Story County Board of Supervisors
Animal Feeding Operation Master Matrix County Criteria - Work Session
1 p.m. - 2:30 p.m.
Tuesday, Feb. 28, 2017
Story County Public Meeting Room
900 6th Street, Nevada

Tentative Agenda

I. Opening remarks; purpose of workshop – Margaret Jaynes

II. Legal limitations for county's increased standards for the Master Matrix (MM) – Ethan Anderson

III. Staff research on MM criteria subject to higher county standards

A. Proposed Facility Characteristics

1. Additional distance to critical public area (MM#6) – Mike Cox
2. Liquid Manure is covered (MM#12) – Margaret Jaynes
3. Emergency containment area (MM#13) – Keith Morgan and Darren Moon
4. Installation of filters (odors) (MM#14) – Aaron Steele and Margaret Jaynes
5. Utilization of landscaping (MM#15) – Jerry Moore and Mike Cox
6. Stockpile facility enhancements (MM#16) – Aaron Steele and Margaret Jaynes
7. Truck turnaround (MM#19) – Darren Moon
8. No history of admin orders in last 5 years (MM#20) – Margaret Jaynes
9. Wet dry feeders (reduce volume) (MM#25) – Margaret Jaynes and Aaron Steele

B. Manure Management

1. Manure incorporation (MM#26) – Margaret Jaynes and Aaron Steel
2. Land application areas have buffer strips (MM#28) – Margaret Jaynes
3. No manure on highly erodible land (MM#29) – Margaret Jaynes
4. Additional distance to public use area (MM#31) – Mike Cox
5. Work safety and protection plans (MM#37) – Keith Morgan
6. Job development/increased property tax base (MM#39) – Wayne Schwickerath
7. Emergency action plan (MM#40) – Keith Morgan
8. Closure plan (MM#41) – Keith Morgan and Jerry Moore
9. Environmental management plan (MM#42) – Margaret Jaynes
10. Groundwater monitoring (MM#44) – Margaret Jaynes

IV. Public comments View additional materials on the following pages.

WE ASK THAT MEMBERS OF THE PUBLIC PROVIDE AN ADVANCE ELECTRONIC COPY OF ANY MATERIALS THEY WANT THE COMMITTEE TO REVIEW. THE DEADLINE IS 5 P.M. FRIDAY, FEB. 24, 2017. SEND TO: LOLSON@STORYCOUNTYIOWA.GOV

No decisions will be made at this meeting. Information provided could be considered in future policy decisions.

11-2011

Air Quality Education in Animal Agriculture: Biofilters for Odor and Air Pollution Mitigation in Animal Agriculture

Kevin A. Janni
University of Minnesota–Twin Cities

Richard E. Nicolai
South Dakota State University

Steven J. Hoff
Iowa State University, hoffer@iastate.edu

Rose M. Stenglein
University of Minnesota

AIR QUALITY

Biofilters for Odor and Air Pollution Mitigation in Animal Agriculture

Kevin A. Janni, Professor, Department of Bioproducts and Biosystems Engineering, University of Minnesota kjanni@umn.edu
Richard K. Nicolai, Associate Professor, Department of Agricultural and Biological Engineering, South Dakota State University
Steven Hoff, Professor, Department of Ag and Biosystems Engineering, Iowa State University
Rose M. Stenglein, Junior Scientist, Department of Bioproducts and Biosystems Engineering, University of Minnesota

This publication discusses biofilters use and design and performance factors.

Contents

eXtension
Air Quality in Animal Agriculture
http://www.extension.org/pages/15538/air-quality-in-animal-agriculture

Biofilters are a proven and effective method for reducing odor and other gaseous emissions from mechanically ventilated animal facilities and manure storage units. Biofilters work by absorbing noxious gases into a biofilm where microorganisms break down the gases into carbon dioxide, water, and salts and use the energy and nutrients to grow and reproduce. Well-designed and managed biofilters can reduce odors and hydrogen sulfide (H_2S) by as much as 95 percent and ammonia (NH_3) by 80 percent. Biofilters have been used by nonagricultural industries for many years and on animal facilities for over 12 years in North America.

Biofilters are actively being researched; additional information about pollution reduction efficiencies, biofilter media, configurations, and maintenance will be available in coming years. Additional potential benefits may include reducing airborne transmission of viruses and reducing greenhouse gas emissions.

What Is a Biofilter?

Biofilters used to treat air from livestock barns include biofilter media, ductwork, distribution plenum, and fans. *Figure 1* shows a flat-bed biofilter treating air from a livestock barn with a belowground manure pit. The biofilter media supports a moist, biologically active biofilm in which gases in the air are absorbed and broken down before the air leaves the biofilter. Ductwork connects the livestock barn or other air source and fan to the plenum where the air is distributed evenly to the media. Fans are required to draw air from the barn and push it through the ductwork and biofilter media.

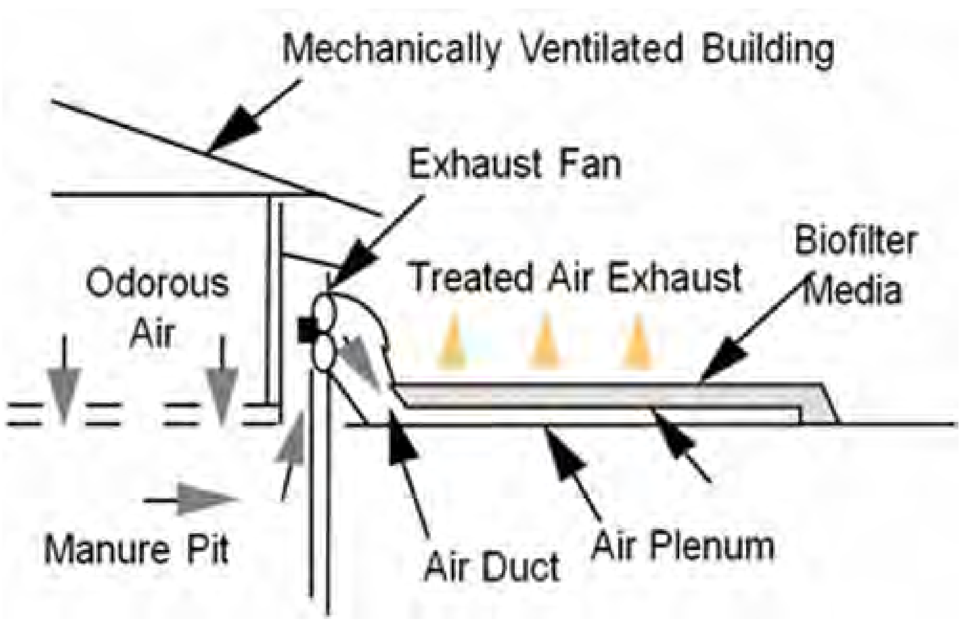


Figure 1. Typical flat-bed biofilter on mechanically ventilated livestock building.

Biofilters are actively being researched. Additional information about pollution reduction, configurations, and maintenance will be available in the future.

Biofilter media treats contaminated air both physically and biologically. Physical treatment occurs when contaminants (such as odorous gases, aerosols, and small particles) are trapped on the media surface and/or absorbed into the moist biofilm. Biological treatment occurs when microbes in the biofilm degrade contaminants into carbon dioxide (CO_2), water (H_2O), mineral salts, volatile organic compounds (VOCs), and microbial biomass. The microbial action is what differentiates a biofilter from a simple filter or wet scrubber.

Where Are Biofilters Used?

Biofilters are used to treat air from mechanically ventilated buildings that use fans to control airflow. The ventilating fans allow contaminated air to be collected and directed to a biofilter. In some cases, biofilters treat 100 percent of the exhausted ventilation air. In many other cases, biofilters treat a portion of the exhaust ventilation air. Manure pit fan exhaust can be treated with a biofilter.

Biofilters also can be used to treat air from a covered manure storage unit or enclosed treatment facility. Manure gases that are trapped under the cover can be blown through a biofilter for treatment.

Biofilters cannot treat air that exhausts from naturally ventilated barns through open sidewalls or ridges because the air cannot be collected and directed to a biofilter. Biofilters can be used to treat air from pit fans on naturally ventilated barns. These pit fans take air from the underground manure storage pit under the naturally ventilated buildings. In cold weather these pit fans may move 100 percent of the exhaust air, which can be treated with a biofilter. During warm weather, pit fans may move only 10 percent of the exhaust air. One way to treat more air during warm weather is to increase the pit fan capacity to 40 percent of the maximum hot weather ventilation. The increase pit fan capacity will assure that most pit gases will be treated by the biofilter before the sidewall curtains open.

Biofilters also can be used to treat a critical minimum amount of ventilation air from animal facilities when stable atmospheric conditions reduce odor dispersion. Stable atmospheres are more common during the evening and early morning hours when there is very little air mixing in the lowest few hundred feet of the atmosphere. Biofiltration of mechanically ventilated air during these stable periods reduces emissions when odor plumes can travel long distances close to the ground. Biofilters used in this manner are expected to reduce odor nuisance complaints, while costing less to operate than systems that biofilter all exhaust air all the time.

Biofilter Types

Biofilters are classified in several ways, depending on the layout. Biofilters can be either open- or closed-bed. The media in open-bed biofilters is uncovered and exposed to weather conditions, including rain, snow, and temperature extremes. Closed-bed biofilters are mostly enclosed with a small exhaust port for venting of the cleaned air. Open-bed biofilters are the most common type used to treat air from animal facilities. Some open-bed biofilters can have roofs over the biofilter to provide some weather protection.

Biofilters also can be classified as horizontal or vertical (*Figure 2*). Horizontal biofilters have larger footprints than vertical biofilters. Contaminated air is distributed evenly under the horizontal biofilter and flows up through the media. Many open-flat-bed horizontal biofilters have media 10 to 18 inches deep. These biofilters are relatively inexpensive to build and easy to maintain.

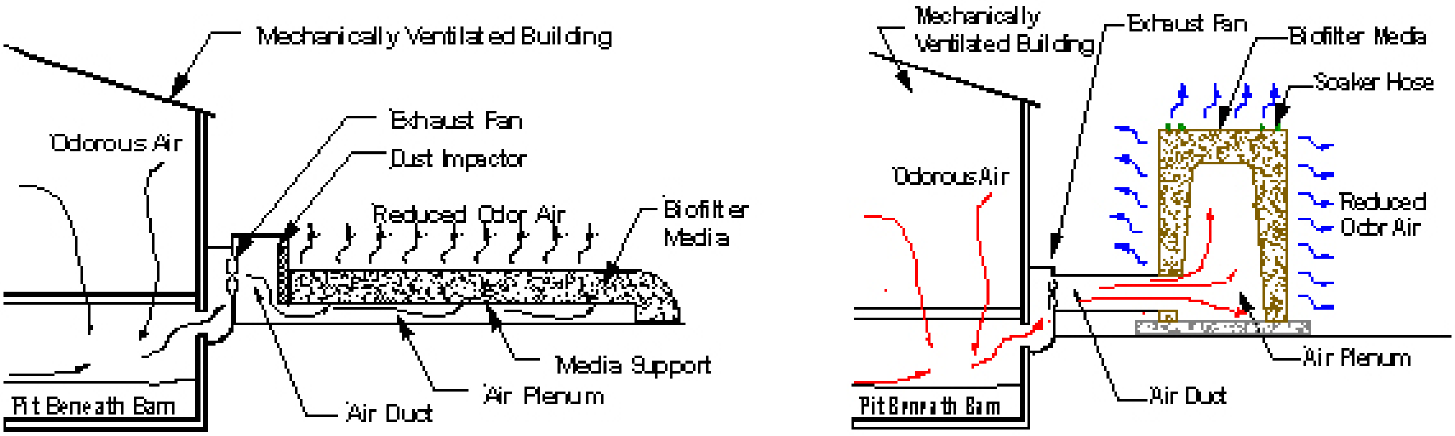


Figure 2. Horizontal flat-bed biofilter (left) and vertical biofilter (right)

Some horizontal biofilters have been built with media depths between 3 and 7 feet. These deep-bed biofilters usually treat smaller airflows and require a smaller footprint than comparable shallower biofilters, but they require more powerful fans, which are more expensive.

Vertical biofilters are being developed to reduce the footprint required. There are different vertical biofilter designs. (See circular and rectangular vertical biofilters pictured in Figure 3A and 3B respectively.) The media in a vertical biofilter is placed between two vertical support structures and across the top. The air passes either horizontally through the vertical supports or through the top. Vertical biofilters use less surface area than a horizontal biofilter for treating the same airflow but are more expensive to build and maintain.

Vertical biofilters must compensate for media settling over time in between the vertical supports. As the media settles, more compaction occurs at the bottom. This reduces airflow through the bottom portion more than through the top. One method for overcoming the uneven airflow through the media between the vertical supports has been to taper the support and the media thickness. The media at the top of the vertical support is thicker than the bottom (*Figure 2*). Initially, tapering allows greater airflow through the bottom but, over time, the media becomes compacted and airflow becomes uniform throughout the vertical supports.

Biofilter Elements

Open-bed horizontal biofilters are the most common in animal agriculture and, as shown in *Figure 1*, include the following elements:

- A mechanically ventilated space with biodegradable gas emissions.
- A fan to move the odorous exhaust air from the building or manure storage through the duct, plenum, and biofilter media.
- Ducting connecting the ventilated space and an air plenum that distributes the air to be treated evenly beneath the biofilter media.
- A porous structure to support the media above the air plenum.
- Porous biofilter media that serves as a surface for microorganisms to live on, a source of some nutrients, and a structure where moisture can be applied, retained, and be available to the microorganisms.

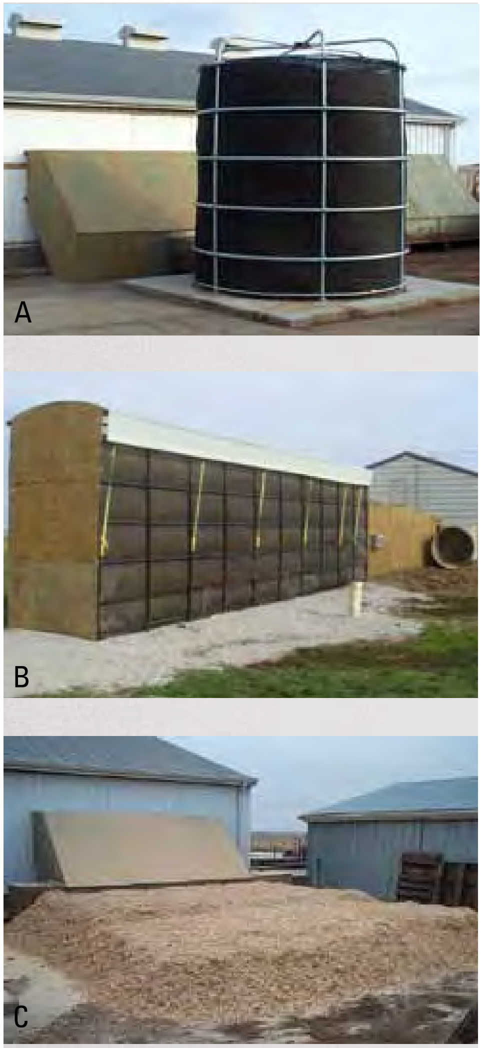


Figure 3. (A) Circular vertical biofilter; (B) rectangular vertical biofilter; and (C) flat-bed biofilter

Table 1. Empty bed contact time (EBCT); listed in seconds required to treat air from different types of livestock and poultry facilities.

Livestock System	EBCT (s)	References
Swine barn with deep pit manure storage	5	Zeisig, 1987; Nicolai and Janni, 1999
Poultry barns with dry litter	3	Zeisig, 1987
Covered manure storage units	10	Zeisig, 1987
Dairy heifer barn with deep pit manure storage	5	Nicolai and Janni, 1999

Biofilters are used to treat air from mechanically ventilated buildings that use fans to control airflow.

Design and Performance Factors

Contact Time and Airflow

Contact time indicates the amount of time that the air is in contact with the biofilter media. Empty bed contact time (EBCT) is defined as the time it takes for the air to flow through a volume the same size as the media. Longer contact times give the biofilter more time to treat gases but also require a larger biofilter. Three to five seconds is sufficient contact time for most livestock facilities but air from covered manure storages usually requires 10 seconds of contact time. (*Table 1*).

When treating air from mechanically ventilated buildings, the airflow rates are determined by the season and the type of livestock housed in the building, specifically the number, species, and size. Higher airflow rates are required during warm weather. Biofilter design should use the highest airflow rate intended for biofiltration. Exhaust fans need to be powerful enough to create a vacuum in the building to draw fresh air in from outside while pushing exhaust air out and through the biofilter. When biofilters are added to mechanically ventilated livestock and poultry barns, the existing fans may not be powerful enough to push air through the biofilter and may need to be replaced.

When treating air from covered manure storage units, the recommended minimum airflow rate is 0.01 cubic feet per minute per square foot of manure surface area.

Once the desired contact time and maximum airflow rate have been determined, they are used to find the volume of biofilter media needed. A typical open-bed horizontal biofilter with media 1 foot deep may require 50 to 85 square feet per 100 cubic feet per minute of airflow. A deep-bed biofilter with media 3 feet deep may require 15 to 30 square feet per 100 cubic feet per minute of airflow.

Moisture Content

Biofilter media moisture control is essential for effective treatment. Inadequate moisture can reduce filter efficiency by allowing the media to dry out, deactivating the microbes and creating cracks that allow air channeling. Too much moisture can plug some of the pores in the media, cause channeling, restrict airflow through the media and the barn, and limit oxygen flow in saturated areas in the media, which creates anaerobic zones in the biofilm. These anaerobic zones may produce nitrous oxide, an important greenhouse gas. Some excess moisture is generally not a problem because the extra moisture could either drain through the media or evaporate due to the airflow through the media.

Typically, biofilters require moisture be added whenever the temperature is above freezing. Lawn sprinklers can easily be used to wet horizontal open-bed biofilters. Soaker hoses laid horizontally along the top of vertical biofilters, especially each vertical section, have been used successfully to add moisture uniformly to the media. The sprinkler and soaker hose systems can be controlled with timers to operate at the duration and frequency needed to maintain the needed moisture content. The recommended moisture content for biofilters ranges from 30 to 70 percent in the top ¾ of the media with an optimum moisture content of 50 percent. In the field biofilter moisture is usually monitored by look and feel rather than measurement. To check media moisture content, dig into the media. Dampness should be felt ½ to ¾ of the way through the media depth. If dampness is felt throughout the depth of the media, the watering system is providing too much water. If, however, only the top few inches are damp, more water needs to be added. Often, watering is done at night to reduce evaporation losses. Research is under way to develop a moisture sensor and automated watering system.

When ambient temperatures are below freezing, moisture need not be added. During colder weather, the warm moist air from a livestock or poultry barn supplies the biofilter with sufficient moisture. Any snow that falls on the biofilter will be melted by the warm exhaust air and will supply additional moisture.

Excessive water from storm events or a watering system failure can cause moisture to saturate the media and seep out the bottom. The water seeping out, known as leachate, can contain high concentrations of organic matter and nitrate. Most biofilter media are capable of absorbing most large rainfall events so the potential for leachate is relatively small. Design guidelines suggest a clay, concrete, or plastic liner be installed under the biofilter bed to collect the leachate. More testing and analysis are needed to determine the effects of excess moisture.

Excessive water from storm events or over watering can restrict airflow through the media and increase the pressure drop across the media. This can reduce the barn ventilating rate to less than the designed rate. As the media dries, the pressure drop will decrease and the airflow rate will be restored.

Temperature

Microorganisms tolerate a range of temperatures. They are most active between 70 and 90°F. In winter the cooler temperatures will reduce the microbial activity, but at the same time, there is less airflow because winter ventilating rates are approximately 1/10 the summer levels. Most biofilters maintain portions of the biofilter media above freezing even in winter due to continuous flow of warm air from livestock or poultry buildings. However, biofilters on manure storages or on unheated buildings will freeze in cold weather, temporarily stopping biofilter treatment. As the biofilter heats up in the spring, microorganisms become active again and biofilter effectiveness is restored. Heating a biofilter to avoid freezing is usually not cost effective in animal agriculture.

Siting

The biofilter bed should be located close to the exhaust fans to limit the duct length but far enough from the building to avoid rain or snowmelt running off the roof onto the biofilter media. It is also important to construct a biofilter in an area where water will not pond. Keeping this area dry will increase system life. Typically, most of the rain or snow that falls on an open-bed biofilter is absorbed by the porous media. However, during periods of high rainfall or if the sprinkling system fails, water potentially could leach out of the biofilter media. Therefore, the biofilter bed should be built on a sloped, well-drained area so excess water can move away from the biofilter.

Media

Media selection is critical in biofilter design. Media must provide a suitable environment for microbial growth and maintain a high porosity to allow air to flow easily. Critical properties of media material include (1) porosity, (2) moisture holding capacity, (3) nutrient content, and (4) slow decomposition. *Table 2* lists the characteristics for various biofilter media. Mixtures of these materials have the advantage of combining these characteristics.

Biofilters can be either open- or closed-bed. Open-bed biofilters are the most common type used to treat air from animal facilities.

Table 2. Biofilter media characteristics.

Material	Porosity	Moisture Capacity	Nutrient Capacity	Useful Life	Comments
Peat	Average	Good	Good	Good	Good Microorganism Sources
Soil (heavy loam)	Poor	Good	Good	Good	
Compost (yard waste)	Average	Good	Good	Good	
Wood Chips	Good	Average	Average	Average	Good Additions for Porosity
Straw	Good	Average	Poor	Poor	

Biofilter media moisture control is essential for effective treatment.

Biofilter media needs to include plenty of voids, 50-80 percent, to allow air to flow through easily. Many biofilters used in animal agriculture use a media that is a mixture of wood chips and compost. Wood chips provide structural support and void space, and compost provides a nutrient-rich environment and an initial source of aerobic microorganisms. Recent research has demonstrated that media comprised primarily of wood chips coated in manure slurry or another microorganism source is also effective and requires less frequent replacement. Other possible filter media include wood bark, coconut fiber, peat, granular-activated carbon, perlite, lava rock, and polystyrene beads.

A proven organic media mixture for animal agriculture biofilters ranges from approximately all wood chips to 30:70 ratio by weight of compost and wood chips or wood shreds. Some early biofilters used a 50:50 wood chip compost ratio but their porosity tended to be less than desired. Media mixtures with more compost (less wood chips) and other fine particles will result in higher pressure drops but only slightly higher efficiencies.

Over time wood chip degradation, dust accumulation, microorganism buildup, and media settling cause biofilters to become clogged, making airflow through the media more difficult. Eventually the fans are unable to force the required ventilation air through the biofilter and ventilating rates decrease, resulting in poor building ventilation. Both biofilter media and exhaust air dustiness affect the length of time before the media needs to be replaced. Typically wood chip media needs to be replaced every 3 to 10 years.

Currently there are no requirements for disposal of biofilter media. Some of the media can be mixed with more wood chips and reused in the biofilter. The remaining media could be handled similarly to compost and land applied to cropland at agronomic rates. If the biofilter media is very dry, it is likely that significant amounts of dust will be generated during loading and land application. Care should be taken to avoid breathing this dust.

Microorganism Seeding

Biofilter treatment efficiency depends on the microbial breakdown of volatile compounds in the air. Microorganism type and number in the biofilter impact performance. Natural media materials such as peat, loam soil, and compost usually contain sufficient microorganisms to seed a biofilter treating air from a livestock building or manure storage. Biofilters also can be seeded with aerated manure. A three- to six-week conditioning period allows the microorganisms to adapt to the compounds in the air. During this conditioning time, the biofilter efficiency is limited.

Construction

During biofilter construction, efforts should be made to minimize media compaction. All ducting work should be completed before the media is placed. No machinery or foot traffic should be allowed on the media to prevent media compaction, which reduces airflow. Access lanes could be constructed to allow for fan or duct maintenance. If there is a need to walk across the media, it is best to lay down planks or plywood to distribute the weight and limit compaction.

To achieve uniform air treatment, it is critical to maintain uniform media depth across an open flat-bed biofilter. Air will follow the path of least resistance, which is often the thinnest area of the media. Any channeling of air reduces the biofilter effectiveness. Untreated air can escape from around the edges of the biofilter media or at the ductwork and plenum intersection. Efforts should be made to seal all duct and plenum joints with appropriate caulking or plastic sheeting to minimize untreated air leaks.

Respiratory protection is recommended during construction, maintenance, and media removal.

Weeds

Weed growth on the biofilter surface can reduce efficiency by causing air channeling and limiting oxygen exchange. Roots can plug biofilter pores. Weeds on a biofilter also reduce the aesthetic appearance of the livestock site. A systemic herbicide or some other means should be used to manage weeds growing in biofilter media.

Rodents

A good rodent control program is essential to protect biofilters. Fortunately, most livestock and poultry operations currently have a good rodent control program, which can be adequate around biofilters. Mice and rats burrow through the warm media during the cold winter months, causing channeling and poor air filtration. Rabbits, woodchucks, and badgers have been suspected of burrowing through and nesting in biofilters. Incorporating a biofilter into existing rodent control programs is simple and inexpensive.

Health and Safety Concerns

There has been very little research on potential health and safety concerns related to biofilters. The reliance on natural microorganisms found in compost, soil, or peat suggests that individuals sensitive to these organisms may need to wear a face mask to minimize exposure to airborne microorganisms and mold spores. Respiratory protection is recommended during construction, maintenance, and media removal.

Biofilter Costs

Capital and installation costs, and operation and maintenance costs are quite variable. Capital costs to install a biofilter include the cost of the materials — fans, media, ductwork, and plenum. Installation costs may include labor and equipment rented to build the biofilter. Typically, cost for a new horizontal biofilter on mechanically ventilated buildings will be between $150 and $250 per 1,000 cfm. A vertical biofilter is approximately 1.5 times the cost of a horizontal biofilter.

Annual operation/maintenance of the biofilter is estimated to be $5-$10 per 1,000 cfm. This includes the increase in electrical costs for fans to push the air through the biofilter and the cost of replacing the media after five years.

References

Chen, L., S. J. Hoff, J. A. Koziel, L. Cai, B. C. Zelle, and G. Sun. 2008. Performance evaluation of a wood chip-based biofilter using solid-phase microextraction and gas chromatography-mass spectrometry-olfactometry. *Bioresource Tech*. 99: 7767-7780.

Devinny, J. S., M. A. Deshusses, and T. S. Webster. 1999. *Biofiltration for Air Pollution Control*. Boca Raton, FL.: Lewis Publishers.

Garlinski, E. M., and D. D. Mann. 2003. Design and evaluation of horizontal air flow biofilter on a swine facility. ASABE Paper No. 034051. St. Joseph, Mich.: ASAE.

Hartung, E., T. Jungbluth, and W. Buscher. 2001. Reduction of ammonia and odor emissions from a piggery with biofilters. *Trans. ASAE* 44(1): 113-118.

Hoff, S. J., J. D. Harmon, L. Chen, K. A. Janni, D. R. Schmidt, R. E. Nicolai, and L. D. Jacobson. 2008. Practical partial biofiltration of swine exhaust ventilation air. In *Proc. Mitigating Air Emissions from Animal Feeding Operations, 144-149*. E. Muhlbauer, L. Moody, and R. Burns, eds. Iowa State University, Ames, IA.

Hoff, S. J., J. D. Harmon, L. Chen, K. A. Janni, D. R. Schmidt, R. E. Nicolai, and L. D. Jacobson. 2009. Partial biofiltration of exhaust air from a hybrid ventilated deep-pit swine finisher barn. *Applied Eng. in Agric*. 25(2): 269-280.

Janni, K. A., W. J. Maier, T. H. Kuehn, C. H. Yang, B. B. Bridges, and D. Vesley. 2001. Evaluation of biofiltration of air, an innovative air pollution control technology. *ASHRAE Trans*. 107(1): 198-214.

Janni, K. A., D. R. Schmidt, A. Goldman, and T. Schaar. 2009. Alternative gas-phase biofilter media characteristics and performance. ASABE Paper No. 097037. St. Joseph, Mich.: ASAE.

Kastner, J. R., K. C. Das, and B. Crompton. 2004. Kinetics of ammonia removal in a pilot-scale biofilter. *Trans. ASAE* 47(5):1867-1878.

Li, X. W., S. J. Hoff, D. S. Bundy, J. Harmon, H. Xin, and J. Zhu. 1996. Biofilters — a malodor control technology for livestock industry. J. *Environ. Sci. Health* 31(9):2275-2285.

Liberty, K. R., and J. L. Taraba. 1999. Solid-state biofilter for nitrification. ASABE Paper No. 994030. St. Joseph, MI 49085 USA.

Luo, J. 2001. A pilot-scale study on biofilters for controlling animal rendering process odours. In *Proc. 1st IWA International Conference on Odour and VOC's: Measurement, Regulation and Control Techniques*. Sydney, Australia.

Martinec, M., E. Hartung, T. Jungbluth, F. Schneider, and P. H. Wieser. 2001. Reduction of gas, odor and dust emissions for swine operations with biofilters. ASAE Paper No. 014079. St. Joseph, MI.: ASAE.

Melse, R. W., and N. W. M. Ogink. 2005. Air scrubbing techniques for ammonia and odor reduction at livestock operations: Review of on-farm research in the Netherlands. *Trans. ASAE* 48(6): 2303-2313.

Nicolai, R. E., and K. A. Janni. 1997. Development of a low-cost biofilter for swine production facilities. ASAE Paper No. 974040. St. Joseph, Mich.: ASAE.

Nicolai, R. E., and K. A. Janni. 1998. Comparison of biofilter retention time. ASAE Paper No. 974053. St. Joseph, Mich.: ASAE.

Nicolai, R. E., and K. A. Janni. 1998b. Biofiltration — adaptation to livestock facilities. In *Proc. USC-TRG Conference on Biofiltration*, 99-106. Los Angeles, CA.

Nicolai, R. E., and K. A. Janni. 1999. Effect of biofilter retention time on emissions from dairy, swine, and poultry buildings. ASAE Paper No. 994149. St. Joseph, Mich.: ASAE.

Nicolai, R. E., and K. A. Janni. 2000. Designing biofilters for livestock facilities. In *Proc. 2nd International Conference Air Pollution from Agricultural Operations*. Des Moines, Iowa.

Nicolai, R. E., and K. A. Janni. 2001. Biofilter media mixture ratio of wood chips and compost treating swine odors. In *Proc. 1st IWA International Conference on Odour and VOC's: Measurement, Regulation and Control Techniques*. Sydney, Australia.

Nicolai, R. E., and K. A. Janni. 2001a. Determining pressure drop through compost-wood chip biofilter media. ASAE Paper No. 014080. St. Joseph, Mich.: ASAE.

Nicolai, R. E., and K. A. Janni. 2001b. Biofiltration media mixture ratio of wood chips and compost treating swine odors. *Water Sci. and Tech*. 44(9): 261-267.

Nicolai, R. E., K. A. Janni, and D. R. Schmidt. 2002. Biofilter design information. Available at: www.bae.umn.edu/extens/aeu/baeu18.html.

Nicolai, R. E., R. S. Lefers, and S. H. Pohl. 2005. Configuration of a vertical biofilter. In *Livestock Environment VII: Proc. 7th International Symposium*, 358-364.Tami Brown-Brandl and Ronaldo Maghirang, eds.

Nicolai, R. E., C. J. Clanton, K. A. Janni, and G. L. Malzer. 2006. Ammonia removal during biofiltration as affected by inlet air temperature and media moisture content. *Trans. ASABE* 49(4): 1125-1138.

Nicolai, R.E., and R. Thaler. 2007. Vertical biofilter construction and performance. In *Proc. Int Sym on Air Quality and Waste Management for Agriculture*, L. Moody, ed. ASAE Pub #701P0907cd.

Noren, O. 1985. Design and use of biofilters for livestock buildings. In *Odour Prevention of Control and Organic Sludge and Livestock Farming*, 234-237. N.Y.: Elsevier Applied Science Publishers.

Ottengraf, S. P. P. 1987. Biological systems for waste gas elimination. *Trends in Biotechnology* 5(5): 132-136.
Prokop, W. H., and H. L. Bohn. 1985. Soil bed system for control of rendering plant odors. *J. Air Pollut. Control Assoc*. 35(12), 1332-1339.
Rosen, C. J., T. R. Halbach, and R. Mugaas. 2000. Composting and mulching, a guide to managing organic yard wastes. University of Minnesota Extension Service, BU-3296-F, p.2.
Sheridan, B. A., T. P. Curran, and V. A. Dodd. 2002. Assessment of the influence of media particle size on the biofiltration of odorous exhaust ventilation air from a piggery facility. *Bioresource Tech*. 84(2): 129-143.
Sun, Y., C. J. Clanton, K. A. Janni, and G. L. Malzer. 2000. Sulfur and nitrogen balances in biofilters for odorous gas emission control. *Trans. ASAE* 43(6): 1861-1875.
VDI. 1991. VDI 3477, Biological Waste Gas/Waste Air Purification Biofilters. Verein Deutscher Ingenieure, Dusseldorf, Germany.
von Bernuth, R. D., K. Vallieu, and H. Nix. 1999. Experiences with a biofilter on a slatted floor hog barn. ASAE Paper No. 994148. St. Joseph, Mich.: ASAE.
Williams, T. Q., and F. C. Miller. 1992. Odour Control Using Biofilters. *BioCycle* 33, 72-77.
Zeisig, H. D., and T. U. Munchen. 1987. Experiences with the use of biofilters to remove odours from piggeries and hen houses. In *Volatile Emissions from Livestock Farming and Sewage Operations*, 209-216. V. C. Nielsen, J. H. Voorburg, and P. L'Hermite, eds. N.Y.: Elsevier Applied Science Publishers.
Zhang, Z., T. L. Richard, and D. S. Bundy. 1999. Effects of organic cover biofilters on odors from liquid manure storage. ASAE Paper No. 994087. St. Joseph, Mich.: ASAE.

Reviewers

Phil Westerman, North Carolina State University
Rhonda Miller, Utah State University
Rick Stowell, University of Nebraska–Lincoln

United States Department of Agriculture
National Institute of Food and Agriculture

The Air Quality Education in Animal Agriculture project was supported by National Research Initiative Competitive Grant 2007-55112-17856 from the USDA National Institute of Food and Agriculture.

eXtension more mind reach

AIR QUALITY

Air Quality Education in Animal Agriculture

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.

IOWA STATE UNIVERSITY
University Extension

PM 1971a July 2004

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 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.

By reducing the amount of nitrogen excreted, less ammonia will be formed and volatilized.

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.

. . . particulates are of concern for human health.

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.

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 ⅛-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.

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

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.

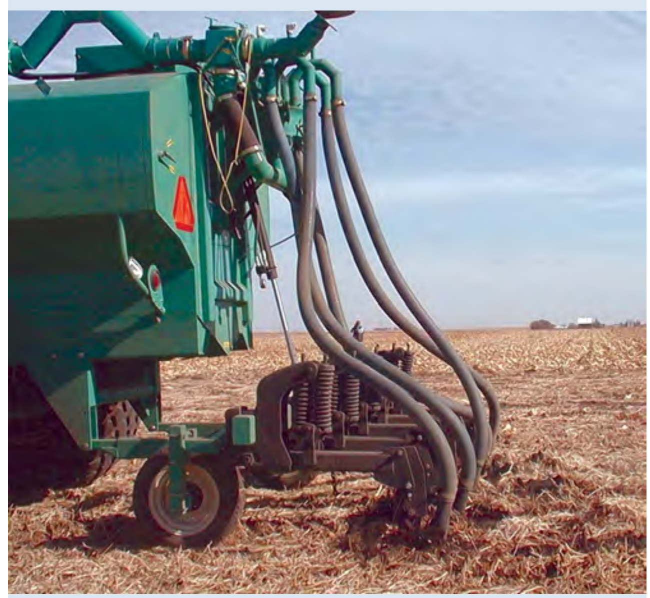
Dry Manure Storage

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.

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.

File: Environmental Quality 4-1

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914 in cooperation with the U.S. Department of Agriculture. Stanley R. Johnson, director, Cooperative Extension Service, Iowa State University of Science and Technology, Ames, Iowa.

Manure Storages—Permeable Covers Overview

Application: used to reduce odors and emissions from manure storages

Pros

- Relatively easy to implement.
- Increases nitrogen retention in the manure.
- Can be used with earthen, concrete, and steel manure slurry manure storages at swine, dairy, or beef animals.

Cons

- Only applicable to outdoor manures storages.
- Some types of permeable covers (biomass covers) have short lifespans.
- Can make agitation of the manure more difficult.
- Effectiveness varies based on level of coverage.
- Rainwater volume must be accounted for in the manure storage since direct precipitation will infiltration through cover and into the manure.

Description

Storage of manure is an important component of manure management as it facilitates delaying manure application until appropriate times in the crop growing cycle, or to avoid manure application on frozen or snow-covered ground. However, slurry/liquid manure storages can be a significant source of odor and gaseous emissions. Liquid manure storages tend to give off odor and gas emissions when the surface is disturbed, such as windy conditions or during agitation. Covers have been demonstrated to provide effective odor and air emission control from manure storages. Two types, impermeable and permeable, cover options are available. Impermeable covers provide excellent odor and emission control, but have a high capital cost. Permeable covers generally are not as effective, but generally have a substantially lower capital cost.

Figure 1. Lightweight expanded clay aggregate (LECA) permeable cover on an in-ground concrete swine manure storage tank. LECA covers are typically applied in a 2 to 4 inch layer.

Permeable covers are materials that lie directly on the surface of the stored manure and provide a physical barrier between the manure and the surrounding air. Examples of permeable covers include natural crusts, layers of natural vegetative materials (such as straw, corn stalks, ground corncobs, etc.), vegetable oils, permeable fabrics (geotextiles), as well expanded clays, ceramics, and ground rubbers (examples include LECA and Macrolite). The success of permeable covers depends on achieving season-long floatation and continuous 100% coverage of the manure storage structure.

The principle behind permeable covers is to increase the resistance of gas transfer from the liquid to air. Permeable covers do this by providing a layer of material on the manure surface that shields the manure from contact with moving air. This reduces transfer of hydrogen sulfide, ammonia, and other volatile odorous compounds from the liquid manure; however, higher emission rates may occur when the cover is removed or the manure is agitated. Due to the potential buildup of manure gasses, especially hydrogen sulfide, caution should be used when removing the cover and agitating the manure. In addition to reduction gas transfer, most permeable cover materials provide an aerobic zone above the manure. Aerobic microorganisms can consume many odorous compounds; therefore covers that provide aerobic layers at the storage surface may facilitate growth and development of these aerobic organisms and provide additional odor reduction.

Permeable covers do not require gas collection systems as gases produced by the decomposition of the manure will slowly migrate through the cover. Similarly, rainwater collection systems are not required, as rainfall onto the cover surface will infiltrate through the cover and into the storage. However, this means that rainfall must be accounted for when sizing the manure storage. Additionally, permeable covers tend to reduce evaporation from the manure storage, thus manure storages using permeable covers need to be sized to have sufficient storage when accounting for the reduced evaporation.

Figure 3. Geo-synthetic cover installed on a manure storage. Edge of the geo-membrane is typically trenched in. Note, these covers are not to be walked on and the storage should be surrounded by a fence.

Cover maintenance varies greatly with the type of cover utilized. Fabric (geotextile) cover maintenance includes repairing tears and punctures, removal of debris that accumulate on the surface of the fabric, and either removal and replacement of the cover for manure agitation and pumping or a design that includes access for agitation of the manure. Straw and crop residue covers may break up or sink due to high winds and heavy rains. To be effective these biomaterial covers should be at least 8” thick, but 12” is recommended as thicker layers have been found to float longer and be more effective. Biomaterials that have waxy coatings and large open cross sections that facilitate floating tend to have longer cover lives as they resist absorbing water and are naturally more buoyant. If straw/biomaterial covers start to break up additional straw material should be added, but it is important to remember that sunk straw will have to be dealt with at the time of agitation and manure removal. Straw and biomaterial covers tend to provide short-term solutions (2 to 6 months) depending on manure solids content and rainfall amounts) for odor control before additional straw is required. Light weight expanded clay aggregates tend to have higher life expectancies (often in excess of ten years) and require less maintenance but do need to be segregated from agitators and pump inlets when removing manure.

Figure 2. Straw cover being installed on a 4-acre lagoon in Iowa. Baled straw is ground and blown on to provide an approximately 6 to12” thick layer of straw. Higher levels of odor control are generally seen at the higher thickness.

One major concern with all covers is the impact it has on our ability to agitate and pump out the manure from the storage unit. Natural crusts and permeable covers made with other biomaterials can usually be broken up, mixed into the manure, and pumped from the manure storage when the manure is land applied but generally require the use of a chopper pump to handle the larger particles. If using custom manure haulers notify them prior to pumping that you have a biocover that will need to be broken up during agitation. Permeable covers made with geotextile fabrics or floating synthetic materials (expanded clays) may need to be moved out of the way to facilitate agitation and. In the case of geotextile covers this may involve removing the cover and then replacing it after pumping or site specific designs that facilitate agitation without cover removal. For expanded clays and ground rubbers, agitation and pump out must be conducted in a way that ensures the floating cover material is not removed. This can generally be performed with minimal changes to standard practices agitation practices by corralling the floating cover material away from agitation and pump out locations.

Effectiveness

Component	Effectiveness	Notes
NH3	30 to 90%	Varies with type and thickness of cover, thicker biomaterial covers perform better and last longer, geotextiles and LECA perform closer to 80 to 90
H2S	40 to 95%	Varies with type and thickness of cover
Odor	40 to 90%	Varies with type and thickness of cover
Particulate Matter	—	—
Volatile Organic Compounds (VOC)	—	—
Cost	$ to $$	Biomaterial low, geotextiles and synthetics material high

Cost Considerations

Costs include the initial costs of purchasing the permeable cover material, the costs of applying it over the surface of the manure storage, and costs associated with extra difficulties in agitating and pumping out the manure storage.

A wide range of organic and manmade materials have been utilized to construct permeable covers with variable results and costs ranging from $0.10 to $1.75 per square foot installed. Straw/corn stover is one of the low cost options at around $0.10 per square foot to purchase material and $0.02 to 0.04 to apply, while longer lasting materials such as LECA may cost $1.00 to $3.00 per square foot.

More Information

National Pork Board

- http://www.pork.org/filelibrary/Factsheets/Environment/Manure%20Storage%201.pdf

eXtension

- http://www.extension.org/pages/24017/a-review-of-permeable-cover-options-for-manure-storage#.U7shbfldXh4
- http://www.extension.org/sites/default/files/Permeable-Covers%20FINAL_0.pdf

References

Clanton, C.J., D.R. Schmidt, L.D. Jacobson, R.E. Nicolai, P.R. Goodrich, K.A. Janni. 1999. Swine manure storage covers for odor control. *Applied Engineering in Agriculture* 15(5): 567-572.

Clanton, C.J., D.R. Schmidt, R.E. Nicolai, L.D. Jacobson, P.R. Goodrich, K.A. Janni, and J.R. Bicudo. 2001. Geotextile fabric-straw manure storage covers for odor, hydrogen sulfide, and ammonia control. *Applied Engineering in Agriculture* 17(6): 849-858.

VanderZaag, A.C., R.J. Gordon, V.M. Glass, R.C. Jamieson. 2008. Floating covers to reduce gas emissions from liquid manure storages: a review. *Applied Engineering in Agriculture* 24(5): 657-671.

This project was funded by the National Pork Board through cooperative agreement #12-006.

Prepared by Daniel S. Andersen, Assistant Professor, Jay D. Harmon and Steven J. Hoff, Professors of Agricultural and Biosystems Engineering, Iowa State University, and Angela Rieck-Hinz, Extension Program Specialist, Iowa State University Extension and Outreach.

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Cathann A. Kress, director, Cooperative Extension Service, Iowa State University of Science and Technology, Ames, Iowa.