# A Review of Permeable Cover Options for Manure Storage

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**Species:** Beef, Dairy & Swine
**Use Area:** Manure Storage
**Technology Category:** Manure Cover
**Air Mitigated Pollutants:** Ammonia, Odor, Hydrogen Sulfide

## Description:

Covers have been demonstrated to provide effective odor and air emissions control for manure storage structures. Impermeable covers made from flexible synthetic materials provide excellent odor and emissions control, but typically have a high capital cost requirement. Part of the cost associated with the installation of an impermeable cover is the infrastructure required to collect and remove gases from underneath the cover as well as to collect and remove rain water that falls onto the cover. Additionally manure storage structures that are emptied on an annual or semi-annual basis, and hence have a large change in manure level, also require special installation considerations to allow an impermeable synthetic cover to travel up and down as the stored manure level changes.

Permeable covers provide an alternative to impermeable synthetic covers. Permeable covers will typically not provide as high of a level of odor control as a properly installed and maintained impermeable covers, but the initial capital cost for permeable covers is typically lower. Additionally permeable covers are much simpler to maintain than impermeable covers since they do not require gas or rain water collection systems since gases are allowed to migrate through the cover and rainwater will infiltrate through the cover into the manure storage. Also, no infrastructure to raise and lower the cover as the manure level changes within the storage structure is typically required with permeable covers, since they are floated on the stored manure's surface.

Permeable covers have been successfully constructed from a variety of materials including straw, cornstalks, Light Weight Expanded Clay Aggregate (LECA), ground rubber, plastic beads and geotextile materials. Other materials such as *Vermiculite*, *Perlite* and various oils have been tested, but found to provide unsatisfactory performance (MAFF, 2000).

Odor control effectiveness ranging from 40 – 90% has been reported for permeable covers made from various materials. Straw permeable covers are reported to have an odor control effectiveness of 40% when applied in a 4 inch depth and 90% at a 12 inch depth. Geotextile covers are reported to have a odor control effectiveness ranging from 40 – 60%, while a floating LECA cover is reported to have a 90% odor control effectiveness (Nicolai, et. al, 2004). Ammonia control effectiveness is typically reported to be lower than odor control while hydrogen sulfide control is usually higher than odor control when comparing the same materials.

## Mitigation Mechanism:

Permeable covers mitigate air emissions from manure storages through two mechanisms. First, permeable covers provide a physical barrier that prevents direct contact of air to the stored manure's surface. This reduces the transfer of gaseous compounds into the atmosphere Additionally, many permeable cover materials provide an environment that promotes the growth of aerobic bacteria in the floating cover material. These aerobic bacteria can oxidize many of the odorous compounds released from the stored manure as they pass through this aerobic interface. Figure 1 shows a simple diagram that illustrates the aerobic zone that can be developed with some permeable cover materials. Materials such as straw, LECA, or other materials that allow air to penetrate the floating cover layer and provide adequate moisture and surface area to allow a population of aerobic bacteria to develop can provide this increased odor reduction effect.

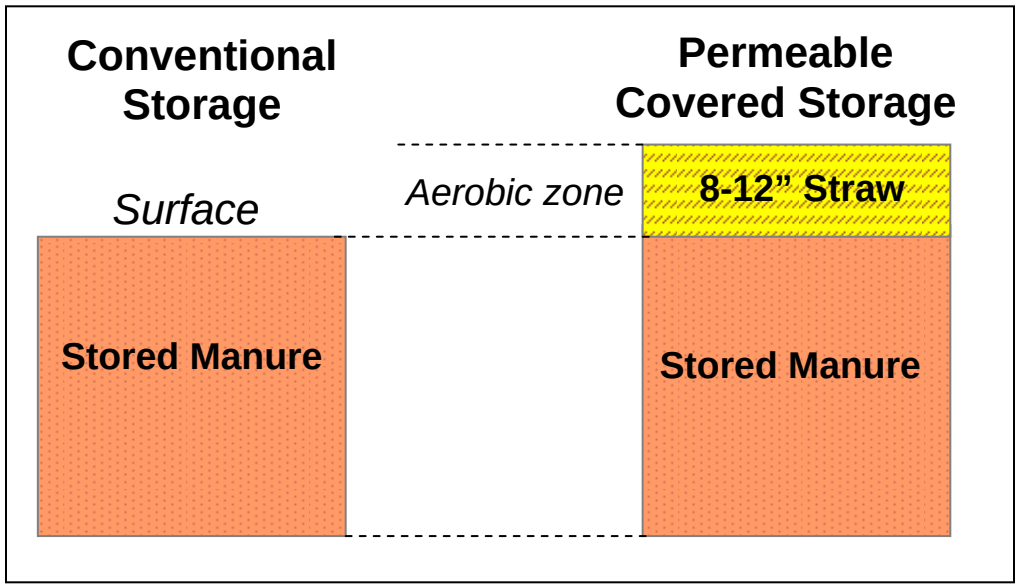


**Figure 1. Cross Section of Manure Storage Structure Demonstrating Aerobic Zone Provided by Some Permeable Cover Materials**

## Applicability:

Floating permeable covers can be used to cover manure slurries of any species. It should be noted however that because these covers float on top of the manure's surface, they will usually have a longer working life when used with manure slurries that have a relatively high total solids content. Research conducted by the Silsoe Research Institute in the United Kingdom directly addressed the impact of both rainfall and manure total solids content on cover longevity. The results of this research show that dry straw floats very well on manure slurries, but that when rained on, the rate at which the straw sinks dramatically increases, and that the rate at which the straw sinks increases as the manure slurry total solids content decreases.

While straw covers are reported as being impractical on manure storages with over two acres of surface area (Nicolai, et. al, 2004), examples of straw covers on manure storage lagoons as large as four acres can be found. The authors agree however that the larger the manure storage structure the more difficult a uniform application of materials such as straw becomes.

**Straw**

Straw is the lowest cost permeable cover material commonly utilized and has a typical installed cost of $0.10 per square foot. While a straw cover has a low initial cost, it also has a short lifespan as a cover. Straw covers floated on manure slurries can be expected to remain floating on the manures surface for two to six months. The length of time that a straw cover will continue to float is a function of rainfall and total solids content of the manure slurry the cover is floated on. Research has demonstrated that straw floated on water and exposed to rainfall sank in less than seven days, while straw floated on an eight percent total solids cattle slurry and exposed to rainfall maintained 80 percent surface coverage for 40 days. Straw floated on a beef manure slurry with four percent total solids and no exposure to rainfall provided an 80 percent surface coverage for 40 days, while straw floated on a beef manure slurry with eight percent total solids and no exposure to rainfall provided a 100 percent surface coverage for the full length of the 77 day test period (MAFF, 2000). At some point however, a straw cover will sink, and when this occurs it increases the difficulty of agitating and land applying the stored manure. Given the short-lived nature of a straw cover and the increased agitation and pumping difficulties that must be dealt with, straw covers are best used as a short-term odor control measure that can be implemented to control an unexpected or severe odor problem associated with a manure storage system. If long-term odor or emissions control is needed, a material with a longer lifespan than straw should be selected. A large round bale of straw can be expected to cover approximately 500 square feet of surface area when chopped and applied to a manure storage structure at a 12 inch depth (Nicolai, et. al, 2004). The cost of such a cover can be easily calculated based on the current price of straw in the region where the cover will be installed. For instance, if a 6 foot diameter roll of straw costs $40 per roll and 500 square feet could be covered per roll, the material cost for the cover would be $0.08 per square foot. Permeable straw covers are typically chopped and blown onto the manure storage surface. Figure 2 shows a straw cover one week after installation on an earthen manure storage structure.

**Figure 2. Permeable Straw Cover Installed on an Earthen Manure Storage Structure**

**LECA**

Lightweight Expanded Clay Aggregate, or LECA, is produced by heating a pre-treated clay with high plasticity in a rotary kiln, followed by burning the material at 1100 degrees C to produce the final LECA product. LECA is typically used as a lightweight aggregate construction material, but has been demonstrated to work very well as a permeable manure cover for both odor and ammonia control. Research has shown LECA to provide 90% odor control and ammonia control ranging from 65-95% (MAFF, 2000, Nicolai, et. al, 2004). LECA applied two to four inches deep on swine manure storage tanks in Iowa has been demonstrated to have a more than a 10 year lifespan, and has provided excellent odor control. While LECA makes an excellent permeable cover, the initial capital cost is more expensive than many other permeable cover materials, with a reported cost of $1.75 per square foot installed (Nicolai, et. al, 2004). Availability within the United States is also a potential issue with LECA. While LECA is produced in many areas of the world including Denmark, the United Kingdom, Iran, Italy and Spain, no producer in the United States is currently known to supply LECA as a permeable manure cover material. Because of this, a large portion of the cost reported with LECA use in the United States as a permeable manure cover is derived from the shipping cost to import the LECA. Figure 3 shows a LECA permeable cover in-place on a swine manure storage tank.

**Ground Rubber**

Ground rubber was tested as a permeable manure cover material and reported to work well over a four month test period (Koppolu et. al, 2005). Koppolu tested a three inch layer of fine ground rubber and found that it reduced odor from stored swine manure from 77 to 99 percent in a six week laboratory study. In the lab study hydrogen sulfide emissions were always below detectible limits from the test tanks, so no hydrogen sulfide emissions control could be tested, and ammonia control was found to be inconsistent in nature. Field tests were conducted in which a two inch ground rubber cover was tested on a swine manure storage structure over a four month period. The fine ground rubber cover was reported to work well in field tests and provide substantial odor, ammonia and hydrogen sulfide reductions over the four month trial period. The rubber used in the tests was an industrial waste by-product from tire recycling and no cost information on the material was provided by Koppolu.

**Geotextile**

Geotextile floated on manure slurries has been tested for odor and ammonia control effectiveness, but mixed results have been reported. Studies have reported that geotextile covers provide from 40 to 65 percent odor control and from 30 to 90 percent hydrogen sulfide control, and limited ammonia control from stored manure (Nicolai, et. al, 2004). The effectiveness of geotextile covers at mitigating odor and gas emissions from stored manure have been reported to decrease with time, with significant decreases in performance occurring by the second year of use (Clanton, 2001, Bicudo, et. al, 2002). Geotextile covers have been tested on earthen lagoons and holding ponds. Because the geotextile cover is usually anchored to the side of the pond, difficulties can arise when the manure storage level changes during manure removal events. Bicudo reported that after manure agitation and pumping in the earthen

manure storages used for the study, that the geotextile covers stayed at the bottom of the manure storage structures, and that snowfall onto the cover in the winter resulted in the cover sinking into the manure. He reported that in the spring the covers at all three test sites had 90% or more of their surface areas submerged below the manures surface (Bicudo, et. al, 2002). This suggests that geotextile covers, much like synthetic impermeable covers must be installed with the infrastructure required to keep the cover intact and afloat during periods of change in the manure level within the storage. Geotextile covers without supporting infrastructure are reported to cost around $0.25 per square foot. Covers that combine geotextile with either closed cell foam or straw have been shown to function better than geotextile alone as a manure cover.

**Figure 3. LECA Cover on A Concrete Swine Manure Storage Tank**

**Mineral Granules**

*Vermiculite* and *Perlite* have both been tested as permeable cover materials and both were found to provide unsatisfactory results. While *Vermiculite* and *Peralite* are both low density materials, they were found unsuitable for use as permeable covers for different reasons. The *Vermiculite* absorbed water and then sank into the manure slurry, while the *Perlite* was easily blown away in windy conditions (MAFF, 2000).

**Oils**

Oils such as rape seed oil and used cooking oil have been tested as potential permeable cover materials, but neither was found acceptable. Researches testing these oils found that because they are biodegradable, they began to breakdown when placed on manure slurries and generated increased methane emissions in the process. Also, as they were biodegraded they also lost their surface integrity (MAFF, 2000).

## Limitations:

Some permeable cover materials, such as straw or cornstalks, have very short effective lives. A straw cover can be expected to last from two to six months before sinking into the manure slurry. Also, once a permeable cover material such as straw or cornstalks sink, they must be dealt with during manure agitation and pump-out and will increase the difficulty of this task.

While material such as LECA provide a long-term permeable cover with an expected working life of greater than 10 years, they are also much more expensive to purchase initially than shorter lived permeable cover materials. The

LECA cost of $1.75 per square foot reported by Nicolai approaches the cost of synthetic impermeable liner materials with 20 year life-spans.

The size of the manure storage structure can also become a limitation in that it can become impractical to place materials such as straw and LECA on the surface of very large manure storage structures. For example, Nicolai suggests that it is impractical to apply a straw cover to manure storage structures with greater than two acres of surface area.

Since permeable covers allow gases to migrate through the cover, there is no opportunity to collect biogas that may be generated within the manure storage. Similarly since direct rainfall onto the cover will infiltrate into the manure storage, the additional storage volume to store this rainfall must be included in the manure storage design volume.

## Cost:

Permeable covers can provide reductions in odor, ammonia and hydrogen sulfide emissions from manure storage facilities. A wide variety 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 is the least cost permeable cover material with an approximate cost of $0.10 per square foot installed. Longer lasting materials such as LECA have installed costs that can approach the cost of impermeable synthetic cover materials.

## Implementation:

Permeable cover materials are typically floated on the stored manure surface and shield manure from direct contact with the atmosphere and can also provide an aerobic zone that manure gases must pass through when released. Permeable covers can be used with earthen, concrete and steel manure storage systems and with slurry manures generated by swine, dairy and beef animals. Installation is a relatively simple process in that the cover materials are either blown or placed directly on the stored manure's surface.

## Technology Summary:

Several permeable cover materials have been demonstrated to provide effective odor and air emissions control for manure storage structures. Permeable covers provide an alternative to impermeable synthetic covers that are simpler and less expensive to install. Permeable covers have been successfully constructed from a variety of materials including straw, cornstalks, Light Weight Expanded Clay Aggregate (LECA), ground rubber and geotextile based covers.

Odor control effectiveness ranging from 40 – 90% has been reported for permeable covers made from various materials. Straw permeable covers are reported to have an odor control effectiveness of 40% when applied in a 4 inch depth and 90% at a 12 inch depth, while a floating LECA cover is reported to have a 90% odor control effectiveness (Nicolai, et. al, 2004). Geotextile covers are reported to have a odor control effectiveness ranging from 40 – 60%, but are also reported to lose their effectiveness over time. For all of the permeable cover materials listed, ammonia control effectiveness is typically reported to be lower than odor control while hydrogen sulfide control is usually higher than odor control when comparing the same materials.

The expected lifetime of a permeable cover varies with the material used to construct the cover. Straw covers typically have the lowest initial installation cost, as well as the shortest working life. Lightweight Expanded Clay Aggregate covers have one of the more expensive initial installation costs, but are also reported to have a long working life.

## Additional Resources:

Covers for Manure Storage Units http://agbiopubs.sdstate.edu/articles/FS925-D.pdf

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