AIR QUALITY

# Covers for Mitigating Odor and Gas Emissions in Animal Agriculture: An Overview

AIR QUALITY EDUCATION IN ANIMAL AGRICULTURE

Mitigation Strategies: Covers - 1
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This fact sheet discusses how manure storage covers work, attributes of permeable and impermeaable covers, and factors to consider when selecting a cover.

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Covers on manure storage and treatment facilities can reduce or mitigate emissions of unpleasant odor and gases, including ammonia ($NH_3$), hydrogen sulfide ($H_2S$), numerous volatile organic compounds (VOC), and greenhouse gases such as carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$). Covers reduce emissions by creating a barrier between the stored manure or anaerobic lagoon and airflow above it. The barrier can be either permeable or impermeable. Permeable covers allow gas molecules and water to pass through while impermeable covers trap most gas molecules between the cover and the manure. Properly installed and maintained covers can be an effective and economical tool for mitigating odor and gas emissions from manure storage facilities.

Many livestock producers store manure in above-ground or below-ground tanks or in lined basins until the manure is either applied to cropland at agronomic rates or removed from the site. In some regions, anaerobic lagoons are used to treat livestock manure. If uncovered, manure storage facilities and anaerobic lagoons can release odors and gases into the air. Odorous gases can be a source of nuisance complaints while other gas emissions can contribute to air pollution and climate change. Livestock producers use various materials for covers, from straw to plastic, each with different costs, effectiveness, designs, and management and operation considerations. This publication provides an overview of cover options and factors to consider when selecting a cover.

## How Covers Work

Manure contains many volatile chemical compounds and bacteria that produce more volatile compounds during manure decomposition. These volatile compounds can move from where they are generated in the stored manure or anaerobic lagoon into the air above the manure. Covers reduce the amount of volatile gases emitted from the manure or anaerobic lagoon into the air. With reduced emissions there are fewer odors and lower gas concentrations in the air, which reduces odor complaints and negative impacts from gas emissions.

The way volatile compounds behave at the liquid-air interface — where the air and liquid manure meet — depends on the conditions and gas concentrations on both sides of the interface. Volatile compound concentrations try to balance at the liquid-air interface. The balance concentrations depend on manure pH and air and manure temperatures. When a compound's concentration in the air is lower than its concentration in the manure, the gas concentrations are out of balance, and gas molecules attempt to move from high to low concentrations. If the gas concentrations in the air above the manure are low, dissolved gas in the manure is emitted into the air to achieve balance. If the gas concentrations are nearly balanced, little dissolved gas in the manure is emitted. If the gas concentration in the air is higher than the balance concentration in the manure, gas molecules will move from the air into the manure. Covers keep the gas concentration in the air between the cover and the manure surface high, which reduces gas emissions from the manure.

Covers increase the resistance to gas transfer between the manure and air above it. The resistance can be described in terms of permeability, which decreases as resistance increases. Physical factors that affect cover gas transfer resistance include

**Manure covers contain the release of volatile gases and odors, and reduce the effects of wind, temperature, and other environmental factors.**

thickness and porosity. Cover resistance increases as cover thickness increases and as porosity decreases. Thin natural films can increase gas transfer resistance and reduce gas and odor emissions. Thick permeable covers and impermeable covers have large gas transfer resistances that reduce gas emissions.

Covers reduce the effect of wind blowing across the surface of a manure storage facility. Wind whisks away gas molecules at the interface and brings in fresh air, which presumably has low gas concentrations. The fresh air creates a concentration imbalance at the interface, which causes more volatile gases to be emitted from the manure. A cover provides a barrier between the wind and manure surface and keeps concentrations under the cover near the manure surface high, minimizing the interface concentration imbalance, which keeps the volatile molecules in the manure.

Covers also can reduce wave action or rippling at the manure surface. Waves and ripples can decrease the resistance of naturally forming films or covers on manure.

Covers increase dissolved gas concentrations in the manure because fewer volatile compounds are emitted. The air space under a cover is limited, so gas concentrations build up quickly to the point where more molecules stay in the manure and fewer are emitted. This increased gas concentration in the manure needs to be managed to avoid excessive emissions during agitation, pump out, and land application. The air under a cover can have dangerous gas concentrations requiring precautions to maintain human and animal safety.

Table 1. Attributes of various permeable and impermeable covers.

| | Material | Percent Reduction: Odor | Percent Reduction: $H_2S$ | Percent Reduction: $NH_3$ | Life Expectancy | Capital Costs ($/yd²) |
|---|---|---|---|---|---|---|
| Permeable Covers | **Natural Crust** | 56 – 78 (a, b) | 81 (b) | (-11) – 37 (b, c) | 3 months (b) | 0.00 |
| | **Straw** | 45 – 83 (a, d, e, f) | 86 – 100 (d, e, f) | 79 – 86 (c, d) | 2 – 6 months (g) | 0.25 – 0.90 (g) |
| | **Straw (8 in) + Geotextile (2.4 mm)** | 76 – 83 (e) | 85 – 98 (e) | 79 – 86 (e) | – | – |
| | **Geotextile (2.4 mm)** | 51 – 63 (d, e, g) | 59 – 71 (d, 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) |
| Impermeable Covers | **Concrete** | 95 – 100 (a) | – | – | 20 years (a) | – |
| | **Wood Lid** | 75 – 95 (a) | – | 98 (h) | – | – |
| | **Positive Air Pressure** | 95 (g) | 95 – 99 (j, k, l) | 95 (j) | 10 years (j, l) | 6.75 – 12.60 (j, k) |
| | **Negative Air Pressure** | 95 – 99 (j, m) | 95 (j) | 95 (j) | 10 years (j, n) | 3.15 – 3.60 (j, n) |
| | **Floating** | 39 – 95 (a, b, i, j) | 90 – 95 (d, j) | 74 – 98 (c, h, j) | 10 years (a, j) | 4.5 – 9.00 (j) |

Information Sources:

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. Bicudo et al., 2004a
k. Zhang and Gaakeer, 1998
l. Funk et al., 2004a
m. Zhang et al., 2007
n. Funk et al., 2004b

*Figure 1. A natural permeable crust on a lined dairy manure storage facility (Source: Kevin Janni, University of Minnesota)*

## Types of Covers

Covers are categorized as either permeable or impermeable. Gas molecules and water can pass through permeable materials. Permeable covers reduce emissions by making it harder for the gaseous molecules to escape. The permeability of a permeable cover is an important selection characteristic. Impermeable covers trap almost all gases and water. Few gas molecules escape through holes in and around the edges of impermeable covers. *Table 1* describes the effectiveness, lifetime, and cost of various covers.

### *Permeable Covers*

Materials used for permeable covers include straw, geotextile (fabric that allows water and gases to pass through), and expanded clay, ceramic, or glass balls such as Leca®, Macrolite®, or perlite. Some cover systems combine two materials, such as geotextile and straw. Newer synthetic materials such as Leca®, Macrolite®, and perlite are more effective at reducing gas emissions, last longer than straw or geotextile, and usually are more expensive.

Natural floating crusts, formed when the manure contains a relatively high percentage of fiber, also are considered permeable covers. Natural crusts often develop on dairy manure storages on farms that use organic bedding (*Figure 1*). Natural crusts or films sometimes develop on swine manure storage facilities. Crust formation and thickness depends on diet and bedding use. Natural crusts are broken up when the stored manure is agitated prior to pumping to empty the storage. A new natural crust begins to form as fresh manure is added to the storage.

Permeable cover effectiveness is highly variable, depending in part on cover thickness. Odor reduction values typically range from 45 to 80 percent (*Table 1*). Permeable covers made of organic materials such as straw degrade over time so they are less consistent than synthetic covers and need to be replaced or replenished frequently, every two to six months. Permeable covers made from biomaterials generally have

**Permeable covers are generally less expensive than impermeable ones, but have a shorter service life and require more maintenance.**

lower capital costs. Synthetic materials, such as geotextile, Leca®, and Macrolite®, that are used for permeable covers, usually last longer, up to 10 years, but have higher capital costs. Permeable covers do not need to collect, treat, or vent emitted gases or precipitation like impermeable covers.

## *Impermeable Covers*

**Impermeable covers have longer lifespans than permeable covers and can reduce hydrogen sulfide and ammonia emissions by 95%.**

Impermeable covers are typically made from plastic, concrete, or wood. Plastic covers can sit on the manure surface and be held in place either by gravity (floating) or by suction created with fans (negative air pressure). Plastic covers also may be inflated by air (positive air pressure) (*Figure 2*) or stretched over a frame to form a dome. Plastic covers usually are sealed around the edges to reduce emissions. Also, concrete and wood covers can be built over manure storage structures.

Impermeable covers can be effective at reducing odors and other pollution: They can cut odors, hydrogen sulfide, and ammonia emissions by 95 percent. Impermeable covers usually have longer life spans, commonly between 10 and 15 years, which are much longer than those of permeable covers made of biomaterials. Cover material costs, manure removal access, venting equipment, and design and installation complexity make impermeable covers more expensive than permeable ones.

Impermeable cover systems need to deal with the emitted gases under the cover, which are highly concentrated, probably toxic, potentially explosive, and capable of creating large amounts of pressure. The gases may be released untreated into the atmosphere through a vent or treated with a gas-phase biofilter, flared for a boiler, or genset to generate electricity, which can offset cover costs. Methane is a potent greenhouse gas that if not flared or used to produce electricity, can contribute to global climate change. If possible, impermeable covers should have a low profile to minimize wind effects.

Impermeable systems need to collect and manage rainwater and snowmelt, especially in regions of high precipitation. Precipitation that accumulates on top of covers floating over manure storage facilities must be removed in regions with excess precipitation.

*Figure 2. A positive air pressure manure storage cover (Source: Ted Funk, University of Illinois)*

## Factors to Consider When Choosing a Cover

Many factors need to be considered when selecting a cover to reduce odor and gas emissions from manure storage facilities. These include:

- Cover purpose and the level of effectiveness needed
- Service life or useful life
- Manure or sludge agitation and removal
- Type of livestock operation
- Type and size of manure storage facility
- Nutrient management
- Precipitation
- Safety
- Costs

**Permeable cover effectiveness varies, depending on the material, thickness, uniformity, and age.**

### *Cover Purpose and Effectiveness Needed*

Covers are commonly used to reduce odor emissions. They can reduce hazardous gas (i.e., ammonia and hydrogen sulfide) and greenhouse gas emissions from manure storage facilities and anaerobic lagoons (*Table 1*). Covers help retain manure nitrogen, which increases the stored manure's fertilizer value if agitated and land applied to minimize nitrogen volatilization.

Permeable cover effectiveness varies depending on the material, thickness, uniformity, and age. Geotextile or straw can provide a 60 to 90 percent reduction in odors from ammonia and hydrogen sulfide.

Properly installed impermeable covers are more effective and consistent. Impermeable covers can provide a 95 percent reduction in odors, hydrogen sulfide, and ammonia emissions. Impermeable covers also may reduce greenhouse gas emissions, particularly when methane emissions are flared or used to generate electricity.

### *Service Life and Maintenance*

Permeable covers made with straw and other biomaterials break down over time and need to be replenished or replaced every two to six months (*Table 1*). Straw covers also may break down or sink due to high winds and heavy rain. Straw covers that start to break up or sink may have additional straw blown onto the surface to re-establish the cover's effectiveness. Straw covers add to the organic load and increase the carbon to nitrogen ratio of the stored manure.

Permeable covers made with geotextile fabrics or expanded clay or glass balls such as Leca®, Macrolite®, or perlite have service lives ranging from 3 to 10 years (*Table 1*). Periodically, balls sink and plug or damage pumps used to agitate or remove manure.

Ultraviolet light resistance is an important consideration for exposed or uncovered geotextile fabrics used as a cover material. Straw on top of geotextile fabrics provides some ultraviolet protection. It may take one to two months in early spring for geotextile covers to float properly after being covered with snow during the winter.

Impermeable covers have service lives ranging from 5 to 15 years (*Table 1*) and may need repairs for tears or punctures. Ultraviolet light-resistant plastics are needed. Most impermeable covers require a venting system to manage gases and bubbles that form under the cover.

Consider ease of manure agitation and removal, among other attributes, when selecting the cover best suited to your operation.

### *Covers and Manure Removal*

Covers on manure storage facilities make manure agitation and removal from the storage unit more complicated. Manure agitation helps suspend solids that have settled to the bottom of the storage unit before pumping for land application.

Natural crusts and straw covers are typically broken up with chopper pumps during agitation and emptying of the manure storage facility. Breaking up natural crusts and straw covers requires additional time and energy for manure agitation.

Manure agitation and removal must be done carefully when Leca®, Macrolite®, or perlite is used to prevent it from going through the agitating equipment and damaging the pump or being removed with the manure.

Geotextile and impermeable covers on manure storage facilities require access for agitation and pumping, which commonly requires removal of part of the cover. Caution and care must be exercised during agitation and removal to avoid exposing workers and animals to hazardous gases. Custom manure applicators may charge a higher rate if conditions to agitate and pump are inconvenient or considered hazardous.

### *Covers on Anaerobic Lagoons*

Impermeable covers on anaerobic lagoons reduce odor and gas emissions. Lagoon liquid is typically removed several times a year without agitating the sludge. Sludge can accumulate for 10 to 20 years before it accumulates to the level that it must be agitated and removed. Sludge accumulation should be monitored every year. To facilitate this, a series of ports should be installed in the cover to allow sludge depth measurement. With such a long time between sludge removal events, the cover can be replaced when sludge is removed to avoid having to agitate the sludge while a cover is in place.

### *Type of Livestock Operation*

Covers can be added to manure storage facilities for all livestock and poultry operations. Natural crusts are common on dairy and other ruminant manure storage facilities that use organic bedding (i.e., straw, sunflower hulls, rice hulls, or sawdust). Natural crusts are much thinner or nonexistent on manure storage facilities on dairy farms that use sand bedding or liquid-solid separation before the manure is added to the storage unit. Swine manure storage facilities sometimes form a natural crust, depending on the diet fiber content.

Covers are not recommended on storages where manure effluent is recycled back into the barns for flushing or pit recharge. High concentrations of hazardous gases dissolved in the effluent will be released when the effluent is brought back into the barn.

### *Type and Size of Manure Storage Facility*

Lined earthen manure basins can be covered using geotextile, straw, commercial permeable products, or impermeable flexible membranes. Straw covers blown onto the manure storage facilities are limited by the range of the straw blower and usually are not practical on storage units over two acres. Wind and wave action on large storage units can damage covers. Concrete lids do not work on steel tanks or lined earthen basins.

### *Manure Nutrient Management*

Covers are expected to increase the nitrogen and sulfur content in the stored manure due to reduced emissions of ammonia and hydrogen sulfide. Phosphorus content does not change due to a cover because there is no volatile form to be emitted. An increase in nitrogen or sulfur can be advantageous because it increases the manure's fertilizer value. Volatile nitrogen and sulfur compounds can be lost during agitation or if anaerobic lagoon effluent is irrigated onto the cropland. Incorporation after land application helps reduce volatile nitrogen emissions and retain the nutrients. Increased nutrient concentrations can be a disadvantage, however, if the additional cropland needed to apply the additional nutrients at agronomic rates is unavailable. Manure sampling and analysis is recommended to determine the nutrient concentrations of covered manure.

## *Precipitation*

Snow, rain, debris, and silt may accumulate on top of impermeable covers, necessitating a system to manage rainwater and snowmelt that accumulate on the surface (*Figure 3*). Small, manually operated pumps are commonly used.

Permeable covers allow water in and probably reduce evaporation, which may require an increase in storage capacity. In regions where annual precipitation is greater than evaporation, rainfall needs to be considered when sizing the manure storage facility.

## *Wind Effects*

Wind can break up naturally formed crusts and straw covers. Winds also can damage other cover materials due to waves and wind action on loose materials or covers with large bubbles. Inflated domes need to be designed to withstand winds.

*Figure 3. Impermeable manure storage covers require additional management to handle precipitation or debris that may accumulate on top of the cover.*
*(Source: Qiang Zhang, University of Manitoba)*

**Safety should be a top consideration when working around covered manure storage.**

### Safety

Covers generally are not designed to have animals or people walk on them. Manure storage facilities should 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.

Concentrations of hazardous dissolved gases such as ammonia and hydrogen sulfide accumulate in the manure under covers. These gases can volatilize quickly if the cover is removed for agitation and pumping or inspection. Covers can create conditions with potentially high toxic gas concentrations near the inspection and agitation openings. Extreme caution should be used when accessing manure under an impermeable cover (i.e., through access flaps or a cover lift system).

People should never enter a covered manure storage unit (i.e., inflated dome or covered tank) without personal breathing protection and adequate safety lines and personnel.

### Costs

Naturally forming crusts have no capital costs. Other permeable covers generally have lower initial costs and shorter life expectancies than impermeable covers (*Table 1*). Impermeable covers usually have higher design and installation costs and require a venting system to handle gases captured under the cover. Most venting systems require electricity and additional operational expenses. Impermeable covers require a system for removing rain and snowmelt and may require more skilled labor for installation and maintenance. Covers made of biomaterials such as straw can be broken up during agitation and land applied with the manure at the end of their service life. Plastic and geotextile covers require proper disposal at the end of their service life which may include recycling or landfill fees.

### Covers and Greenhouse Gas Emissions

More research on the relationship between covers and greenhouse gases is needed. In particular, nitrous oxide emissions are difficult to measure accurately with existing technology because gas concentrations are usually low. Despite low levels, nitrous oxide is a greenhouse gas about 300 times more potent than carbon dioxide and, as such, even small amounts can have a large impact on the environment.

## Conclusion

Covers can be an effective method for mitigating odor and gas emissions from manure storage and treatment facilities. Covers impact manure handling and management and have advantages and disadvantages that need to be considered.

Additional information on permeable and impermeable covers is available in separate fact sheets. More curriculum materials are available at *http://www.extension.org/pages/Air_Quality_in_Animal_Agriculture*.

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