Odor Control for Livestock Systems[1]

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ABSTRACT: Odors are generated primarily as the result of manure storage but also result from animal housing and manure application. Effective odor control is dependent upon implementation of strategies that are complementary to management practices. Some systems use a deep pit or a holding tank for manure storage. In such systems, little or no biological processing occurs, and they are therefore considered high-load systems. In systems where biological processing occurs to a great extent, such as in anaerobic digesters or lagoons, the system would be termed a low-load system. Odor control strategies for manure storage areas, such as solids separation and additives, are best suited for low-load systems, whereas covers and biofilters provide the best results for high-load systems. Strategies that reduce nutrient production, such as dietary restriction of nutrients, are well-suited for all types of manure storage systems. To comply with current or pending odor control regulations, it is imperative that producers be provided with sound recommendations of odor control strategies.

Key Words: Manures, Odors, Covers, Anaerobic Digestion, Aeration

Introduction

Livestock producers face increasing environmental regulations, including odor control. Currently, some states regulate livestock odors and others may be looking to implement such regulations in response to pressure from rural residents and to address air quality concerns. Such regulations may be based on property line dilution-to-threshold odor concentrations or specific odorant concentrations. Frequency and duration of odor or odorant concentrations also may be taken into account. Regardless of whether a state has specific regulations for odor control or plans to implement such regulations, all livestock operators need to implement measures to control odors in an effort to avoid nuisance complaints. A number of odor reduction methods are available to producers; each can be expected to perform differently for different management systems. Costs vary widely for the different technologies, as do required maintenance and management. Some of the more popular methods for controlling odors associated with livestock production are biofiltration, solids separation, anaerobic digestion, aeration, composting, dietary manipulation, landscaping, and the use of covers. Each of these will be addressed by summarizing the available research that evaluates the effectiveness of a technology when associated with specific management practices.

Principles of Odor Control

In livestock operations, manure storage areas can be a principal source of odor, depending on the method of storage. Contributions from animal housing facilities, from feed storage facilities, and during the application of animal manures and other wastes may also play a substantial role in odor generation. An effective means of reducing odors must complement the management strategies of a given system. This

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principle holds true regardless of whether attempts to control odors are made in animal housing areas, feed storage areas, manure storage facilities, or during land application of animal wastes. Questions to be asked before choosing an odor control strategy include what is the cost, will the desired odor reduction be achieved, and does the strategy fit into the overall animal and manure management system? While no odor reduction strategy is completely without cost, the amount a producer is willing to incur to implement methods to reduce odors off-site likely depends on either the pressure felt from neighbors or on established regulatory standards. Likewise, the desired level of odor reduction might be influenced, in part, by these factors. Additional factors influencing the desired level of odor reduction include capital investment and environmental stewardship.

Odor reduction technology must be compatible with the management system and management capabilities of the operation. Technologies that exceed management capabilities will eventually be mismanaged or completely unmanaged and result in failure to reduce odors. Likewise, if a particular technology does not blend into a current scheme, failure to control odors adequately may result. Certain strategies for reducing odors from manure storage areas are best suited for liquid systems. Some strategies are best suited for high-load systems, where little or no biological processing takes place during storage. Some strategies for controlling odors in housing facilities are compatible with specific means of ventilation; land application methods or controlling odor emissions may require liquid manure.

While much of the odor generated in a livestock operation is the result of manure storage, implementation of strategies to reduce odors from animal housing areas and during land application of manure should be considered an integral part of an operation's plans to reduce the incidence of nuisance pollutants.

Odor Control Strategies for Livestock Housing

Odors generated in livestock housing facilities can exit the housing and make their way to downwind neighbors. Even in housing that utilizes external manure storage some manure will be present within the housing itself, creating some odor. Additionally, odors from the feed and from the animals themselves will be present. Odorous compounds tend to be carried on dust particles. Therefore, strategies to reduce odors from animal housing focus primarily on housekeeping measures that reduce dust emissions. Practices include filtration of exhaust air as it leaves the housing facilities, filtration of odorous air prior to moving past the property line, construction of impermeable barriers to arrest particle transport, and reduction in the formation of odorous compounds within the housing environment.

Dry Manure Storage

In open lot facilities, control of dust and lot runoff serve as the principal means of managing odor from the housing facilities. Lots should be well-drained and avoid the unnecessary addition of water (e.g., overflowing waterers). Quite often, beef or dairy facilities that utilize open lots house animals in facilities with bedded-packs. Control of odor from these housing facilities can best be achieved by maintaining a dry bedding area through proper maintenance of the packs. Adequate bedding must be added on a routine basis and no unnecessary water added. Guidelines for management of these systems, including appropriate amounts of bedding needed and the absorption capacity of various bedding materials, is available (MWPS-18, 1993).

Filtration and Biofiltration

One method of preventing the movement of odors is to provide a method of trapping them as they exit through the ventilation system. Filtration serves as a mechanism for this purpose. Odors travel attached to particles, so by effectively trapping particle emissions, odorous compounds can be trapped as well. By trapping approximately 45% of particles between 5 and 10 μm and 80% of particles greater than 10 μm from animal housing areas, the odor dilution threshold can be reduced 40 to 70% (Hoff et al., 1997). Biofilters also can be developed to reduce odorous emissions from manure storage areas within the housing facilities. Such biofilters trap emissions from pit ventilation systems (Nicolai and Janni, 1997). While mechanical filtration may be costly, biofiltration methods can prove to be low-cost means of effectively reducing exhaust odors. Biofiltration costs at a 700 farrow-to-wean commercial site are an estimated $.22 per pig produced, amortized over a 3-yr life (Messenger, 1998). This same operation reports odor reductions of 90%, over 90% reduction in hydrogen sulfide emission, and greater than 74% reduction in ammonia emission (Nicolai and Janni, 1998).

Biofilter design requires that suitable conditions be provided for the growth of bacteria within the biofilter. These bacteria degrade the odorous compounds to less odorous end products. Oxygen concentration, temperature, residence time, and moisture content are among the parameters that must be considered when building a biofilter (Nicolai and Janni, 1998). While management must be taken into consideration, it is clear that low-cost biofiltration systems can be implemented in livestock housing facilities.

Impermeable Barriers

Following the concept that odor is transmitted on dust particles, an alternative to filtering these particles during air movement is to stop their movement altogether. Windbreak wall designs have proven effective in reducing downwind dust particle concentrations as well as odor concentration (Bottcher et al., 1998). Windbreak walls were constructed with 3×3 m pipe frames and tarpaulins and placed at the east end of swine finishing buildings. Plume dust concentrations were reduced in areas with the windbreak walls due to plume deflection. Odor intensity, measured with a Scentometer, was stronger downwind when no windbreaks were in place and within the windbreak wall enclosure than downwind of the windbreak wall.

Landscaping

Landscaping can reduce the emission beyond the property line of housing odors, as well as odors generated by other components of the livestock operation, by acting as a permeable filter for particle emissions. Trees and shrubs act as biofilters for odorous compounds that are attached to fine particles. When landscaping includes both a treeline and a row of shrubs, particles at various heights within a plume can be adsorbed. Landscape materials should have a large surface area, to maximize adsorption. In addition to acting as a natural filtration system for odors, landscaping has the benefit of being aesthetically pleasing and(or) restricting the view of the operation. Costs associated with landscaping vary, depending on selected trees and shrubs and perimeter size. One cost estimate suggests that landscaping strategies start at approximately $.20 per animal of a finishing unit capacity (Lorimor, 1998c).

Dietary Manipulation

An alternative to filtration of odors as they leave housing facilities is to reduce the concentration of odorous emissions that can be produced upon anaerobic decomposition of the manure. Manipulation of livestock diets to alter excretion composition, and thus the odor of excretions, is one method that may be effective in reducing odor from housing areas. Hobbs et al. (1996) demonstrated reduced concentrations of odorous compounds when swine diets were formulated with crystalline amino acids, thereby reducing dietary crude protein concentration. Obrock et al. (1997) also reported a trend in reduced odor intensity by reducing crude protein concentration. Sutton et al. (1998) varied crude protein concentration, amino acid composition, and mineral supplements to demonstrate a reduction in sulfur-containing compounds in swine manure. Odor intensity was not measured in this study. However, the ability to alter manure nutrients through slight dietary modifications was clearly illustrated. By altering the composition of manure, it seems plausible that degradation products and resultant odors can be altered as well.

Some research suggests that adding supplemental fructooligosaccharides to the diet improves nutrient utilization by providing a more suitable energy ratio for protein digestion (Bunce et al., 1995). Often when formulating livestock diets we consider the energy: protein or energy:carbon ratio. Perhaps more attention to the components of the energy source will aid in odor prevention and reduce nutrient excretions.

Feedstuff selection may impact manure odor when excreted or during storage. Powers and Faust (1998) observed a trend of increasing odor intensity when diets containing increasing concentrations of bloodmeal were fed to nursery pigs. Diets were formulated to contain 0, 1.5, or 3% bloodmeal. Other research has shown that the addition of peppermint to cattle diets improved excreted manure odor (Kellems et al., 1979). Fermentation characteristics of barley resulted in improved manure odor compared with that from sorghum diets (Watts and Tucker, 1993; 892 vs 1,197 standard odor units).

Dietary manipulation is a potential means of reducing manure odors before excretion and during manure storage when anaerobic decomposition is taking place and odorous intermediate compounds are being formed. Only a limited amount of research is currently available to indicate which diet regimens or ingredients benefit odor reduction.

Odor Control Strategies for Manure Storage Facilities

Methods to decrease or alter the stored manure are one strategy employed to reduce odors from manure storage facilities. Such methods include dietary manipulation to influence manure characteristics as excreted or the addition of additives to stored manure to alter manure characteristics. Additional methods include the use of solids separation to remove recalcitrant material and decrease nutrient concentration going into the storage facility, and composting or anaerobic digestion to provide an opportunity for some biological processing of a portion of the collected manure, thereby reducing the source concentration. A number of these techniques have demonstrated some success in reducing odor intensity.

A second strategy seeks to reduce the surface area from which odorous compounds can be volatilized. Methods include sizing of manure storage areas, orientation of manure storage areas with respect to frequency of wind direction, and the use of permeable and impermeable covers that reduce the amount of surface area directly exposed to outside air.

A third strategy involves reducing the volatilization of odorous compounds by reducing the net radiation on a manure storage facility. Methods to implement this strategy commonly involve the use of permeable and impermeable covers.

Malodor is the result of the incomplete anaerobic decomposition of stored manure. During the decomposition process, malodorous intermediate compounds are produced and can accumulate if insufficient populations of bacteria that degrade these compounds are present. It is these accumulations that result in odor nuisance. Complete decomposition would produce odorless gases, carbon dioxide and methane, as well as some odorous gases, ammonia and hydrogen sulfide, that contribute little to overall odor intensity (Powers et al., 1999). Some manure storage facilities are designed and sized to allow for biological treatment and complete decomposition and would be considered low-load systems; other facilities serve the purpose of storage only. The latter, high-load systems, are more prone to accumulation of the odorous compounds and, thus, odor concerns. Odor control strategies for high- and low-load systems must be fundamentally different.

Strategies for Low-Load Systems

In a system where the nutrient load is low relative to the biological processing capability of the system, such as a lagoon, further reduction of the nutrient load on the system is a plausible strategy for reducing odors. This can be accomplished through an increase in the rate of processing of manure in the system or via a reduction in the loading rate of nutrients introduced to the system. Decoupling of the solution/air interface is another means of reducing odorous emissions from low-load systems.

Solids Separation. Solids separation by sedimentation, screening, filtration, or centrifugation allows for the removal of material that exceeds the screen opening size. Often, in the case of ruminant manures, this is fibrous material that is resistant to decomposition during storage. By removing larger-sized material, thereby decreasing the loading rate, the life of the storage area can be extended. Decomposition of remaining stored material may benefit from removal of the poorly digestible material. Reduced odor emissions from the storage facility, in terms of odor intensity and concentration of odorants, ensues improved decomposition. A 50% reduction in odor threshold from swine housing air samples was observed when a filter net was installed under the floor slats with daily removal of solids collected on the net (Kroodsma, 1986). Solids separation prior to anaerobic digestion of dairy flushwater modestly, but nonsignificantly, reduced odor intensity pre- and postdigestion (Powers et al., 1997).

Anaerobic Digestion. Anaerobic digestion enhances a naturally occurring process by providing conditions suitable for complete decomposition of organic matter to low-odor end products. During the process, manure is contained in a closed system, preventing release of odorous emissions to the atmosphere. The use of anaerobic digestion has proven to be a very effective means of reducing manure odors during storage and during land application (Pain et al., 1990; Powers et al., 1997). As much as a 50% reduction in dairy manure odor intensity was observed using 20-d HRT conventional laboratory-scale digesters. Anaerobic digestion can be a capital-intensive venture. Efforts to enhance the biological processing of a digester, and hence reduce the HRT and necessary volume storage requirement, have resulted in modifications to a conventional digester. Fixed-film digestion with a 3-d HRT performed similarly to a 10-d conventional digester in terms of odor control (Powers et al., 1997). While generally thought to be a capital-intensive system, some estimates illustrate that anaerobic digestion is economically feasible for larger operations. One example budget shows that a positive net income per cow of $31/yr can be realized if the methane is captured and used as an energy source (Wright and Perschke, 1998). The following economic information is provided based on a 3,000-animal finishing facility: $1.10 (20-yr life) to $4.00 per animal (10-yr life) for initial construction minus gas harvesting equipment; $40 per animal capacity to install and purchase gas harvesting equipment; $3.00 per animal capacity recaptured as income from energy produced (Lorimor, 1998a).

Additives. In a low-load system, bacterial populations are more likely to occur in quantities sufficient to provide a balanced production and utilization of intermediate degradation compounds. The storage facility is not overloaded. Whereas in a high-load system, where the addition of supplemental bacteria to a failing system would be futile due to environmental conditions, the addition of supplemental bacteria to a low-load system may enhance the rate of processing because conditions are suitable for bacterial growth and function. Unpublished field reports indicate a direct relationship between decreased odor reduction and the occurrence of anaerobic photosynthetic bacterial populations in lagoons. The anaerobic photosynthetic bacteria utilize hydrogen sulfide, hydrogen, and organic compounds such as volatile fatty acids and aromatic compounds to provide needed reducing equivalents and carbon. Reduced odor from lagoons where the pink-rose color, indicative of the populations, is present is likely the result of degradation and utilization of such odorous intermediates. Purple nonsulfur phototrophic bacteria, a predominate population in many lagoons, have demonstrated efficient degradation of highly odorous compounds such as organic acids, p-cresol, methyl mercaptan, ethyl mercaptan, and propyl mercaptan (Kobayashi and Kobayashi, 1995).

Enzymatic or chemical additions are more likely to have a greater benefit on odor intensity in a low-load system than a high-load system due to the stability of the environment. Mode of action of many commercially available products remains unknown, but it is plausible that some enzymes could enhance the biological decomposition of odorous compounds to less odorous end products.

Impermeable Covers. Covering a manure storage area with an impermeable cover completely decouples the air and solution interfaces thereby preventing the release of odorous gases into the atmosphere. Wind and radiation effects on emission rates are eliminated. Polyethylene covers typically range in price from $4.30 to 9.15/m^2, with the average price near $.50 (Freese, 1997). Additional costs for installation approximate $6.46/m^2 (Lorimor, 1998e). Odor reduction efficiencies of 70 to 85% have been observed when surfaces are completely covered by these impermeable covers (Mannebeck, 1986). Dilution-to-threshold concentrations have been reduced from 340 to 30 by covering a storage area with an impermeable plastic cover; meaning that without the cover, the odorous air sample requires 340 dilutions with odor-free air in order to be imperceptible, whereas with the cover only 30 dilutions are required before the odor cannot be detected (Lorimor, 1998e). More intense odors require a greater number of dilutions.

Permeable Covers. Permeable covers, or biocovers, act as biofilters on the top of manure storage areas. Materials often used as covers include straws, cornstalks, peat moss, foam, and Leka rock. Permeable biocovers reduce odor, in part, by reducing solar radiation onto the manure storage surface and reducing the wind velocity over the surface of the storage area. Covers act as a barrier to these forces. Humidity at the solution/air interface is relatively high, which creates a stabilized boundary, thus slowing the emission rate of odorous volatiles at this interface. An aerobic zone exists within the biocover, allowing the growth of aerobic microorganisms that utilize the carbon, nitrogen, and sulfur from the odorous emissions for growth. By further degrading and making use of these compounds beneath the biocover, it is possible to alter and reduce odors emitted above the biocover. Mannebeck (1986) reported a 40 to 50% reduction in odor when straw was used, 45 to 55% reduction when foam pellets were used, and up to 85% reduction efficiency with the use of a floating mat or corrugated materials. In an Iowa State University Extension odor demonstration field evaluation, use of a biocover reduced the odor intensity of stored hog manure from 2.2 to 1.2, on a scale of 0 to 3 (Lorimor, 1998b). Costs for biocovers vary widely depending on the material used and method of application. Straws and cornstalks cost approximately $.11/m^2, peat moss and foam cost about $2.80/m^2, and Leka rock is approximately $9.68/^{2}. Leka rock is a product of Norway, thereby requiring considerable shipping costs ($176 to $212/m^2, Freese, 1997). Most recommendations suggest a minimum of 20 cm, preferably 25 to 30 cm of coverage on a manure storage surface. New covers may need to be applied annually.

Strategies for High-Load Systems

In a high-load system, biological processing is incomplete due to an imbalance in microbial populations. Strategies to increase the processing rate are therefore futile. Successful odor reduction strategies focus on decoupling the solution and air interfaces. Examples of high-load systems are deep pits, holding ponds, and earthen or aboveground storage tanks. In each of these systems less biological processing takes place. Loading rate exceeds the microbial ability to utilize the waste to an extent necessary to prevent the accumulation of odorous intermediate compounds. Odors emanating from high-load systems such as deep pits or in-house manure storage facilities can be controlled through biofiltration, as discussed above.

Use of impermeable covers is perhaps the most effective means of reducing odorous emissions from an outdoor high-load system. Similar to low-load systems, the air and solution interfaces are decoupled, preventing the escape of odorous emissions. The biological function of a permeable cover is greatly hindered in a high-load system due to the unbalanced microbial populations. Some odor reduction may still be achieved, however, by reducing wind and temperature effects on the volatility of emissions.

Landscaping also will be of benefit in a high-load system by acting as a natural biofilter. The aesthetic value of landscaping is difficult to assess but can contribute to a reduction in “perceived” odors.

Dietary manipulation potentially can be effective, regardless of manure storage system. Perhaps a greater benefit can be observed under high-load than low-load systems due to the greater accumulation of odorous intermediate compounds that form under the unbalanced conditions present with a high-load system.

Strategies to Reduce Odors During Land Application

Injecting manure or incorporating manure shortly after surface application can best prevent odorous emissions that occur as the result of land application. Costs to inject manure are estimated to be $.01/L above the cost to haul and spread liquid manure. A portion of the added cost can be recaptured in the form of reduced nitrogen losses for injected manure versus broadcast application.

Odor reduction can be substantial with injection. One source reports odor dilution thresholds of 2,818, 130 to 200, 50, and 32 for broadcast, broadcast plus incorporation, no manure application, and direct injection methods, respectively (Lorimor, 1998d). Field tests in Iowa demonstrated odor reduction ranging from 50 to 75% with injection versus broadcast application (Lorimor, 1998d). Based on these reports, great benefits can be realized by incorporating after broadcast application as well.

Pivot irrigation systems can be a substantial source of downwind odor. Using systems that spray close to the canopy can minimize the dispersion of odorants by altering the dispersion plume. Nozzle selection may also contribute to improved odor control. These two factors likely improve uniform nutrient application as well. Many states have pivot irrigation restrictions in place to avoid odor nuisance. In situations where pivot application is the most desirable means of nutrient application, care should be taken in timing the application to minimize nuisance. Nozzles should also be positioned to avoid application outside of property boundaries and, if possible, the use of low-rise or trickling systems should be employed to achieve maximum odor control of irrigated manure waters.

Odor Policy

Many states have or are considering implementation of an odor standard or odor regulation. Such regulations must serve the interest of the general public while being fair to the livestock producer. Selection of the most appropriate method of regulating odors and development of a fair policy based on the chosen method are crucial to the viability of the livestock industry. Measuring odor emissions from a livestock facility is both a cost- and a labor-intensive process. Therefore, most states that have developed livestock regulations to protect neighboring residents from odor nuisance have sought alternative means of quantifying odor.

One policy designed to address odor nuisance is the implementation of separation distances between livestock operations and residences or public-use areas. These setback distances increase with increasing animal capacity and often are also established as a function of manure storage method. While not a guarantee that a neighbor will not smell any odor from the livestock operation, separation distances do protect rural residents from unlimited encroachment by an expanding livestock operation. From the producer’s perspective, it is important that the required distances adequately reflect farm management practices to reduce odor. A large operation does not always generate more odors than a small operation if odor control techniques are implemented on the larger facility.

A second strategy employed in odor policy is the use of a single or few gas concentration(s) that serve as odor indicators. Often, hydrogen sulfide and(or) ammonia serve as the indicators. The weakness in this strategy is that an odor emitted from a livestock facility is comprised of many, probably hundreds, of individual odorants with no single odorant accurately characterizing the odor. Analytes that are easily measured onsite, such as ammonia and hydrogen sulfide, do not necessarily serve as good indicators of odor intensity or odor offensiveness.

Another approach is to base odor policy on nuisance complaints (Schmidt and Jacobson, 1995). Operations receiving or expected to receive complaints, based on proximity to a nonagricultural area, would be required to implement odor control strategies. The weakness in this strategy is that unsubstantiated complaints, issued as the result of political and(or) social issues, cannot be distinguished easily from legitimate complaints. Also, it would be difficult for a new operation to predict odor response before construction.

Conclusions

Strategies to effectively reduce odor from animal housing areas, manure storage areas, and during land application are currently available. While no strategy ever will be free of cost, research developing and demonstrating low-cost options continues to take place. Numerous odor control options are available to producers; however, care must be taken to select a strategy that complements the farm management capabilities and waste handling system.

Implications

Odor control has become a necessary and integral part of livestock production. Adequate odor reduction levels are specific for each operator based on proximity to and reaction by neighbors. Willingness to incur costs associated with odor control is an additional consideration. Regardless, livestock producers must take the responsibility to implement effective odor control methods.

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