



Practices to Reduce Ammonia Emissions from Livestock Operations

Practices to control ammonia emissions associated with livestock production can be applied to animal housing, manure and compost storage areas, and land where manure is applied. This document provides an overview of control 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 control ammonia emission will result in odor control and vice versa, even though ammonia is certainly associated with livestock production.**

Ammonia Emission Control Strategies for Livestock Housing

In livestock facilities, ammonia results primarily from the breakdown of urea (present in urine) by the enzyme urease (excreted in feces). In poultry, urease is excreted with uric acid. Undigested feed protein and wasted feed are additional sources of ammonia in animal production systems. Strategies to reduce ammonia from animal housing focus primarily on preventing ammonia formation and volatilization, or downwind transmission of ammonia after it is volatilized. Four practices used to control ammonia emission from livestock housing are discussed below.

Filtration and Biofiltration

Filters trap particles and emissions, whereas biofilters not only trap emissions but also provide an environment for aerobic biological degradation of trapped compounds. Biofilters have been developed primarily to reduce emissions from the deep-pit manure ventilation exhausts, and, to a lesser extent, from the building exhaust. Although mechanical

filtration may be costly, biofiltration can effectively and inexpensively reduce 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. Reductions of ammonia emission at that operation are approximately 74 percent, whereas reductions in both hydrogen sulfide and odor emissions are about 90 percent.

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, including ammonia. 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—200 per 1,000 cfm of air treated) can be implemented in livestock housing facilities that are mechanically ventilated and can contribute to greater efficiency of the operation.

Impermeable Barriers

An alternative to filtering particles and gases during air movement is to stop the movement altogether. Windbreak walls or air dams have proven effective in reducing both downwind dust particle concentrations and odor concentration. As a consequence of the presence of impermeable barriers, one might expect a reduction in ammonia concentrations. However, no scientific data is available so far to support this argument. 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.

The kind of materials used for the barriers (tarpaulins on a frame or solid wood, for example) will determine the life of barriers, which can be from a few years to decades before replacement is needed.

Landscaping

Landscaping may reduce both housing emissions and emissions generated by other components of the livestock operation, beyond the property line. Landscaping acts as a permeable filter for particle emissions, slowing the emission movement and diluting the concentrations of emissions. Trees and shrubs act as biofilters for fine particles. By landscaping with both a tree line 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 cannot impede building ventilation and are often located on the property limits.

Costs associated with landscaping will vary depending on selected trees and shrubs, and on perimeter. Estimates of a shelterbelt planted around a 3,000-head hog facility using “higher” cost trees (\$25 per shrub or tree), is \$0.68 per pig for one year. Amortized over 20 years at 5 percent, and including maintenance costs, the estimate is only \$0.09 per pig. In addition to acting as a natural filtration system, landscaping has the additional benefits of being aesthetically pleasant 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 cannot be underestimated. However, the time between the planting of immature trees and the time when those trees are large enough to be effective must be considered before producers decide on the best practice for their systems. In Iowa, this time lag may be as long as seven years, depending on the planting varieties.



Dietary Manipulation

Minimization of nitrogen (N) excretion is the most obvious method to curb ammonia emissions. By reducing the amount of nitrogen excreted, less ammonia will be formed and volatilized. When common feeds are included in the diet, protein sources are added to meet animal needs for lysine, typically the most limiting amino acid. All other amino acids are consequently supplied in excess and excreted.

The most promising dietary manipulation consists of supplying non-ruminants with the amino acids they need, including crystalline ones, instead of

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supplying feeds based on crude protein. In the ruminant animal, meeting the needs of the rumen, independently of the lower digestive tract, effectively reduces the content of dietary crude protein. In swine, dairy, and poultry, nitrogen excretion is reduced by approximately 8.5 to 10 percent for each one-percentage unit reduction in dietary crude protein. Greater reductions are possible and, in fact, direct emissions of ammonia are reduced by 19 percent for every percentage unit of dietary crude protein that is reduced in

swine diets. As animals are fed closer to true nitrogen requirements, further reductions in dietary protein may result in less pronounced reduction in nitrogen excretion and ammonia losses.

Addition of fermentable carbohydrates, such as bran or pulp, into grow-finishing diets, resulted in a 14 percent reduction of ammonia emission for each increase in carbohydrate. More work evaluating the

balance of carbohydrate and protein in diets is needed. The reduction may be due to a pH effect, to the shift from urinary to fecal nitrogen excretion, or both. Additives that bind ammonia have shown reductions in ammonia emission (26 percent over a period of seven weeks in swine fed a yucca extract).

Lysine is economical for both swine and poultry diets. By-products are important and economical sources of



rumen bypass protein for ruminants. Therefore, some dietary strategies do not increase diet costs to the producer. Further protein reductions will increase ration cost but may be considered affordable, depending on the operational objectives of each producer.

Ammonia Emission Control Strategies for Manure Storage Facilities

In the air, ammonia can combine with other gases to form ammonium nitrate and ammonium sulfate, which are fine particulates. These particulates are of concern for human health and are regulated under the Clean Air Act. Therefore, minimizing the release of ammonia from animal feeding operations is desirable. Similar to housing strategies, strategies to reduce ammonia from animal housing focus primarily on preventing ammonia formation and volatilization or downwind transmission of ammonia, after it is volatilized. A summary of practices to reduce ammonia from manure storage facilities is provided below.

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. Odor reduction

efficiencies of 70 to 85 percent have been observed when surfaces are completely covered by impermeable covers. Although undocumented, ammonia reductions may be similar. 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 and extended use of impermeable covers. Damage due to weather alters the life of the cover and impacts the requirements for capital investment over time. Many manufacturers list a useful life of 10 years for facilities 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 straw, 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 liquid surface of the storage area. 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 the carbon, nitrogen, and sulfur from the emissions for growth. By further degrading and making use of these compounds prior to exiting the biocover, odors emitted from the

biocover are altered and reduced. Reports of odor reductions of 40 to 50 percent are common whenever 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. Although ammonia emission reductions are undocumented, the processes that occur in the biocovers suggest that ammonia emissions may be reduced to the same extent.

... particulates are of concern for human health.



Liquid swine manure in concrete pit covered with Leka rock.

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 costs. Straw was added on top of the geotextile cover for additional odor control. Straws and cornstalks cost approximately \$0.10 per square foot, applied; peat moss and foam cost about \$0.26 per square foot, and Leka rock is approximately \$2.50 per square foot for a 3-inch depth. All costs depend on the depth of the material used. Leka is a product of Norway, thereby requiring considerable shipping costs of \$5—\$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.

Most recommendations suggest a minimum of 8-inch and preferably 10- to 12-inch depth of coverage on a manure storage surface. New covers (except Leka rock) may 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. One disadvantage of both permeable and impermeable covers is a probable increase in ammonia emissions and odors during land application.

Mineral and chemical amendments have been used to reduce ammonia emissions from animal manures.

Urine/feces Segregation

Because ammonia results from the interaction of urine and feces in swine and ruminants, efforts to separate them immediately upon excretion have reduced ammonia emissions successfully. Manure handling systems designed to prevent urease from coming in contact with urea are under investigation. Most systems employ a separator or a belt conveyor whereby feces, containing urease, are captured on the belt and urine is stored below. As much as 80 percent reduction in ammonia emissions is expected from using this system but the practice has not yet been commercially implemented. However, several urine/feces segregation systems are in the developmental phase at this time.

Acidification

Depending on the pH, N can exist in different forms. Reducing the pH maintains more nitrogen in the form of ammonium, which is not released as a gas. Therefore, strategies that acidify manure (reducing the pH) can be used to trap ammonium and prevent its release as ammonia. Among these strategies are dietary practices used to acidify urine by including phosphoric acid. However, ammonia emissions are more related to the buffering capacity, or alkalinity, of the manure than to pH, suggesting that pH of excretions may increase during storage, therefore reducing the effectiveness of this strategy. A disadvantage of acidification is that although it traps ammonia, the reduced pH is conducive to volatilization of

hydrogen sulfide, another odorous compound produced from the anaerobic decomposition of manure. Costs associated with this practice include the acid and the equipment to apply and mix the acid with the stored manure.

Additives

Additives to control ammonia emission predominantly function by either binding ammonia or by inhibiting urease, the enzyme that breaks urea down to ammonia. Two inhibitors, thiophosphoric triamide

and cyclohexylphosphoric triamide, restrained the production of urease following application to cattle feedlot pens (0.32 oz. per pound of manure).

Similarly, weekly additions of phenyl phosphorodiamidate to cattle and swine slurries prevented the urea from being hydrolyzed up to 70 and 92 percent, respectively. Because urease occurs widely in nature, the inhibitor must be applied routinely to prevent future emissions. Routine application, however, may pose problems once the manure is land-applied, unless plants can quickly use the nitrogen. Urease inhibitors are not widely available commercially, and the above-mentioned compounds are chemical rather than products. However, one product, manufactured by Agrotain, is distributed throughout the United States.

Mineral and chemical amendments have been used to reduce ammonia emissions from animal manures. Phosphates and gypsum reduced ammonia losses from dairy manure storage by 28 and 14 percent, respectively. Triple superphosphate, superphosphate, calcium chloride, and gypsum treatments reduced ammonia losses by 33, 24, 13, and 8 percent, respectively, when surface-applied to dairy manure. All additives involve the cost of the products themselves and the application equipment associated with them. Continuous application is likely needed in manure storage whereas a single application of the additive may suffice during manure application if manure is then incorporated.

Dry Manure Storage

In open lot facilities and facilities that store dry manure, ammonia control can be a greater challenge. Ammonia loss during composting depends on the carbon to nitrogen (C:N) ratio: ammonia volatilization is significant below 15:1. Increased use of bedding will help maintain a higher C:N ratio but also results in a dryer product that will not compost as readily without the addition of moisture. Application of a layer of 38 percent zeolite, placed on the surface of the composting poultry manure, reduced ammonia losses by 44 percent.

... dry manure, ammonia control can be a greater challenge.

Strategies that focus on source reduction, such as diet manipulation, are applicable and may prove to be the best control measure. Covering manure can be effective as well. Similarly, practices that involve binding ammonia or altering the pH, so that ammonia is less volatile, can control its emission. Calcium chloride and triple superphosphate treatments are effective in reducing losses

when surface applied to poultry manure (19 and 17 percent, respectively).

Strategies to Reduce Ammonia Emissions During Land Application

Estimates of whole-farm ammonia emissions suggest that as much as 35 percent of the total ammonia emissions may occur during land application of manure. Therefore, control strategies beyond those implemented in housing and manure storage areas should be considered, as reported below for injection and manure amendments.



Injecting manure can reduce ammonia emissions during land application.

Injection or Incorporation

Injecting or incorporating manure shortly after surface application can best prevent nitrogenous emissions that result from land application, in

addition to reducing odorous emissions. Costs to inject manure are estimated to be \$0.003 per gallon above the cost to haul and spread liquid manure. A portion of the added cost can be recaptured, agronomically, in the form of reduced nitrogen losses for injected manure versus broadcast application. The benefits of reduced nitrogen losses through volatilization can also be realized by incorporation, after broadcast application.



Closeup of injectors.

Manure Amendments

Research has demonstrated that some products can effectively reduce ammonia losses through either a binding or a pH effect. Urease inhibitors may also prove effective. Costs are product-specific, and often determined as much by application rate and frequency as by the cost per unit weight. Following land application of fresh chicken slurry amended with calcium chloride, a reduction in ammonia losses of 37 percent was found. Aluminum sulfate, ferrous sulfate, and phosphoric acid reduced ammonia volatilization from litter by 96, 79, and 93 percent, respectively. Aluminum sulfate is often recommended as amendment, due to the enhanced phosphorus content of litter following addition of phosphoric acid, and to toxicity concerns associated with addition of ferrous sulfate.

Conclusions

Employing specific practices can reduce ammonia emissions. A number of practices are available but not all are suited for all operations. Careful consideration and selection will help ensure that you achieve the desired results.

Neither endorsement of companies or products mentioned is intended, nor is criticism implied of similar companies or products not mentioned.

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>.

PM 1970a *Practices to Reduce Odor from Livestock Operations* is found on the Web at: <http://www.extension.iastate.edu/Publications/PM1970a.pdf>

PM 1971a *Practices to Reduce Ammonia Emissions from Livestock Operations* is found on the Web at: <http://www.extension.iastate.edu/Publications/PM1971a.pdf>

PM 1972a *Practices to Reduce Hydrogen Sulfide from Livestock Operations* is found on the Web at: <http://www.extension.iastate.edu/Publications/PM1972a.pdf>

PM 1973a *Practices to Reduce Dust and Particulates from Livestock Operations* is found on the Web at: <http://www.extension.iastate.edu/Publications/PM1973a.pdf>

Prepared by Wendy Powers, environmental extension specialist, Department of Animal Science, Iowa State University. Reviewed by David Schmidt, extension engineer, University of Minnesota. Edited by Marisa Corzanego, extension communications intern, Communication Services, Iowa State University Extension. Designed by Jane Lenahan, graphic designer, Instructional Technology Center, Iowa State University.

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