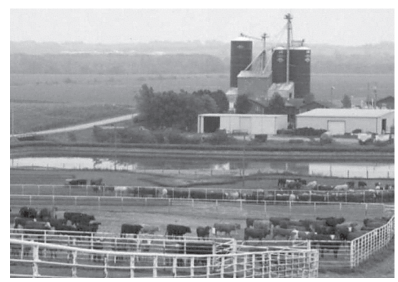
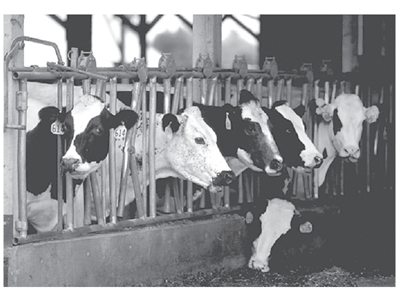
Lesson 42

Controlling Dust and Odor from Open Lot Livestock Facilities

By Brent Auvermann, Texas A&M University



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Disclaimer

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By Brent Auvermann, Texas A&M University

Intended Outcomes

The participants will

- Develop an odor and dust management plan for open lot livestock facilities, such as beef feedlots and open lot dairies.
- Determine the best combination of technologies and management practices to reduce air pollution from open lot livestock facilities.
- Discuss the framework in which air quality is regulated with respect to open lot livestock facilities.

Contents

Activities

- Lecture, slides/video
- Show products
- Checklist of technologies for each participant

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

Citizens of the United States are increasingly aware of dust and odor from confined animal production. In contrast to air quality impairment from most swine and poultry facilities (which are under roof), air quality impairment from the open lot systems characteristic of beef and dairy production tends to be driven principally by short-term weather patterns. Although it is not the only predictor, the most obvious predictor of dust and odor emissions is the moisture content of the open lot or corral surface. Figure 42-1 is a conceptual diagram of the qualitative relationship between dust potential and odor potential for open lot systems.

Clearly and intuitively, dust predominates at low moisture content and odor at high moisture content, so minimizing both dust and odor by moisture management alone is impossible. However, Sweeten and Lott (1994) and other researchers found that when the moisture content of the open lot surface is between 25% and 40%, both dust and odor potential are at manageable levels. Researchers studying swine odor (Hoff et al. 1997) have found that a significant component of odor results from odorous compounds that are bound to dust particles, so odor potential never completely drops to zero. In the optimum moisture range of 25% to 40% (wet basis), other manure properties such as depth, bulk density, and texture become the more important determinants of dust and odor potential. To better understand the odor risks associated with your own open lot animal housing, an Animal Housing self-assessment tool (see Appendix A) is provided to assist you in a review.

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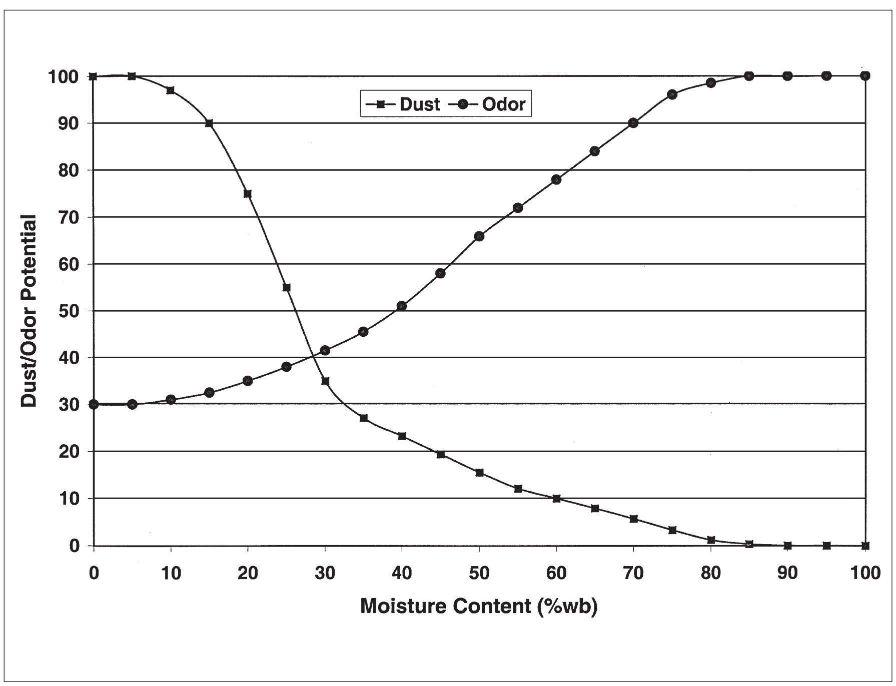

Figure 42-1. Conceptual, qualitative relationship between dust potential and odor potential as a function of the moisture content of an open lot corral surface. (Readers should infer no quantitative significance from the values on the vertical axis.)

Regulating Air Pollution from Open Lot Livestock Facilities

Animal feeding operations (AFOs) are subject to several layers of air quality regulations. Through the federal Clean Air Act Amendments (CAAA), Congress has delegated the authority to the Environmental Protection Agency (EPA) to regulate sources of any air quality impairment that may compromise public health or well-being. In turn, the EPA has delegated the responsibility to the states to implement federal air quality standards as well as the federal monitoring and permitting functions. Some states have adopted their own air quality regulations that either (a) address issues not addressed by the federal program or (b) impose standards that are more stringent than the federal standards. Municipalities and administrative units of comparable scale may also impose air-quality standards exceeding federal and state requirements. Other air quality regulations that may apply to AFOs are promulgated and enforced by the Occupational Safety and Health Administration (OSHA), but such regulations are beyond the scope of this lesson.

Federal air quality regulations

Clean Air Act (CAA). The open lot AFO operator should be familiar with three major aspects of federal clean air statutes. The first concerns so-called "major sources" of air pollution and the assessment of emissions fees. The second pertains to the combined effect of industrial operations on regional air quality, to which significant human populations would be routinely exposed in the course of their regular activities. The third concerns the suite of management techniques, operating parameters, air pollution abatement measures, maintenance and training procedures, self-monitoring, and recordkeeping under which the facility will be permitted to operate to meet emissions targets.

Definitions, major source classification, and emissions fees. Major sources of air pollutants are determined on the basis of emissions thresholds. In the case of routine, regulated pollutants such as particulate matter (PM) and nitrogen (N) oxides, a facility having the potential to emit more than 100 short tons of a single pollutant annually to the atmosphere would be considered a major source. In the case of constituents listed as hazardous air pollutants (HAPs; e.g., trichloroethylene), the major source threshold may be 10 tons/year or even less, depending on the constituent. *Potential to emit* refers to the amount of emitted pollutant that would be expected from a facility operating year-round at full capacity. The list of all applicable regulated pollutants and their expected annual emissions is known as a facility's *emissions inventory*. Facilities classified as major sources can be assessed emissions fees. For industrial sources, these fees average about $30 per ton of emissions, but states have the flexibility to set the fee structure however they wish.

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Until recently, the emissions inventory for an industrial facility was based only on (a) point source emissions, which are emissions that can be traced to a specific point such as the end of a pipe, the top of a stack, or a cyclone exhaust and (b) process fugitive emissions, which are identified with a discrete process but are not traceable to a single emission point (e.g., hay grinding). In the case of a cattle feedlot, the emissions inventory has generally been limited to emissions from the flaker cyclones, hay grinding, grain unloading, and feed loading. Fugitive emissions, which are analogous to nonpoint source (NPS) pollution, are not included in the emissions inventory for the open-lot AFO source category. (Fugitive emissions from a cattle feedlot or an open lot dairy include dust resulting from cattle activity on the feedlot surface or from vehicle traffic on unpaved roads.) As a result, open lot AFOs have not typically been classified as major sources and therefore have not been assessed emissions fees.

Within the last two years, however, legislatures in a few western states have explicitly authorized their state air pollution regulatory agencies (SAPRAs) to include fugitive emissions in the statewide emissions inventory. In 1998, for example, the state of Washington introduced language to that effect into the Washington Administrative Code. Special air quality districts in the State of California also consider fugitive emissions in the enforcement of their air quality regulations. Lesikar et al. (1996) showed that including fugitive emissions of PM_{10} (particulate matter having a diameter less than 10 micrometers) in the inventory would suddenly require that cattle feedlots as small as 8,000-head one-time capacity be reclassified as major sources. Emissions fees for those feedlots would be set by the state in question.

If warranted by public health considerations, the EPA could conceivably reduce the major source thresholds, bringing smaller operations into the major source classification. The pollutants of primary concern to the open lot livestock facility are hydrogen sulfide (H_2S), PM_{10}, and $PM_{2.5}$ (particulate matter with a diameter less than 2.5 micrometers). Odors are not a regulated pollutant per se, but they may create nuisance conditions that would be the basis for action by the SAPRA or for litigation. Despite its ubiquity near AFOs and its reputation as an odorous gas, ammonia (NH_3) is not a federally regulated pollutant under the CAAA[1].

National Ambient Air Quality Standards (NAAQS). Ambient air quality refers to the quality of the outdoor air to which humans are exposed during the course of their normal lives. The EPA has established a list of maximum concentrations–pollutant thresholds–above which human exposure may result in adverse health effects. The NAAQS, as the list is called, serves as an administrative benchmark for clean air. Those areas found to exceed the NAAQS for any one or more *criteria pollutants* (carbon monoxide, lead, PM, sulfur oxides, nitrogen oxides, and ozone) are subsequently classified as nonattainment areas (NAAs), which are then required to develop and implement a plan to reduce emissions and bring the area into attainment. Under EPA's oversight, SAPRAs determine compliance with the NAAQS by installing and operating a monitoring network.

The NAAQS are derived from a synthesis of epidemiological and clinical data relating exposures to human health effects. As such, the NAAQS for an individual pollutant may consist of one or more acute (short-term) standards and/or one or more chronic (long-term) standards. The multiple standards reflect the idea that humans can endure exposures to relatively high concentrations for a short duration and relatively lower concentrations for longer periods. For example, the current NAAQS for PM_{10} consists of two standards, a 24-hour average concentration of 150 micrograms per cubic meter ($\mu g\ m^{-3}$) and an annual average concentration of 50 $\mu g\ m^{-3}$.

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[1]In 2002, EPA is scheduled to promulgate rules implementing the new NAAQS for fine particles ($PM_{2.5}$). Because ammonia is a *precursor gas* (i.e., ammonia reacts with other atmospheric gases to form fine particles), these new federal rules may contain provisions related to ammonia emissions.

Ambient air quality standards apply to any location to which the public has access.

Because rural areas have a relatively low population density, ambient monitoring stations tend to be concentrated in urban areas. That fact should not obscure the true regulatory meaning of "ambient," which refers to any area to which the public has access. That definition implies that the NAAQS apply not only in population centers but also at a facility's property line irrespective of that facility's proximity to population centers.

Federal operating permits (FOPs). In addition to emissions fees, FOPs are a fact of life for facilities classified as major sources of air pollutants. Again, no U.S. AFOs are currently classified as major sources. Because the FOP program was authorized under Title V of the CAAA, states that have been delegated authority to administer it typically refer to their permit-issuing program as the "Title V Program." Your state's Title V office may have published a guidance document outlining the permitting requirements for your AFO type or livestock species.

Because open lot AFOs are seldom classified as major sources, they are rarely required to obtain FOPs. They may be required, however, to apply for state authorization in the form of (a) a standard exemption from permitting, (b) a standard air permit or (c) an individual air permit. In states where the AFOs are sometimes required to obtain individual permits, the process of evaluating permit applications may involve the use of dispersion modeling to predict worst-case downwind concentrations of any pollutants of local or regional concern. Dispersion modelers use complex mathematical algorithms to predict downwind pollutant concentrations from the interaction of the AFO's orientation, pollutant emission rate, and mesoscale weather conditions. Permit reviewers then compare the predicted concentrations to the NAAQS (or, if more stringent, to the state's own air quality standards) to determine if additional abatement measures are necessary. The relevant air quality standards are applied at the property line, and if modeled property line concentrations exceed the NAAQS, regulators may deny permit applications for remote sources based on the modeled limits. Open lot AFOs, particularly in arid and semi-arid regions where dust is a persistent challenge, may be susceptible to increased regulatory requirements in that regard.

OSHA. The cattle-feeding industry has long suspected that dusty feedlot conditions contribute to impaired livestock health, feed-to-gain performance and overall profitability. MacVean et al. (1986) was the first major, peer-reviewed study to link the health and performance of feeder cattle to the onset and magnitude of dust events, and the effects they showed received increased attention from research animal scientists, veterinarians, and engineers. Superficially, it is reasonable to expect that an increased risk of impaired livestock health implies an increased risk to human health, but in the case of cattle feedlots and open lot dairies, that link has not yet been demonstrated in the refereed literature. Researchers (Donham et al. 1995; Reynolds et al. 1996; Schiffman 1995; Thu et al. 1997) have linked adverse health responses of both workers and neighbors to dust and odors emitted from swine confinement. Extrapolating those results to open lot AFOs, which are typically bovine confinements in which worker exposure is outdoors rather than indoors, is difficult to justify without experimental data. Still, outdoor exposure to molds and fungi (and their active biochemical components) emitted from agricultural operations such as hay grinding and cotton processing have long been linked to both acute health responses (Campbell 1932) and chronic conditions such as farmer's lung (Gudmundsson and Wilson 1999). Occupational safety and health are not regulated by EPA but by the OSHA. Specific pollutants such as hydrogen sulfide (H_2S) have clear occupational health implications ranging from irritation to nausea to sudden death of agricultural workers (Doss et al. 1993).

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State air quality regulations

States have a key role in regulating air pollution. As mentioned previously, they are free to establish their own air quality standards provided that they are at least as stringent as any corresponding federal standards. States may regulate pollutants not listed as federally regulated pollutants. They may also impose their own permit requirements in addition to administering a delegated FOP program. To meet the CAAA air quality requirements, states are required by the regulations implementing the Act to write a State Implementation Plan (SIP) and submit it for EPA approval. When non-attainment designations are made as a result of ambient monitoring, states must also submit, for EPA approval, an amendment to the SIP that shows how their non-attainment areas will be brought into compliance with the NAAQS.

SAPRAs. State air pollution regulatory authorities are the "heavy lifters" in the regulation of air pollution. They administer ambient monitoring programs, operating permits, compliance inspections, and federally mandated emissions-reduction programs for NAAs. In relation to EPA, SAPRAs have sovereign authority only with respect to regulations that are either (a) not addressed by EPA or (b) more stringent than the federal rules.

State-level air quality standards. Some SAPRAs have elected to set air quality standards that are more stringent than their federal counterparts (either EPA or OSHA). For example, the state of Minnesota has set an ambient standard for H_2S at 30 parts per billion (ppb) on a 30-minute average. Although H_2S was originally included in the list of HAPs, it has been "delisted" and currently has no federal ambient air quality standard attached to it.

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SIPs for NAAs. When results of ambient monitoring indicate that the region represented by a monitoring site is not in compliance with the NAAQS–i.e., is designated as an NAA–the responsible SAPRA is required to develop and submit, for EPA approval, an amendment to the SIP that will bring the NAA into compliance with the NAAQS within a reasonable time. In the plan, SAPRAs will include all significant sources of the pollutant in question that contribute to the non-attainment condition. In the case of the San Joaquin Valley in California, a serious NAA for PM_{10}, agricultural practices such as tillage and harvesting are subject to abatement requirements. Although the nationwide distribution of open lot AFOs differs greatly from the distribution of federal ambient monitoring sites (which tend to be located near population centers), managers of open lot AFOs need to be aware of attainment classifications that may affect their operations.

Nuisance is commonly defined as any condition that inhibits the reasonable use or enjoyment of property. Nuisance doctrine...include[s] an expectation that future use of that property will not be unreasonably affected by the activities of others.

The most important principle of odor control is avoiding anaerobic conditions by keeping

(a) manure and other organic materials as dry as practical,
(b) manure storages and surfaces exposed to oxygen, and
(c) corral surfaces hard, smooth, and free of uncompacted manure.

Nuisance and liability

Another means of addressing air pollution from open lot AFOs is the nuisance complaint. In its mildest form, it may consist only of a phone call from a neighbor to the AFO manager or company headquarters, followed by informal meetings to determine an appropriate response. In persistent, adversarial, or emergency cases, the nuisance complaint may be registered with the SAPRA headquarters, the nearest SAPRA field office, or law enforcement authority. In these cases, SAPRA inspectors may visit the site of the complaint in an attempt to verify it, although quite often the time lag between complaint and inspection makes verification difficult or impossible. In severely adversarial cases or where dust or odor problems may have contributed to documented accidents or injury, the last recourse may be litigation. Litigation may take the form of a lawsuit based on either a nuisance or a tort.

Definition of nuisance. Nuisance is commonly defined as any condition that inhibits the reasonable use or enjoyment of property. Nuisance doctrine implies that private property rights include an expectation that future use of that property will not be unreasonably affected by the activities of others. In the case of open lot AFOs, for example, neighboring property owners have the right to expect that they can schedule an outdoor barbecue with the reasonable assurance that dust or odor will not detract from their enjoyment. In some cases, special topographical features such as ravines, canyons, or draws may transport a dust plume for several miles, causing a nuisance in towns and residences not obviously adjacent to the AFO.

Liability issues for open lot livestock facilities. The principal liability issue facing open lot AFOs, such as cattle feedlots, concerns reduced visibility on nearby roadways. Severe dust storms from cattle feedlots may reduce visibility to a mile or less, especially in the early- to mid-evening when the atmosphere is becoming more stable and winds are light. Feedlots and open lot dairies located on major thoroughfares and highways where tractor-trailer traffic is substantial are highly exposed, especially where prevailing winds push the dust cloud toward the roadway. As with nuisance conditions, liability exposure may exist miles from the AFO where special topography serves as a conduit for dust plumes.

Elements of an Odor Management Plan (OMP) for Open Lot Livestock Facilities

Odor management plans have not yet been standardized nationally. Some states now require an OMP under special conditions (e.g., Texas, when requesting a waiver from the minimum setback distance from neighbors), but the elements of an acceptable OMP are typically defined on a case-by-case basis. The most important principle of odor control is avoiding anaerobic conditions by keeping (a) manure and other organic materials as dry as practical, (b) manure storages and surfaces exposed to oxygen, and (c) corral surfaces hard, smooth, and free of uncompacted manure. The following elements should constitute a broadly acceptable OMP for open lot facilities such as cattle feedlots and open lot dairies and may be used as a self-assessment checklist.

Self-Assessment Tool: Question and Answer

1. The State Air Pollution Regulatory Agency (SAPRA) in my state is:

Agency Name: ______________________________

Address/City/State/Zip: ______________________________

____

Telephone: ______________________________

Nearest Local Field Office Address: ______________________________

City/State/Zip Code: ______________________________

Telephone: ______________________________

Name of Field Representative: ______________________________

2. The prevailing winds in my location come from the following directions. Circle all that apply:
W NW N NE E SE S SW

3. My facility is located in a federal nonattainment area with respect to the NAAQS? Circle one:

Yes No Don't Know

If "yes," for which regulated pollutant? ______________________________

4. Are agricultural operations exempt from air quality regulations in my state? Circle one:

Yes No Don't Know

5. Neighbors (businesses, homes, schools, churches, other public venues) nearest my facility in any direction are within ___ miles of my property line.

6. Neighbors nearest my facility in the downwind direction with respect to the prevailing winds are within ______ miles of my property line.

7. Is my facility near topographical features (ravines, canyons, draws etc.) that are prone to transport air pollution over large distances and/or in directions other than those regional air currents? Circle one:

Yes No Don't Know

8. My facility's property line is within ___ miles of the nearest major highway (truck route, divided highway) and ___ miles of the nearest public roadway (county roads, farm-to-market highways, other lightly traveled thoroughfares).

9. Are fugitive emissions included in the emissions inventory in my state? Circle one:

Yes No Don't Know

10. My facility would be considered a major source subject to a Federal Operating Permit (FOP) under Title V of the Clean Air Act Amendments (CAAA)? Circle one:

Yes No Don't Know

11. My facility is required to get a State Operating Permit (SOP) either by itself or in conjunction with a water permit? Circle one:

Yes No Don't Know

12. Does the county or parish in which my facility is located have ordinances specifying maximum property line odor intensities or other numerical air quality standards? Circle one:

Yes No Don't Know

Corral design

Although AFO design may not appear a realistic place to begin for existing facilities, well-designed AFOs should take credit for aspects of the original design that are known to reduce odor, either directly or indirectly. In preparing an OMP, operators should first highlight any of the following design criteria that apply:

1. The corral slopes between 3% and 5%, down away from the feed apron. A 3% to 5% slope sheds rainfall more rapidly than a flatter corral, reducing the likelihood of puddles that go anaerobic. Where these slopes are not practical or where they are thought to impair livestock performance, drainage should be enhanced through the use of feedlot mounds (Sweeten 1982).
2. Pen-to-pen drainage of rainfall runoff has been minimized. Corrals that drain discretely and directly into a runoff conveyance are seldom likely to detain water behind the manure ridges that develop under fence lines between corrals.
3. Access to the corrals by manure-harvesting equipment is convenient. Frequent manure harvesting is vital to ensuring rapid, complete drainage. If access by manure-removal equipment is difficult or awkward, the corral surface will be difficult to manage.
4. Corral soils are firm, stable, and not easily eroded into rills and gullies. Eroded corrals are prone to detain water.
5. A supply of fill dirt is abundant and convenient. When gouging or erosion occurs in a corral, rapid maintenance reduces the likelihood of puddles developing from rainfall or spilled drinking water.
6. Pen shape is conducive to edge-to-edge manure removal. Pens that are irregularly shaped cannot be maintained in the hard, smooth conditions that are central to effective manure removal.
7. The potential for backwater from major drainage channels is low. In some older feedlots, the downstream edges of the corrals are prone to temporary flooding. Stagnant water in a corral is a major contributor to intense, disagreeable odors. Ensure that runoff channels are well maintained and do not create backwater, especially within corral boundaries.
8. Clean rainfall runoff is diverted around corrals and manure storages, relieving pressure on the holding pond and reducing the amount of water that is potentially detained on the corral surface or around the base of manure stockpiles.

...the key is to keep the corral surface hard, smooth, and as dry as possible... . Corrals that shed water rapidly and completely have the least potential to create odors.

Corral maintenance

No matter how well an open lot AFO has been designed, corral maintenance will make or break the AFO with respect to odorous emissions. 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. Corrals that shed water rapidly and completely have the least potential to create odors.

Frequent, proper manure harvesting. Open lot dairies are frequently capable of daily manure removal while the cows are in the milking parlor. Daily manure removal may be too frequent, however, especially if manure-removal equipment cannot be adjusted to maintain a 1- to 2-inch layer of compacted manure above mineral soil. Weekly manure removal may be a better option, both operationally and economically. In cattle feedlots, on the other hand, manure removal typically occurs only after each corral of cattle is emptied for slaughter or transfer, an interval of 120 to 180 days. In flat feedlots or where rainfall is plentiful, an interval of 120 days or more between manure removal activities will almost certainly lead to corral conditions that generate odor. A few modern, large (capacity > 35,000) feedlots in Texas have experimented with continuous manure harvesting in which two or three tractors with box scrapers operate continuously across the yard, even with cattle present. Corral conditions are excellent, and managers report little to no depression in feed-to-gain performance or increased cattle stress.

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

Operator training in manure-harvesting objectives and techniques. As with any essential AFO function, employees need to be trained both in the techniques of manure harvesting and in the justification, motivation, and objectives of the manure-harvesting function. Machinery operators who understand both the "what" and the "why" will be more apt to make sound decisions when managers are not around to answer questions.

Frequent inspection for and correction of pits, holes, and wallows. Bunk readers, feed-truck drivers, pen riders, and nighttime security providers employed by a feedlot or dairy should be trained and equipped to note pits and holes developing in the corrals. Such corral damage should be corrected with compacted fill dirt as soon as practical. Managers should assign higher priority to holes and wallows near water troughs and feed aprons, where spilled and excreted water may collect even during dry weather.

Manure mounds for flat corrals. Construction of manure mounds serves a threefold purpose: (1) a temporary storage for excess manure, (2) a cattle refuge from muddy, wet, and cold conditions and (3) a means of enhancing the water-shedding efficiency of corrals with little or no slope.

Rigorous maintenance of overflow waterers, misters, and water distribution systems. Water leakage in corrals, near feed bunks, and near manure storage areas can contribute significantly to odor. Feedlot employees should be trained to look for signs of leaky distribution systems and water troughs.

Frequent inspection of fence lines for manure ridges, especially before rainfall events. The moist manure that accumulates under fence lines as a result of hoof action is a fertile breeding ground for flies. When rainfall occurs, these ridges also function as dams, creating puddles and wet spots that generate odors. Especially when rainfall is expected or when flies are becoming a major nuisance, these ridges should be knocked down and the manure spread out across the corral to dry.

Feeding strategies

Balance nitrogen (N) in ration; avoid overfeeding protein. Of the 170 or more compounds known to contribute to livestock odor, many contain N and/or sulfur. Balancing the ration with respect to N may reduce the amount of N excreted in manure and urine. Balancing the ration will not eliminate odors, but it makes sense economically and contributes to a conscientious odor management regime.

Balance sulfur in ration, avoid overfeeding sulfur, and account for dissolved sulfate in drinking water. The same principles apply for sulfur (S) as for N. In addition to feedstuffs, excess S may be unwittingly "fed" in the form of high-sulfate drinking water. Nutritionists retained by the AFO should be aware of high-sulfate water and should consider the additional S when formulating rations.

Investigate innovative feeding strategies (cyclical rations, grouping methods). Although these strategies still await conclusive experimental verification with respect to feed-to-gain efficiency or milk production, any feeding strategies that result in more efficient nutrient use should also reduce nutrient excretion and may improve overall profitability. Contact animal scientists at your land-grant university for options appropriate to your region.

Drainage structures and runoff holding ponds (design, operation, and maintenance)

Management of treatment lagoons and other wastewater retention structures has been covered in great detail in other lessons. This simple checklist fills in some gaps concerning runoff control structures.

1. Corrals, settling basins, and open channels should not be prone to clogging, backwater, or poor drainage.
2. Where settling channels are used to reduce solids loading in holding ponds, machinery access for solids removal should be convenient under all weather conditions.
3. Consistent sludge monitoring and timely removal of excess sludge will improve long-term lagoon performance and reduce long-term odor potential.
4. Shallow holding ponds (< 4 ft., where feasible using natural topography) are less prone to go anaerobic than deep ponds. This option is probably not feasible in high rainfall areas.
5. When weather permits, holding ponds should be pumped down soon after storms.

Mortality management

1. Carcasses should be quickly removed from corrals followed by proper disposal, especially in warm weather.
2. Short-term mortality storage should not be visible from off-site and should not be located near the property line.
3. The same principles apply as for other species and AFO configurations (see Lesson 51, Mortality Management).

Manure stockpiles and composting operations

Avoid long-term stockpiling of manure, if possible. Unmanaged stockpiles will eventually exclude oxygen, and even if the stockpiles are not odorous, old, stockpiled manure releases more odor upon land application than manure exposed to oxygen. If stockpiling is necessary, minimize stockpile size.

To avoid overheating, **put manure up dry (< 45% moisture).** When land applied, charred stockpiles release intense, uniquely disagreeable odors.

Locate stockpiles and composting operations upwind relative to prevailing winds and the AFO center. Because of the odor potential of stockpiles and storage areas, they should be located as far upwind of the principal downwind property line as topography or other operational considerations permit.

Provide supplemental carbon for composting. A proper carbon-to-nitrogen ratio in a compost pile or windrow encourages faster composting and reduces odors over the long term (see Lesson 25, Manure Treatment Options).

Aerate compost piles at a frequency appropriate to their moisture content and composition. In general, for wet manure put up for composting, aerate at 2-day intervals until the moisture content is reduced to 65% or less, then weekly or bi-weekly thereafter. High moisture content reduces the oxygen content of the pore spaces in a compost pile.

Preferably use drier manure for land application. Dry manure spreads more uniformly than moist manure, and because it has probably been exposed to more oxygen than manure with more moisture, dry manure releases less odor upon land application.

Elements of a Dust Management Plan for Open Lot Livestock Facilities

Other than the different moisture dependence shown in Figure 42-1, dust control strategies for open lots follow the same lines as odor control strategies with respect to pen surface management. Major dust events (Figure 42-2) occur when dry, loose manure accumulates on the corral surface and is pulverized and suspended by hoof action. The well-known evening dust peak appears to result from the following three main factors:

1. The afternoon heat, wind, and solar radiation have driven off surplus moisture, leaving the manure pack drier than at any other time of the day.
2. Cattle emerge from their typical afternoon lethargy to move to the feed bunk, to take a drink of water, or to play.
3. With the atmosphere's tendency to become more stable between dusk and midnight than during the afternoon, the manure particles suspended in the air by cattle activity tend to remain near the ground, creating a "dust cloud." The resulting dust event may persist well into the evening or early morning.

The general approach to dust control consists, then, of (a) removing dry, loose manure from the corral surface; (b) manipulating the moisture regime at

Figure 42-2. Feedyard dust event in the Texas Panhandle.

The well-known evening dust peak appears to result from the following three main factors:

1. The afternoon heat, wind, and solar radiation have driven off surplus moisture... .
2. Cattle emerge from their typical afternoon lethargy... .
3. ...The manure particles suspended in the air by cattle activity tend to remain near the ground, creating a "dust cloud."

the corral surface to achieve optimum moisture content; and (c) attempting to reduce peak cattle activity during the critical late afternoon hours.

Corral design

The same design principles apply to dust control as to odor control. Managing the corral surface for both odor and dust control is easiest and most effective when the pens do not accumulate moisture in small or localized areas. Pen areas that retain moisture are most likely to end up mushy, disturbing the firm 1- to 2-inch compacted layer that provides a firm base for operating manure-harvesting machinery.

Provide easy access to water throughout the feedlot for water trucks. In semi-arid and arid regions, application of supplemental moisture is often necessary to keep up with daily evaporation and maintain optimum moisture content in the corral surface. Feedlots and dairies that opt for water trucks (as opposed to sprinkler systems) should ensure that distribution pipelines across the AFO put water where trucks will not be required to "deadhead, " or roll empty, over large distances.

Corrals should be conducive to cross fencing for stocking density manipulation, if applicable. Dust control in regions with moderate annual moisture deficits (e.g., semi-arid and temperate regions of the High Plains or the Trans-Mountain West) may be improved by periodic adjustment of stocking density in existing pens. Stocking density increases of up to 100% (i.e., from 150 ft^2/hd to 75 ft^2/hd cattle spacing) have been shown to reduce downwind dust concentrations by up to 29% (Romanillos 2000). Increasing the number of cattle per pen is one approach, but it reduces the linear bunk space available to each animal and may result in behavioral changes that increase stress and reduce livestock performance. A more plausible alternative is to install temporary (e.g., electric hot wire) or permanent fences in suitable corrals, being careful to maintain convenient herd management and easy access by pen riders and machinery. Preliminary, unpublished evidence suggests that the behavioral effect of increased stocking density may be more significant in large (> 150 head) pens than in small (< 100 head) pens, so managers should experiment with stocking density manipulation cautiously and on a small scale.

Corral and road maintenance

Besides those practices outlined for odor control, the following measures reduce dust potential in corrals and on unpaved roads within the AFO.

Remove loose material on surface; maintain a compacted layer of manure 1 to 2 inches thick. Frequent harvesting of loose, dry manure from the feedlot surface improves manure quality for land application and reduces the amount of material that may be pulverized and suspended in air by hoof action.

Topical application of crop residues on corral surfaces (experimental). Top dressing corral surfaces with organic residues of crop harvesting or processing may increase the manure's moisture-holding capacity. In addition, the residue may provide a cushioning property that reduces the hoof's shearing effect. No research data yet exist to document this technique's effectiveness. Candidate top dressings include straw, waste hay, cotton "gin trash," and peanut hulls. These carbonaceous additives may also improve the quality of the manure-composting process.

Topical application of chemical resins on dirt or caliche roads (experimental). Corral dust control is vastly different from road dust control because livestock are continually adding new material to the corral surface. As a result, topical treatments would probably require frequent re-application to be effective. Applying expensive resins or petroleum derivatives to dirt or caliche roads, however, appears to effectively (Gillies et al. 1999) reduce dust from truck traffic.

Feeding strategies

Discourage end-of-day spike in livestock activity (experimental). Morrow-Tesch (1999) collected preliminary data suggesting that delay of the last daily feeding (typically, the third of three) into the afternoon may drastically reduce cattle activity in the late afternoon and early evening. Although the method requires further validation, the concept has some merit.

Modest increase in ration's fat content (experimental). Slight excess fat content in rations may increase the cohesiveness or plasticity of the resulting manure, making the dried manure less susceptible to re-suspension. This method has not been conclusively evaluated in production-scale research and is likely to be expensive. Anecdotal evidence suggests that this approach may increase the hazard to pen riders due to the slicker corral surface.

Other Technology and Landscaping Options for Reducing Emissions from Open Lot Livestock Facilities

Solid-set sprinkler systems

Solid-set sprinkler systems are an effective but expensive means of dust control in cattle feedlots. Research in California showed that interior corral dust concentrations increased 850% after sprinkler operation had ceased for two days. Sprinkler systems require a great deal of site-specific design based on seasonal water balance calculations, but in general terms, systems should have sufficient capacity to deliver 0.25 inch or more of water per day across the entire yard. Sprinkler patterns should overlap by 50% of the diameter of throw, and sprinklers should be located so that their throw does not extend all the way to the feed apron. Water for sprinkler systems should be drawn from a holding tank to avoid a demand peak on the main water system that may reduce drinking water delivery during the hot afternoon. Using holding pond effluent in sprinkler systems is an experimental technique that may reduce operation costs, but it may also increase the risk of disease transmission in the livestock. Until and unless research shows that the health risks are negligible, holding pond effluent should at least be blended with fresh water, if used at all. Water wagons with rear- or top-mounted pumps and sprinkler cannons operated on roads or alleys away from the feed bunk are an alternative to solid-set sprinklers. Water wagons are less capital intensive than solid-set sprinklers, but the operating costs (e.g., fuel, labor, road wear, "deadheading") can be considerably higher.

Water for sprinkler systems should be drawn from a holding tank to avoid a demand peak on the main water system that may reduce drinking water delivery during the hot afternoon.

Manure-harvesting equipment

Manure-harvesting equipment should permit skilled operators to leave a firm, smooth, and evenly graded corral surface with 1 to 2 inches of compacted manure on top of the mineral soil. Box scrapers, being "pull" blades, do an excellent job and are often adjustable with respect to blade depth.

Vegetative barriers

Vegetative barriers may be used to increase dispersion by elevating dust-laden air from the ground surface and mixing it with cleaner air aloft. Fast-growing trees also provide a visual barrier that may indirectly reduce nuisance complaints or improve relations with neighbors and passersby. Where flies are a persistent problem, however, vegetative barriers may make the problem worse by providing additional pest habitat.

Stocking density

Stocking density (number of animals per unit corral area), or its inverse, animal spacing, may be adjusted to compensate for increases in net evaporative demand (evaporation depth less the effective or retained precipitation), shifting the moisture balance in favor of dust control. Auvermann and Romanillos (2000) evaluated this option experimentally on a commercial feedlot in the Texas Panhandle and found that decreasing the cattle spacing from 150 ft^2 hd^{-1} to 75 ft^2 hd^{-1} reduced net (measured less background) PM_{10} concentrations at the corral fence line by about 20%. As daily net evaporation increases, the effectiveness of increased stocking density is likely to decrease; furthermore, increasing the stocking density may induce behavioral problems and reduce overall feed-to-gain performance.

Corral surface amendments

Corral surface amendments are still in the experimental phase with respect to dust and odor control. Crop residue mulches (waste hay, cotton gin trash) may cushion hoof impact and reduce the shearing that causes dust, and they may decrease the net evaporative demand by storing additional water and reducing evaporation rates. Resins and petroleum-based products, which have been shown to reduce dust emissions significantly from unpaved roadways, may also be effective, although the continuous deposition of manure on the corral surface suggests that these compounds would need to be reapplied frequently and would therefore be cost prohibitive.

APPENDIX A

Environmental Stewardship Assessment: Open Lot Animal Housing

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.

Odor and Dust Management

Potential Odor Risk	High Risk	Moderate Risk	Low Risk
Open lot design			
• Corral slope?	No slope or slope is toward feed apron or other feed areas.	Slope is less than 3% away from feed apron or other feed areas.	Slope is 3% to 5% away from feed apron or other feed areas.
• Adjacent pens?	Pen-to-pen drainage is the norm.	Pen-to-pen drainage occurs in isolated regions of the facility.	Pens drain discretely.
• Corral shape?	Pens are irregularly shaped and not conducive to edge-to-edge manure removal.		Pen shape allows edge-to-edge manure removal.
• Corral surface?	Corral soil easily erodes and is prone to rills and gullies.	Corral surface is well compacted paved, or constructed of firm stable soil.	Corral surface is concrete.
• Drainage from corral?	Downstream corral surfaces are part of the runoff storage pond.	Downstream corral surfaces are prone to temporary flooding.	After a storm event, downstream corral surfaces drain quickly.
• Runoff control?	Significant manure or runoff is not controlled and regularly pools in areas around open lots.	Some manure and runoff is not controlled and regularly pools in areas around open lots.	All manure/runoff is contained within runoff control pond.
• Vegetative barrier?	No vegetative barrier is located downwind of corrals, based upon prevailing winds during times of year of high dust or odor concerns.		A dense shelterbelt or other vegetative barrier is located downwind of corrals, based upon prevailing winds during times of year of high dust or odor concerns.
Open lot management			
• Frequency of manure removal	Fewer than twice a year	120- to 180-day intervals	Every 60 days or less
• Operator training in manure removal and pen management	No employee training is offered.	Manager are knowledgeable in techniques of manure removal and motivation for this practice.	All appropriate employees are trained in techniques of manure removal and motivation for this practice.
• Pen surface management	Holes, pits, or depressions are regularly corrected.	Holes, pits, or depressions are corrected only at time of manure removal (commonly collection. Wet areas are manure removal).	Pen surfaces are frequently inspected. Few holes, pits, or depressions exist for water several months between quickly corrected.
• Water leakage	Overflow waterers and system leaks are not a priority.	Inspections for overflow waterers and system leaks are infrequent.	Regular inspections are made for overflow waterers and system leaks, AND problems are quickly corrected.
• Manure ridges at fence line	Removal of manure ridges is not priority.		Manure ridges are removed with each pen cleaning.

APPENDIX A

Environmental Stewardship Assessment: Open Lot Animal Housing (continued)

Odor and Dust Management			
Potential Odor Risk	**High Risk**	**Moderate Risk**	**Low Risk**
During periods of dust problems, the following dust control measures are possible:			
• Dry manure and dust harvested frequently	Fewer than three times a year	Manure is harvested frequently (every 120 days under normal conditions and every 30 days under severe drought conditions).	Manure is harvested at least every 60 days (30 days under severe drought conditions).
• Daily watering of corral surfaces	No additional dust control measures are implemented.	Corral watering is implemented on at least 50% of occupied lots under severe drought conditions.	Corral watering is implemented on at least 80% of occupied lots under severe drought conditions.
• Cross fencing to increase stocking density	No additional dust control measures are implemented.	Increased stocking density is implemented on at least 50% of occupied lots under severe drought conditions.	Increased stocking density is implemented on at least 80% of occupied lots under severe drought conditions.
• Topical application of crop residue on corrals	No additional dust control measures are implemented.	Topical application of crop residue is implemented on at 50% of occupied lots under severe drought conditions.	Topical application of crop residue is implemented on at 80% of occupied lots under severe drought conditions.

About the Author

This lesson was prepared by Brent Auvermann, Assistant Professor of Agricultural Engineering, Texas A&M University Agricultural Research and Extension Center, Amarillo, who can be reached at this e-mail address:
b-auvermann@tamu.edu

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Glossary

Ambient air quality. Quality of the outdoor air to which humans are exposed in areas to which the public has access.

Amendment. An ingredient, such as waste hay, cotton gin trash, or peanut hulls, added to corral surfaces to improve dust and odor control or to enhance the composting process.

Anaerobic. Microbial processes that occur in the absence of free oxygen.

Animal feeding operation (AFO). Any facility that relies on imported feed or feeds livestock or poultry in confinement such that the animals are not sustained on forages growing in the confinement area.

Caliche. A naturally occurring limestone material often used for paving rural roads.

Clean Air Act Amendments (CAAA). The statutory basis for federal regulation of air pollution, revised and reauthorized every five years.

Composting. Controlled microbial degradation of organic waste yielding an environmentally safe and nuisance-free soil conditioner and fertilizer.

Emissions inventory. The list of all applicable regulated pollutants and their expected annual emissions. In the case of a cattle feedlot, the emissions inventory has generally been limited to emissions from flaker cyclones, hay grinding, grain unloading, and feed loading. A statewide emissions inventory is the aggregate of all emissions from all sources in the state, including fugitive emissions.

Federal operating permit (FOP). An operating permit obtained under the auspices of the Clean Air Act, outlining the maximum emissions rates and abatement measures required of all sources under the permit's purview.

Feed apron. Pavement extending 8 to 15 ft from the feed bunk to prevent erosion or potholing from hoof action or other animal activity.

Fugitive emissions. Emissions identified with a discrete process but not traceable to a single emission point such as the end of a stack (e.g., grain unloading). Fugitive emissions from a cattle feedlot or an open lot dairy include dust resulting from cattle activity on the feedlot surface or from vehicle traffic on unpaved roads. Analogous to nonpoint source water pollution.

National Ambient Air Quality Standards (NAAQS). List of maximum concentrations, or pollutant thresholds, above which human exposure may result in adverse health effects. Serves as an administrative benchmark for clean air.

Nonattainment area (NAA). Area found to exceed the NAAQS for any one or more regulated pollutant and subsequently required to implement a plan to reduce emissions and bring the area into attainment.

Nonpoint source (NPS). Entry of effluent into a water body in a diffuse manner so there is no definite point of entry.

Nuisance. Any condition that inhibits the reasonable use or enjoyment of property.

Pollutant threshold. Maximum concentration beyond which both short-term and long-term exposure to various pollutants may be reasonably expected to cause adverse health effects.

Potential to emit. Amount of emitted pollutant that would be expected from a facility operating year-round at full capacity.

State Air Pollution Regulatory Agency (SAPRA). Administers ambient monitoring programs, operating permits, compliance inspections, and federally-mandated emissions-reduction programs for NAAs. Develops and submits for EPA approval an implementation plan that will bring the NAA into compliance with the NAAQS within a reasonable time.

State Implementation Plan (SIP). A state's plan for attaining and maintaining statewide compliance with the Clean Air Act.

Stocking density. Number of cattle per unit corral area. Increased density may reduce downwind dust concentrations modestly, but it reduces the linear bunk space available to each animal and may result in behavioral changes that increase stress and reduce livestock performance.

Wet basis. Refers to the fraction of a given constituent in a moist mixture as a proportion of the total weight of dry matter plus incorporated water. Is always numerically less than the corresponding "dry basis" proportion.

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(Page numbers highlighted in green are linked to corresponding text.)

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Click on road map to return to Contents.

Reviewers

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Ted Funk
Extension Specialist
Agricultural Engineering
University of Illinois

Carol Galloway
USEPA Ag Center
Kansas City, KS

Mohammed Ibrahim
Extension Specialist
North Carolina A&T State University

Gary Jackson
Professor, Soil Science, and Director,
National Farm*A*Syst Program
University of Wisconsin, Madison

Barry Kintzer
National Environmental Engineer
USDA-NRCS
Washington, D.C.

Rick Koelsch
Livestock Environmental Engineer
University of Nebraska

Deanne Meyer
Livestock Waste Management Specialist
University of California-Davis

Mark Risse
Extension Engineer, Agricultural Pollution Prevention
University of Georgia

Peter Wright
Senior Extension Associate, PRO-DAIRY
Cornell University

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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
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Module E. Outdoor Air Quality

40. Emission from Animal Production Systems
41. Emission Control Strategies for Building Sources
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44. Emission Control Strategies for Land Application

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