environmental Stewardship Assessment: Land Application and Outdoor Air Quality Issues

The goal of this assessment is to help you confidentially evaluate environmental issues that relate to outdoor air quality. For each issue listed in the left column of the worksheet, read across to the right and circle the statement that best describes conditions on your farm. If any categories do not apply, leave them blank.

Potential Odor Risk	High Risk	Moderate Risk	Low Risk
General Considerations			
Relative risk of • Spray irrigation	Spray irrigation of top water or slurry from manure storage, earthen basin, or undersized anaerobic lagoon	Spray irrigation of top water from lagoon designed according to standard engineering designs.	Spray irrigation of top water from aerobic lagoon, purple lagoon, or lagoon designed for odor control (permanent pool twice as large as standard engineering designs)
• Tanker or towed hose application	Surface application of stored slurry manure	Surface application of slurry manure followed by same day incorporation OR Surface application with drop hose applicator	Subsurface injection of slurry manure
• Solid manure spreader	Surface application of wet solid manure	Surface application of dry or heavily bedded solid manure	Surface application of dry or heavily bedded solid manure followed by same day incorporation OR Immediate incorporation of wet solid manure
Have other odor treatment technologies been adopted for the manure storage or lagoon?		Independently documented odor control additive OR Anaerobic lagoon sized for odor control OR Purple lagoon	Anaerobic digestion OR Aerobic treatment OR Composting
Timing of Manure Application			
Time of day?	Time of day is not commonly considered. Evening application is common.	Commonly applied during daylight hours before 5 pm	Always applied during daylight hours after 8 am and before 5 pm
Weather conditions?	Weather conditions are not commonly considered.	Commonly applied on sunny, windy days	Always applied on sunny, windy days
Weekends/Holidays?	Weekends and holidays are not commonly considered.	Weekends and holidays are commonly avoided.	Weekends and holidays are always avoided.
Spray Irrigation Considerations			
Type of spray nozzle?	Big guns or high-pressure nozzles that direct spray into the air	Low-pressure drop nozzles that release liquid above crop canopy	Low-pressure nozzles that release liquid below crop canopy
Dilution with fresh water?	No dilution	Mixing of fresh to lagoon water at a ratio of less than 3 to 1	Mixing of fresh to lagoon water at a ratio of 3 to 1 or greater
Time of year for application (for anaerobic lagoons only)?	Spring (shortly after lagoon has become active) or winter (when lagoon is inactive)	Early summer (after lagoon has been active for 2 months or more)	Mid summer through fall (when lagoon has been active for several months)
Time delay between last lagoon feeding and spray irrigation?	Lagoon receives manure within few days of spray irrigation from lagoon.		Manure flow to lagoon is stopped for two weeks prior to spray irrigation from lagoon.

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Glossary

Aerobic. Condition within a storage mass that includes dissolved oxygen and allows the existence of microorganisms that require oxygen. The breakdown of organic material tends to be odor free.

Ammonia volatilization. Loss of ammonia (NH_3) to the atmosphere.

Anaerobic. Condition that does not include dissolved oxygen. It results in the transformation of manure by microorganisms that do not require oxygen.

Center pivot irrigation system. Automated irrigation system consisting of a sprinkler line rotating about a pivot point and supported by a number of self-propelled towers. The water is supplied at the pivot point and flows outward through the line, supplying the individual outlets.

Crop canopy. Overhanging leaf cover of a growing crop.

Detection threshold. Volume of non-odorous air needed to dilute a unit volume of odorous sample air to the point where trained panelists can detect a difference between the two.

Dilution threshold. *See* Detection threshold.

Effluent. Liquid discharge of a waste treatment process.

Intensity. Describes the strength of an odor.

Traveling gun irrigation system. Automated irrigation system consisting of a single, large-nozzle gun that moves in a straight line at a predetermined speed from one end of a field to the other end.

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Reviewers

Many colleagues reviewed drafts of the Livestock and Poultry Environmental Stewardship curriculum and offered input over a two-year period. Thus, it is impossible to list all reviewers; however, certain reviewers provided in-depth reviews, which greatly improved the curriculum's overall quality, and pilot tested the curriculum within their state. These reviewers, also members of the Review and Pilot Team, are listed below.

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Finally, recognition must also be given to three individuals, members of the Access Team, who helped determine the final appearance of the curriculum lessons: Don Jones, Purdue University; Jack Moore, MidWest Plan Service; and Ginah Mortensen, EPA Ag Center.

Livestock and Poultry Environmental Stewardship Curriculum: Lesson Organization

This curriculum consists of 27 lessons arranged into six modules. Please note that the current lesson is highlighted.

Module A. Introduction

1. Principles of Environmental Stewardship
2. Whole Farm Nutrient Planning

Module B. Animal Dietary Strategies

10. Reducing the Nutrient Excretion and Odor of Pigs Through Nutritional Means
11. Using Dietary and Management Strategies to Reduce the Nutrient Excretion of Poultry
12. Feeding Dairy Cows to Reduce Nutrient Excretion
13. Using Dietary Strategies to Reduce the Nutrient Excretion of Feedlot Cattle

Module C. Manure Storage and Treatment

20. Planning and Evaluation of Manure Storage
21. Sizing Manure Storage, Typical Nutrient Characteristics
22. Open Lot Runoff Management Options
23. Manure Storage Construction and Safety, New Facility Considerations
24. Operation and Maintenance of Manure Storage Facilities
25. Manure Treatment Options

Module D. Land Application and Nutrient Management

30. Soil Utilization of Manure
31. Manure Utilization Plans
32. Land Application Best Management Practices
33. Selecting Land Application Sites
34. Phosphorus Management for Agriculture and the Environment
35. Land Application Records and Sampling
36. Land Application Equipment

Module E. Outdoor Air Quality

40. Emission from Animal Production Systems
41. Emission Control Strategies for Building Sources
42. Controlling Dust and Odor from Open Lot Livestock Facilities
43. Emission Control Strategies for Manure Storage Facilities
44. **Emission Control Strategies for Land Application**

Module F. Related Issues

50. Emergency Action Plans
51. Mortality Management
52. Environmental Risk and Regulatory Assessment Workbook