AIR QUALITY

Permeable Covers for Odor and Air Pollution Mitigation in Animal Agriculture — A Technical Guide

AIR QUALITY EDUCATION IN ANIMAL AGRICULTURE

Mitigation Strategies: Covers - 2
October 2011

Rose M. Stenglein, Junior Scientist
Charles J. Clanton, Professor
David R. Schmidt, Research Associate
Larry D. Jacobson, Professor
Kevin A. Janni, Professor
kjanni@umn.edu

Department of Bioproducts/ Biosystems Engineering, University of Minnesota

This publication discusses how permeable manure storage covers work, types and attributes of permeable covers, and factors to consider when selecting a cover.

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Permeable covers reduce odor and gas emissions from manure storage facilities and anaerobic lagoons by creating a barrier that slows gas emissions from stored or treated manure. Effective permeable covers include naturally forming, floating crusts on the surface of stored manure and covers made with straw, geotextile fabrics, or floating commercial products placed on liquid manure storage units. Livestock manure is commonly stored in tanks, lined earthen basins, or anaerobic lagoons until the material is applied to cropland at agronomic rates or removed from the site.

Uncovered manure storage units and anaerobic lagoons release odorous, hazardous, and greenhouse gases including hydrogen sulfide (H_2S), ammonia (NH_3), volatile organic compounds (VOC), methane (CH_4), and nitrous oxide (N_2O). Odors can cause nuisance complaints and other gases can contribute to air pollution and climate change.

Livestock producers currently use various permeable materials, from straw to plastic, for covers on manure storage units or anaerobic lagoons. Each material has different cost, effectiveness, design, and operation considerations. This publication provides information on *permeable* covers. Information on *impermeable* covers is available in another factsheet.

Permeable Covers

Permeable covers lie directly on the stored manure or lagoon surface, creating a physical barrier between the manure and surrounding air. The physical barrier reduces gas emissions by increasing the resistance to gas transfer from the manure to the air above the cover. Permeable cover effectiveness increases as the resistance to gas transfer increases. Overall resistance depends on the overall permeability and cover thickness. Permeable covers reduce gas emissions in proportion to their thickness — the thicker the cover, the more gas emissions are reduced. As cover effectiveness increases, the dissolved gas concentrations in the manure increase.

The difference between the gas concentration in uncovered manure and that in the air above the manure impacts gas emission rates. When the concentration of a particular gas is high in the air above the manure, less gas is emitted from manure. When the concentration in the air is low, more gas is emitted. Permeable covers resist gas emissions and allow gas concentrations in the manure and air immediately under the cover to increase.

Covers can reduce the effect of wind blowing across the surface of an uncovered manure storage unit. Wind removes gases at the manure-air interface and brings in fresh air, which has low gas concentrations. Covers shelter the manure-air interface from wind action, allowing gas concentrations in the air under the cover to increase.

Covers increase dissolved gas concentrations in the manure because fewer gas molecules are emitted. Gas concentrations build up quickly under permeable covers. The increased gas concentration in the manure needs to be managed to avoid excessive emissions during agitation, pump out, and land application.

Permeable covers lie directly on stored manure to slow the release of gases and odors.

Permeable covers may allow for the growth of a biofilm, an aerobic layer of bacteria and other microorganisms on the manure surface and cover. This biofilm may help break down odorous gas molecules into carbon dioxide and water. More research is needed to establish the presence and role of the biofilm on reduced gas emissions.

Permeable covers are common and include natural crusts that form on some manures, straw, geotextile (fabric that allows water and gases to pass through), and geotextile covered with straw. Newer synthetic materials include expanded clay, ceramic, or glass balls such as Leca®, Macrolite®, or perlite. Covers made from these newer synthetic materials reduce gas emissions more effectively and are longer lasting; they also are more expensive than other permeable options.

Table 1 summarizes the performance, typical life expectancy, and capital costs per square yard for permeable cover materials. The data sources are listed below the table. Citations are attached.

Initial, operating, and recycling/disposal costs are key considerations when choosing a cover. Other factors to consider are effectiveness, service life, and maintenance requirements. The type and size of the livestock operation and storage system, labor available, proximity of neighbors and public areas, climate, and safety are additional factors that need to be considered when selecting a manure storage cover.

Permeable covers are initially cheaper than impermeable covers but have shorter service lives and are less effective than impermeable covers. The effectiveness of permeable covers depends on the material used, cover thickness, and age. Covers made of biomaterials such as straw can sink or degrade, providing less consistent emission reduction over time.

Table 1. Percent reductions in odor, hydrogen sulfide, and ammonia for permeable cover materials, their life expectancies, and capital cost per square yard of covered surface area.

Material	Percent Reductions			Life Expectancy	Capital Costs ($/yd^2)
	Odor	H_2S	NH_3		
Natural Crust	56 – 78 (a, b)	81 (b)	(-11) – 37 (b, c)	3 months (b)	0.00
Straw (minimum 12 inches)	68 – 80 (d, e)	88 – 92 (d, e)	79 – 86 (c, d)	2 – 6 months (g)	0.25 – 0.90 (g)
Straw (12 inches) + Geotextile (2.4 mm)	76 – 83 (e)	85 – 98 (e)	79 – 86 (e)		
Geotextile (2.4 mm)	51 (e, g)	59 – 72 (e, g)	(-15) – 37 (e, g)	3 – 5 years (g)	1.25 – 2.00 (g)
Leca®	69 – 89 (f)	64 – 75 (f)	83 – 95 (h)	10 years (i)	15.45 (i)
Macrolite	56 – 62 (d)	64 – 84 (d)		10 years (i)	15.45 (i)
Perlite	30 – 93 (j)	63 – 91 (j)		10 years (j)	
Polyethylene foam with geotextile layer and clinoptilolite			80 (k)		

a. Mannebeck, 1985
b. Bicudo et al., 2001
c. De Bode, 1991
d. Clanton et al., 1999
e. Clanton et al., 2001
f. Guarino et al., 2006
g. Bicudo et al., 2004b
h. Sommer et al., 1993
i. Nicolai et al., 2004
j. Hörnig et al., 1999
k. Miner et al., 2003

One major maintenance concern with all covers is the ability to agitate and pump out the liquid manure storage unit. Natural crusts and permeable covers made with straw or other biomaterials are usually broken up and mixed into the manure and removed with the liquid manure. Permeable covers made with geotextile fabrics or floating balls need to be moved out of the way to allow agitation and equipment access, often at several points around the structure.

In wet regions where annual precipitation exceeds evaporation, rainfall needs to be taken into account. Since precipitation can soak through permeable covers, larger storage volumes may be warranted to account for reduced evaporation and accumulation of precipitation. A rain collection system is generally not feasible with a permeable cover.

Permeable covers do not collect gases like impermeable covers, so they do not need gas collection and treatment systems. They cannot be used in a biogas (methane) production system nor can they be credited with greenhouse gas (GHG) reduction.

Types of Permeable Covers

Natural Crust Covers

Natural crust covers are formed by undigested fibrous material in the diet, organic bedding, and foams that float to the surface. Dairy and beef manure usually contain fiber that floats so development of a natural crust on the manure surface is common. Crust formation and thickness depends on diet and bedding use. Some stored swine manures develop a natural crust, but the crust consistency is usually much different than that on dairy manure. Thin floating films reduce odor and gas emissions too.

Figure 1. Natural crust covers help reduce odor and gas emissions from stored manure, but researchers have found it difficult to quantify these reductions. Reductions are likely to be similar to crusts formed using straw. The physical, chemical, and biological mechanism by which natural crusts form and dissipate is not understood at this time. (Photo courtesy of Kevin Janni, University of Minnesota)

A 12-inch layer of straw can be an inexpensive and effective cover, but can break up and lose its effectiveness when wet.

Straw Covers

Straw covers are common and effective as a short-term solution to odor problems *(Figure 2).* Both barley and wheat straw are effective permeable cover materials. Producers use a straw chopper/blower to create a uniform straw layer, between 4 and 12 inches deep, over the stored manure. Six-inch thick barley or wheat straw covers typically last two to six months.

The degree of odor reduction is a function of the straw depth. Thicker layers of straw are more effective and last longer. Researchers have found that a 4-inch layer of straw alone gave 60, 69, and 61 percent reductions of odors, H_2S, and NH_3, respectively. Thicker layers of straw (8 to 12 inches) resulted in even better odor and gas reductions (70 to 90 percent), with the exception of the NH_3 reduction in the 8-inch layer (about 60 percent). Twelve-inch straw covers are recommended as they float longer than thinner layers. Adding biodegradable oil to the straw during application can increase the cover's useful life.

Once the straw becomes wet and starts sinking, the cover loses effectiveness. Odor reduction will vary from 90 percent on a thick, newly applied cover to 40 percent or less depending on straw thickness and uniformity.

Straw covers may break up or sink due to high winds and heavy rain. If a straw cover starts to break up or sink, additional straw may be blown onto open areas to re-establish an effective cover. Straw-covered storages can be successfully agitated and pumped using chopper pumps. Straw is not appropriate for storages or lagoons larger than two acres because wave action on these large areas will disrupt cover uniformity.

Figure 2. A straw cover being installed on a manure storage structure. Straw must be replenished frequently to maintain cover effectiveness. (Photo courtesy of the Pork Checkoff)

The amount of straw needed depends on the manure storage surface area and desired straw layer depth. A single large round straw bale (6-foot diameter) can cover about 500 square feet with a 12-inch layer at a cost of $0.25 to $0.90 per square yard.

Geotextile and Geotextile-Straw Covers

Geotextile is a porous fabric composed of thermally bonded, continuous polypropylene filaments that allows water and gases to pass through. Non-woven geotextile is preferred over woven because it is stronger. Geotextile fabrics are self-floating and provide a physical barrier to the gas transfer from manure to the air. Geotextile covers can be used alone or in combination with straw and will perform reasonably well if properly managed. A geotextile cover alone can reduce odors 40 to 65 percent and H_2S 30 to 90 percent. A geotextile cover will not reduce NH_3. A geotextile cover with a straw layer, 4 inches or more, on top can reduce odors 50 to 80 percent, H_2S 60 to 98 percent, and NH_3 8 to 85 percent.

Geotextile materials are initially more expensive than straw covers but last longer and require less maintenance. Geotextile covers have typical life expectancies of three to five years. Additional costs are usually incurred for geotextile cover removal and proper recycling/disposal (i.e., transportation and landfill fees). Ultraviolet resistance, tensile strength, and joint strength are important characteristics to consider when selecting a geotextile fabric to be used as a cover.

Long-term floatation of geotextile covers was a concern when geotextile covers were first introduced. In two field situations, with an early product, some partial sinking of the geotextile cover was observed in the spring after surface ice thawed. However, in both situations, the cover came back to the surface as the stored manure warmed.

Geotextile covers are initially more expensive than straw covers, but have a longer life expectancy and require less maintenance.

Newer geotextile fabrics have a layer of closed-cell foam between two geotextile layers, doubling the cover service life and preventing sinking. The top geotextile layer protects against ultraviolet radiation. New geotextile covers will likely last longer (up to 10 years), but the cost can be twice that of first-generation geotextile covers. Microbial buildup between the layers of the newer geotextile fabric covers may increase emission reductions but research is needed.

Geotextile covers should be installed to allow access for manure or sludge agitation and removal. Access to agitate manure under a geotextile cover is usually provided by either partially removing the cover — typically one corner of the manure storage unit — or by lifting the cover with a cable and winch system. The agitation/pumping equipment is positioned under the cover. Neither of these options allows for vigorous agitation commonly achieved with uncovered manure storage units. Individual cover system manufacturers have developed flaps or lift systems in an effort to resolve the manure agitation problem.

Anaerobic lagoon liquid is typically removed several times a year from covered lagoons without agitating the sludge. Sludge in anaerobic lagoons can accumulate for 10 to 20 years before it must be agitated and removed. Sludge accumulation should be monitored every year, so a series of ports should be installed in the cover to allow sludge depth measurement. Often cover replacement can be timed to occur with sludge removal to avoid having to agitate the sludge while a cover is in place.

Recycling/disposing of geotextile material after its useful life can be costly. One producer paid $1,000 for pick-up and hauling a 2,000-square foot geotextile cover and an additional $800 in landfill fees. Pick-up, hauling, and landfill fees vary with location and hauling distances. The example given may not be representative of service fees in your area.

Permeable Polyethylene Foam Covers

A laboratory study evaluated covers using a permeable polyethylene foam board, geotextile, and zeolite particles as a cover and aerobic organism support media on swine manure. Results indicated that greater NH_3 reduction was achieved with time as the cover thickness increased, presumably as aerobic bacterial populations within the cover increased to oxidize NH_3. Average NH_3 concentration reduction above the cover

Several synthetic products can effectively reduce odor and gas emissions by 77 to 96 percent.

ranged from 70 to 82 percent with 1.5-inch thick foam board as geotextile and zeolite were added to the cover. A field demonstration had approximately 80 percent reduction in NH_3 emission rate from an anaerobic swine lagoon covered with 1.5-inch thick permeable polyethylene foam and a permeable proprietary geocomposite made with reinforced polyester and a natural zeolite (i.e., clinoptilolite).

Porous Clay, Ceramic, and Glass Balls for Covers

Air-filled clay (Leca®), ceramic (Macrolite®), and glass (perlite) balls have been used to create floating covers on manure storage units with reasonable success *(Figure 3).* The porous balls float on liquid manure and create a permeable physical barrier that reduces odor and gas emissions. These materials have an estimated service life of 10 years and are quite expensive to purchase. Care must be taken during manure agitation and pumping to prevent the balls from being run through the pump and out the tank. The balls may plug or damage manure pumps.

Ground Rubber

A laboratory study investigated the use of ground rubber from tire recycling as a permeable cover material. Results indicated that a 3-inch thick layer of ground rubber reduced odors from stored swine manure by 77 to 99 percent. A field test on a 110-foot diameter concrete tank indicated that a 2-inch thick layer of ground rubber reduced concentrations of odors (87 to 96 percent), NH_3 (77 to 98 percent), and H_2S (99 percent) above the ground rubber cover compared to the uncovered tank. Questions about the fate of ground rubber after agitation, pump out, and land application were not addressed. Rubber is not considered biodegradable.

Figure 3. A permeable manure storage cover made of lightweight expanded clay aggregate (LECA) installed on a swine farm. (Photo courtesy of the Pork Checkoff)

Vegetable Oil

Rapeseed and used cooking oil are not acceptable permeable covers. Oils degrade, lose their surface integrity, and add to methane emissions. In addition, vegetable oil commonly develops unique undesirable odors.

Safety

Natural crust covers and permeable covers are not designed to have animals or people walk on them. Manure storages must be surrounded by fences to prevent animals or people from accidentally walking onto and falling through a cover that appears to be solid. Check local and state regulations.

Dissolved gas concentrations of hazardous gases such as NH_3 and H_2S accumulate in the manure and the air under covers, even permeable covers. These gases can volatilize quickly if the cover is removed for agitation and pumping or for inspection. Covers can create high toxic gas concentrations near the inspection and agitation openings. Extreme caution should be used when accessing manure under a membrane cover through an access flap or cover lift system.

Permeable Covers and Greenhouse Gases

More research is needed on the relationship between covers and greenhouse gas mitigation. Research results on permeable covers are mixed. Low N_2O concentrations under covers make it difficult to measure concentrations and emissions accurately with existing technology. One study reported that a natural crust cover reduces CH_4 emissions. Expanded clay particles were shown to decrease CH_4, increase N_2O, and had no impact on CO_2 emissions. Studies in Canada and Europe have found increased CH_4 emissions from dairy and swine manure storage units with natural covers or permeable covers using straw. Other studies found decreased emissions of CH_4 and N_2O with permeable covers. Additional research is needed to clarify the conditions and quantify the changes in greenhouse gas emissions from manure storage units with permeable covers using straw.

Hazardous gases can become concentrated under any manure cover, including permeable ones. Use extreme caution when opening a cover to test or agitate manure.

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Reviewers

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

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USDA 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.

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