Practices to reduce hydrogen sulfide emissions associated with livestock production apply to animal housing, manure storage areas, and land where manure is applied. This document provides an overview of practices for each situation, highlights their advantages and disadvantages, and allows producers to make informed choices after evaluating production and economic aspects of their operations. Note that not all practices that achieve hydrogen sulfide emission control will result in odor control and vice versa, even though hydrogen sulfide is certainly an odorant associated with livestock production.

**Hydrogen Sulfide Control Strategies for Livestock Housing**

Gases generated in livestock housing facilities can exit the facility and make their way to downwind neighbors. Even systems that utilize external manure storage will have some manure within the housing itself, which may lead to gaseous emissions. Strategies to decrease hydrogen sulfide emissions from animal housing focus primarily on reducing the formation and movement of sulfur compounds. Five practices used to control hydrogen sulfide emission from livestock housing are discussed below.

**Filtration and Biofiltration**

Filters function by trapping particles and emissions. Biofilters not only trap emissions but also provide an environment for aerobic biological degradation of trapped compounds. Biofilters have been developed to reduce emissions from deep-pit manure ventilation exhaust, and, to a lesser extent, from the building exhaust. Although mechanical filtration may be costly, biofiltration can be a low-cost means of effectively reducing exhaust odors. Biofiltration costs for a 700-head farrow-to-wean swine facility are estimated at $0.25 per piglet, amortized over a 3-year life of the biofilter. Hydrogen sulfide reductions at that operation exceeded 90 percent, and similar reductions occur in odor (90 percent) and ammonia emissions (74 percent). Similar hydrogen sulfide and odor reductions were observed using biofiltration on a dairy facility. Because of the dust generated in the building, biofilter performance on a poultry facility was poorer (< 40 percent hydrogen sulfide and odor reduction).

Biofilters must be designed to provide suitable conditions for the growth of a mixture of aerobic bacteria within the biofilter. These bacteria will 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. Although management must be taken into consideration, it is clear that low-cost biofiltration systems ($150 to $200 per 1,000 cfm of air treated) can be implemented in livestock housing facilities using mechanical ventilation.

**Impermeable Barriers**

An alternative to filtering particles during air movement is to stop the movement altogether. Windbreak walls or air dams have proven effective in reducing downwind dust particle concentrations and odor
concentration. However, no data is currently available regarding hydrogen sulfide. Windbreak walls have been constructed with 10-foot × 10-foot pipe frames and tarpaulins, and placed at the end of swine-finishing buildings, immediately downwind of the exhaust fans. Downwind dust and odor concentrations were reduced on demonstration facilities, in areas with windbreak walls, due to plume deflection. Depending on the materials used for the barriers (tarpaulins on a frame or solid wood, for example) the life of the barrier could be from a few years to decades before replacement is needed.

**Oil Sprinkling**
Coating surfaces to control emissions and dust has involved the use of vegetable oil, either sprayed or sprinkled in animal pens. Data from a Minnesota study showed that hydrogen sulfide reductions were 40 to 60 percent in the oil-sprinkled rooms, following a detailed protocol for oil application. There was a 40 to 70 percent reduction in odor, but no effect on ammonia concentration was observed. Oil sprinkling involves safety issues such as the slippery conditions of pens and alleys following repeated oil applications. Costs are minimal for the vegetable oil, and other costs involve a sprayer and labor for the daily oil application.

**Landscaping**
Landscaping may reduce the emission of housing odors, as well as odors generated by other components of the livestock operation, beyond the property line. Landscaping acts as a permeable filter for particle emissions, slowing the particulate movement and diluting the concentrations of emissions. Trees and shrubs act as biofilters for odorous compounds that are attached to fine particles. By landscaping with both a treeline and a row of shrubs, particles at various heights within a plume can be adsorbed. To maximize adsorption, landscape materials with large surface areas are recommended. Trees and shrubs placed around the facility should not impede building ventilation and therefore are often located on the property lines. Costs associated with landscaping will vary depending on selected trees and shrubs, and on perimeter size. The estimate of a shelterbelt planted around a 3,000-head hog facility using “higher” cost trees ($25 per shrub or tree), calculated as $0.68 per pig for one year, amortized over 20 years at 5 percent, is just $0.09 per pig. These costs include maintenance costs. In addition to acting as a natural filtration system for odors, landscaping has the additional benefits of being aesthetically pleasing to the eye and of restricting the view of the operation. So, while documented effectiveness on emissions is scarce, the value of creating a facility that is pleasant to the eye should not be underestimated.

**Dietary Manipulation**
An alternative to filtration of emissions, as they leave housing facilities, is the reduction of the concentration of precursors to emissions. These precursors are produced upon anaerobic decomposition of the manure. Therefore, manipulation of livestock diets to alter excretion composition, and thus emission potential, may be effective in housing areas. Swine studies have identified trends toward reducing hydrogen sulfide concentration by reducing crude protein concentration and mineral sources that contain sulfur. For example, calcium oxide instead of calcium sulfate should be used, where possible, to reduce sulfur content in excretions. Nonetheless, research to quantify reductions is limited. However, some results suggest a reduction of as much as 40 percent in hydrogen sulfide concentration when
pigs are fed only the required amount of sulfur. Long-term storage effects on hydrogen sulfide emissions from manure are not currently available.

Producers also need to consider the sulfur content of the water supply. In some regions, water consumption means considerable sulfur intake by animals. To avoid overfeeding of sulfur, test the water supply and subtract the mass of sulfur consumed via water intake from the total daily sulfur needs. Excess sulfur will ultimately be excreted. Dietary manipulation can reduce manure sulfur content not only prior to excretion but also during manure storage, when anaerobic decomposition is taking place and reduced sulfur compounds are being formed. A limited amount of research is currently available to indicate which diet regimens or ingredients lead to the reduction of hydrogen sulfide.

**Hydrogen Sulfide Control Strategies for Manure Storage Facilities**

Hydrogen sulfide forms when manure is stored anaerobically. During the decomposition process, malodorous (offensive odors), intermediate compounds are produced and can accumulate if insufficient populations of bacteria that degrade these compounds are present. The summary below contains the recommended management practices that can be employed to reduce the emission of hydrogen sulfide from manure storage facilities.

**Impermeable Covers**

Covering a manure storage area with an impermeable cover prevents the release of gases into the atmosphere, and eliminates the effects of wind and radiation on emission rates. Although documented effectiveness for reducing hydrogen sulfide emissions is not available, impermeable covers are used to block any gas transfer, suggesting that emission reductions should be high and similar to those observed with odor (70 to 85 percent). Polyethylene covers typically range in price from $1.00 to $1.40 per square foot, installed.

Wind and snow-load damage present the greatest challenges with respect to implementation of the extended use of impermeable covers. Damage due to weather alters the life of the cover, impacting the capital investment required over time. Many manufacturers list a useful life of 10 years for storage areas constructed to prevent snow accumulation on the cover, but do not provide any guarantee against wind damage.

**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, geotextile fabric, and Leka rock. Permeable biocovers reduce emissions, in part, by reducing both the radiation onto the manure storage surface and the wind velocity over the surface of the storage area. Covers act as a barrier to these forces. At the solution/air interface, humidity is relatively high, which creates a stabilized boundary that slows the emission rate of odorous volatiles. The aerobic zone within the biocover allows the growth of aerobic microorganisms that utilize carbon, nitrogen, and sulfur for growth. This aerobic zone should also curtail the formation of reduced sulfur compounds, such as hydrogen sulfide. Reported reductions in hydrogen sulfide emissions have not been found; however, reports of odor reductions of 40 to 50 percent are common when various straw materials are used. An odor reduction efficiency of 85 percent has been noted following the use of a floating mat or corrugated materials.
Costs for biocovers vary widely depending on the material used and the method of application. In Minnesota, an operation employed a 1⁄8-inch thick geotextile material that cost $0.25 per square foot, plus installation. Straw was added on top of the geotextile cover for additional emission control. Straws and cornstalks cost approximately $0.10 per square foot, applied annually; peat moss and foam cost about $0.26 per square foot, applied annually; and Leka rock costs in excess of $2.50 per square foot for a 3-inch layer, but only has to be applied one time. Leka rock is a product of Norway, thereby requiring considerable shipping costs ($5 to $6 per cubic foot). The cost to cover a 1.5-acre earthen storage was $6,000 whereas an above ground tank over 0.2 acre was $500, for the same material.

Cover depth is very important for permeable covers. Most recommendations suggest a minimum of 8-inch depth, preferably 10- to 12-inch depth of coverage on a manure storage surface. Leka rock needs to be at least 3- to 4-inch deep. New covers (except Leka rock) need to be applied at least annually, and one study showed that only 50 percent of the straw cover remained four months after installation. Therefore management and re-investment costs need to be considered. Removal of large, fibrous material during storage cleanout must also be considered before selecting this option.

Aeration
Because hydrogen sulfide results from anaerobic processes, strategies to supply oxygen and maintain an aerobic environment can be effective in controlling the formation and emission of hydrogen sulfide. Capital investment and operating costs are considerable ($2 to $4 per pig marketed or $3,000 to $6,000 per aerator; often, more than one aerator needed). Selection and size of an aerator or aeration system is critical to obtain the desired performance, so a consultant needs to be involved in the decision-making and planning processes. Systems that aerate only the top portion of manure storages, which reduce costs, are under evaluation.

Aerator on second-stage lagoon at swine facility will reduce hydrogen sulfide emissions, but may also increase ammonia emissions.

Aeration, by design, incorporates oxygen into the manure storage. Most commonly, mixing of the manure is used to introduce oxygen. During this process, nitrogen is volatilized to the atmosphere, primarily as ammonia. Therefore, aeration, although effective for decreasing hydrogen sulfide, can increase ammonia emissions.

Composting
Composting can control hydrogen sulfide from solid manure because it maintains an aerobic environment in the manure. Hydrogen sulfide reduction benefits are not well documented. Disadvantages of composting include the high levels of management required to keep the process timely.
minimal management leads to slow decomposition, whereas intensive management can lead to quick decomposition. Another disadvantage is the need to bring in a bulking agent (newspaper, straw, wood chips) to maintain a balance of carbon and nitrogen during the decomposition process. Loss of nitrogen to the atmosphere, primarily as ammonia, is a problem that needs to be weighed carefully when considering this option, particularly when controlling ammonia emissions is also an objective.

Facilities should be covered to prevent runoff due to precipitation, and storage on a compacted area will prevent leaching of nutrients. Composting costs involve construction of the site with compacted floor and roof, and continuous maintenance of the compost with appropriate equipment to turn and aerate the pile. For example, a 4-feet × 6-feet × 3-feet-deep pile may be turned more properly with a small skid loader, whereas a considerably larger pile could be better handled with a front-end loader.

Composting is a better option for operations that handle solid manure. Liquid systems will require either some type of drying process or a large amount of bulking agents to avoid problems during the composting process.

**Dry Manure Storage**

Hydrogen sulfide is not typically associated with systems that handle dry manure. Management to maintain the dry conditions, preventing anaerobic activity from occurring, is essential to prevent the formation of hydrogen sulfide.

**Strategies to Reduce Hydrogen Sulfide During Land Application**

During land application of manure, producers may be more likely to receive nuisance complaints. In addition to increased road traffic, manure spreading brings odors closer to nearby residents than when manure is stored at the livestock facility. Therefore, measures to minimize nuisance during time of application should be considered, in addition to measures that control hydrogen sulfide during manure storage.

**Injection or Incorporation**

Injecting or incorporating manure shortly after surface application can best prevent odorous emissions that occur as result of land application. Estimated costs to inject manure are $0.003 per gallon above the cost to haul and broadcast liquid manure. A portion of the added cost can be recaptured in the form of decreased nitrogen losses for injected manure versus broadcast application. Although hydrogen sulfide impacts have not been documented, field tests in Iowa demonstrate odor reduction ranging from 50 to 75 percent with injection as compared to broadcast application. Similar results would be anticipated for hydrogen sulfide. Based on these reports, great benefits can be realized by incorporating after broadcast application as well.
Timing of Application
Practices that do not involve any physical changes to their existing operations should be implemented by producers. One such practice is timing of manure application. More frequent manure application and therefore less storage time is most desirable from the standpoint of emissions control. However, to make best use of nutrients, manure application should coincide with the time when crops are most in need of manure nutrients. The compromise, then, is to apply manure in the spring and in the fall, or in both seasons, but plan the applications for those times when they will be least offensive to neighbors. Producers should avoid holidays and be aware of wind conditions, so that neighbors will be in the downwind direction as little time as possible. Application in early evening, when air is still, is conducive to greater emissions than at midday, when air is more turbulent, allowing odor and other gases to dissipate more readily. Notifying neighbors of manure application plans is also a very important strategy to be undertaken.

Conclusions
Several practices to control hydrogen sulfide from livestock facilities are available. However, not all practices are suited for all operations. Careful consideration and selection of each practice will ensure the desired results. Regardless of the practice selected, common sense and consideration of neighbors are necessary components of a sound odor management plan.

Resources
For a list of research reports, ISU Extension publications, and links to current news regarding air quality and animal agriculture, please visit the Air Quality and Animal Agriculture Web page at:
http://www.extension.iastate.edu/airquality.


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