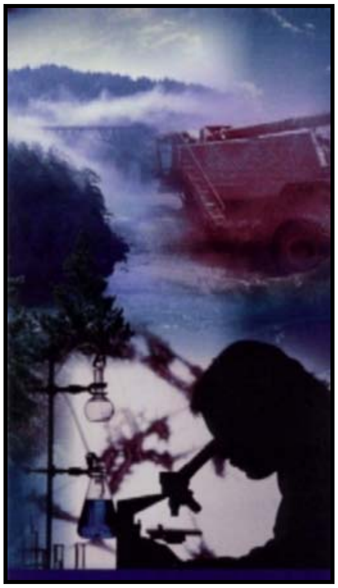

Agricultural &
Natural Resource
Engineering Applications

Covers: A Method to Reduce Odor from Manure Storages

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INTRODUCTION

Most swine and dairy producers in South Carolina use some sort of earthen basin or tank to store manure from animal facilities. The vast majority of these manure storage structures are earthen basins with surfaces open to the air. Some earthen basins are designed to merely store manure until it can be utilized as a plant nutrient source for crop production. Such structures are often called storage ponds. In other cases, the earthen basins are sized using biological treatment principles to provide degradation of volatile solids as well as storage, and are called treatment lagoons.

The design and management of a manure storage structure will determine the amount of odor that will be generated.

Several studies performed over the last 10 years have indicated that covers can be an effective method of controlling the release of odor from a manure storage. Adding a cover to manure storages can reduce odor emission by 40% to 95% depending on cover type.

Covers can also be used on treatment lagoons to allow use of higher loading rates and to capture and burn odorous biogas. Burning biogas will greatly reduce odor and release of methane, a potent greenhouse gas, to the atmosphere.

OBJECTIVES

The objectives of this publication are to: (1) describe the types of manure storage covers that are available, (2) provide a summary of the expected odor reduction, and (3) provide a comparison of costs.

NEED FOR ODOR CONTROL

A treatment lagoon and a storage pond are very similar in appearance. Therefore, information concerning the initial design, history of use, and current management practices is required to distinguish between the two. Additional information on the design and management of treatment and storage ponds is provided by Chastain and Henry (1999 and 2004).

Manure in most storage ponds or treatment lagoons will be maintained in an anaerobic condition—that is, without oxygen. Microbes that break down volatile solids anaerobically will release odorous compounds.

Research has shown that the frequency of odor, or the rate of odor occurrence, near a manure storage structure will vary with the amount of volatile solids (VS) added per 1000 ft^3 of volume per day (Humenik, et al. 1981). This is referred to as the loading rate (lb VS / 1000 ft^3 / day).

In general, manure storages have a much higher loading rate than treatment lagoons. Consequently, the odor frequency for manure storages can be much higher than for treatment lagoons as shown in Figure 1.

The loading rate has a large impact on the amount of odor that is generated from a lagoon or storage pond (Figure 1). The data indicates that significant odor will be produced from a manure storage 62% to 80% of the time. The maximum recommended loading rate for a treatment lagoon in South Carolina is 5.0 lb VS/1,000 ft^3/ day and as a result odor will be precent near the lagoon 33% of the time. At very low loading rates, a treatment lagoon will generate odor about 20% of the time.

The variation in odor frequency with loading rate given in Figure 1 also demonstrates that it is critical to maintain the required anaerobic treatment volume in a lagoon. The treatment volume will be greatly reduced if sludge is allowed to build up excessively in a lagoon. The decreased treatment capacity has the same effect as an increase in loading rate and will cause an increase in odor frequency.

Strong odors are also common near manure storage structures during agitation and pumping of manure for land application. Agitation of minimally treated manure greatly increases the rate of odor release.

Agitation and removal of well treated lagoon sludge generally generates fewer odors than agitation of a structure that is only used to store manure.

COVER TYPES AND EFFECTIVENESS

Storage covers can be made from a large variety of natural and synthetic materials. Some of these materials can float on the surface and others must be supported by cables or air. All of the types of covers can be placed in one of two categories—permeable or impermeable.

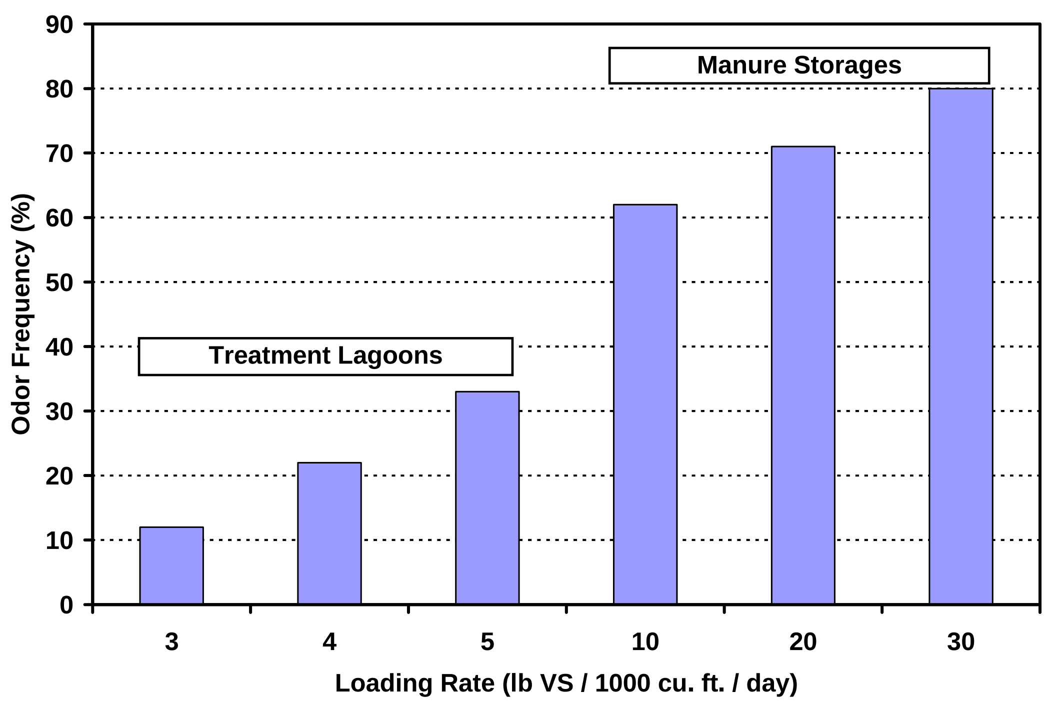

Figure 1. Variation of odor frequency observed near treatment lagoons and manure storages (adapted from Humenik, et al. 1981).

Permeable Covers

A permeable cover does not completely seal the surface of the manure. As a result, rainwater can pass through a permeable cover and will not pond on the surface. Manure gases pass very slowly through a permeable cover and provide a reduction in odor. Since gas will not build up beneath a permeable cover a vent is not needed.

Permeable covers are made from plant residues, geotextiles, or a combination of the two.

Biocover

Covers made from plant residues are called biocovers. A biocover consists of a 4 to 12 inch layer of floating plant residue (Figure 2). Materials that have been used for biocovers include wheat or barley straw, chopped corn stalks, and dried grass.

Figure 2. A biocover formed by a layer of chopped corn stalks on the surface of swine manure (Lorimar et al., 1998).

The depth of the biocover material influences its odor reduction effectiveness. Results from a controlled laboratory study indicated that a straw biocover of four inches provided an odor reduction of 60% as compared to an uncovered tank of swine manure (Bicudo et al., 1999). Increasing the straw depth to eight inches provided 81% reduction in odor emission. A straw depth of 12 inches provided 86% reduction in odor emission. While the increase in odor reduction between an 8 and 12 inch biocover is small, many producers prefer the greater material depth to extend the useful life.

Over time, the odor reduction provided by a biocover will decrease as a portion of the straw begins to sink, or as wind and wave action cause a portion of the cover material to drift exposing the liquid surface. Near the end of the useful life of a biocover the odor reduction can drop from 80% to about 40%. The average odor reduction provided by a 10 to 12 inch biocover will be about 50% (Nicolai et al., 2004).

The main factors that affect the useful life of a biocover are the materials ability to float for a long period of time and the depth of the material. The greater the cover depth, the longer it will last. Biocovers with a depth of 10 to 12 inches are the most common and have a useful life of four to six months.

A biocover is typically applied to the surface of a manure storage using a chopper-blower (Figure 3). Consequently, biocovers are difficult to use on large manure storage ponds. The maximum liquid surface area that is recommended for use with a biocover is two acres.

Figure 3. Blowing wheat straw onto a manure storage pond to form a biocover (Lorimor at al., 1998).

Use of a biocover will also influence the equipment used for loading and unloading a manure storage. Manure should be loaded in such a way that it is added below the surface of the biocover. Many manure storage tanks and ponds are loaded by gravity or pump using a large pipe near the bottom. If manure is added to the surface by using a pipe, add a 20º to 45º elbow to the end of the pipe. Another section of pipe or a heavy rubber boot can then be added to the elbow to direct manure down near the bottom of the storage. The used cover material will be removed when the manure is agitated and pumped to spreading equipment, and will add organic matter and carbon to the soil.

Geotextile Cover

Geotextile covers are made from non-woven geotextile fabrics that float on the manure surface; hence the name geotextile cover. A non-woven geotextile is made of thermally bonded PVC or polypropylene fibers. Geotextiles are available in a variety of thicknesses and resemble felt in appearance and texture (Figure 4).

Figure 4. Floating geotextile cover on a swine manure storage pond (Bicudo, 2002).

Fibers used to make geotextile covers contain UV inhibitors to reduce degradation by sunlight to acceptable levels. The useful life for most geotextile covers is three to five years.

Maintaining the floating characteristics of the non-woven fabric over several years was one of the initial problems encountered with geotextile covers. The fabrics were slow to re-float after pumping manure for land application. However, after a period of time the fabrics would re-float (Nicolai et al., 2004). Using thicker fabrics reduces re-floatation problems.

Re-floatation problems appear to be more of a problem in the cold climate of the Midwest than in warmer climates.

The odor reduction provided by a newly installed geotextile cover can be as high at 65%, but the performance will decrease as it ages. Long-term average odor production is about 50%; which is about the same as a biocover. A geotextile cover will provide more consistent odor reduction over a longer period of time than a biocover.

Thicker geotextile fabrics (0.0945 in or more) are recommended because they provide more odor control and a longer useful life than thin fabrics (0.0433 in; Bicudo et al., 1999).

Geotextile covers have one main concern when compared to biocovers; good agitation of manure below the cover may be difficult to achieve. Most manure agitation and pumping equipment provide vigorous mixing by pumping manure from near the bottom and discharging it over the surface through a large nozzle. Such equipment cannot be used with a geotextile cover unless a mechanical method of temporarily removing a large portion or all of the cover is provided.

Providing adequate agitation below a cover prior to pumping the manure for land application requires design of a pipe and pumping system to achieve the required mixing. Such systems are best designed as an integral component of the storage structure or as a custom retrofit by an engineer.

A recent innovation in geotextile cover technology has been the addition of a layer of closed-cell foam between two layers of geotextile material (Nicolai et al., 2004). This doubled the life of the cover and prevented sinking (Figure 5). However, the longer life comes at a higher price.

Figure 5. A two-layer geotextile cover with additional floatation provided by a layer of closed cell foam (Nicolai et al., 2004).

Combination Cover: Geotextile + Biocover

A combination cover combines the effectiveness of a biocover with the longer life of the geotextile cover. It is made by blowing a layer of straw, chopped corn stalks, or other plant residue on top of a geotextile cover (Figure 6).

Figure 6. Combination cover made of geotextile and a layer or straw (Lorimor, 1999a).

Research has indicated that combining a thin, floating geotextile cover with a layer of straw or chopped corn stalks can provide an effective cover for odor control (Table 1). Odor reduction increased as the biocover thickness was increased from 4 to 12 inches. The optimal depth of the straw or chopped corn stover was determined to be eight inches. The thickness of the geotextile was not an important factor in odor reduction for the combination cover.

Table 1. Affect of biocover thickness on the performance of combination covers (adapted from Clanton et al., 2001).

Biocover Thickness Over a Geotextile Cover	Odor Reduction (%)
4 in	47 to 63
8 in	69 to 78
12 in	76 to 83

The useful life of a combination cover is the same as for a geotextile cover—three to five years. However, periodic additions of plant residue may be required.

A combination cover has the same concerns related to agitation of manure as was discussed previously for a geotextile cover. Removal of a combination cover may be more difficult than for a simple geotextile cover. Consequently, careful attention must be given to design and selection of the pumping and agitation equipment if a combination cover is used.

Impermeable Covers

An impermeable cover provides a complete seal of the covered manure surface. Therefore, it must be designed to vent manure gases. Also, a method to prevent rainwater from collecting on the surface must be provided to prevent cover failure.

Plastic Cover

A floating plastic cover, often made from sheets of HDPE or PVC, will provide consistent odor reduction ranging from 60% to 95% depending on the amount of liquid surface covered. Full covers can provide 95% reduction in odor.

A well designed and installed plastic cover can last for 10 years.

In South Carolina, use of a plastic cover will cause the structure to function as a covered lagoon digester (Figure 7). A covered lagoon digester is an anaerobic digester that is unheated and operates at near air temperature. Such a structure provides odor control as well as biological treatment of the manure.

Figure 7. A covered lagoon digester (PSU, 2007).

The cover and biogas collection system solves the odor problem from the lagoon and yields another product—biogas. Biogas contains about 560 Btu of energy per cubic foot. The energy is from methane and is a byproduct of anaerobic decomposition. Biogas is 60% to 70% methane. The remainder is mostly carbon dioxide, and small but significant amounts of hydrogen sulfide and other odorous compounds.

Biogas must be burned using a flare to eliminate its odor. If desired, the biogas can be used as a fluctuating, but significant source of energy.

The temperature in an unheated covered lagoon digester will vary with the average outside temperature. During the winter months, anaerobic digestion is slow resulting in a decrease in biogas production. Estimates of the usable, or net, biogas energy from simple covered lagoon digesters located in South Carolina are given in Figure 8.

Well stabilized solids that are removed from a covered lagoon digester also have a lower odor than untreated slurry. As a result, odor is less of a concern during land application of digested manure than for untreated manure.

A study performed by faculty at Clemson University (Chastain et al, 2002), concluded that a covered lagoon digester can be a practical type of digester for manure treatment and odor control in warm climates.

Very little of the nitrogen is lost during anaerobic digestion since the cover greatly reduces the volatilization of ammonia. During the digestion process, a large portion of the organic nitrogen is broken down and is converted to ammonium nitrogen (NH_4^+-N). Therefore, the nitrogen in the digester effluent is more plant available than in fresh manure.

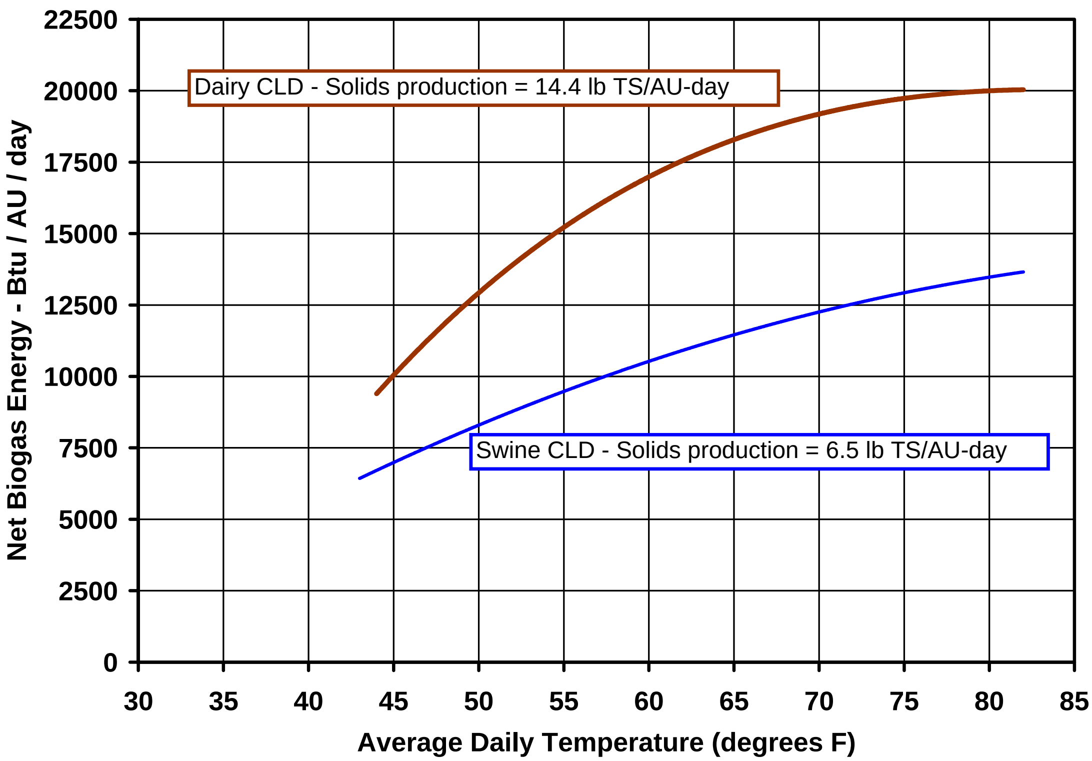

Figure 8. Net biogas energy produced from unmixed covered lagoon digesters (CLD) in South Carolina (1 AU = 1000 lb live animal weight).
Estimates based on an update of the model by Chastain and Linvill (1999).

Inflated Dome

An inflated plastic dome was developed and tested by Zang and Gaakeer (1996) for use as an impermeable cover (Figure 9). Their design eliminated problems associated with collection of rainwater, and provided venting by way of a pressurization fan.

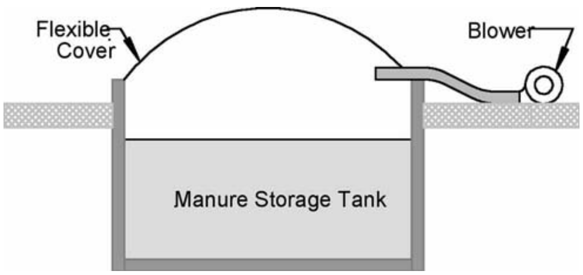

Figure 9 Diagram of an inflatable plastic dome (Nicolai et al., 2004).

The odor reduction for this type of cover was 95% and the estimated life of the cover was 10 years.

Prior to agitation and pumping of the manure, the dome was allowed to deflate and rest on supports that hold the plastic cover above the manure surface. Access doors were provided to allow entry of pumping equipment (Nicolai et al., 2004).

The main disadvantage of the inflated dome is the high cost as compared to other options.

COST COMPARISON FOR STORAGE COVERS

All of the types of covers reviewed in this publication have been shown to be effective at reducing odor from manure storages. However, the five types of covers vary with respect to useful life and cost. As one would expect, the longer a cover lasts the greater the initial cost.

Cost estimates are provided in Table 2 based on a review published in 2004 (Nicolai et al., 2004). While these estimates maybe lower than current prices they still provide a valid comparison.

A biocover is one of the least expensive type of covers at about 63¢ per square yard. However, straw or chopped cornstalks must be reapplied whenever the cover begins to break up due to sinking or wave action. Manure storages must be well agitated prior to removing the slurry for land application. Therefore, the biocover must be replaced each time manure is removed from the storage. Depending on the weather and the number of times manure is applied to cropland, a biocover must be applied to a manure storage two to four times per year. Therefore, plant residue availability, and labor and energy costs must be considered when considering the use of a biocover.

Geotextile covers provide a longer lasting, permeable cover than a biocover

Table 2. Relative cost of several manure storage covers (adapted from a review by Nicolai et al., (2004)).

Cover Type	Material	Odor Reduction (%)	Useful Life	Capital Cost ($US / yd^2)
Permeable	Biocover (8 to 12 in)	40 to 80	2 to 6 months	$0.25 to $1.00
	Geotextile	40 to 65	3 to 5 years	$1.25 to $1.60
	Geotextile + 8 in Biocover	69 to 78[a]	3 to 5 years[b]	$1.50 to $2.60
Impermeable	Floating Plastic (HDPE)	60 to 95[c]	10 years	$3 to $5
	Inflatable Plastic Dome	95	10 years	$7 to $15

[a] Values from Table 1 for an 8 inch layer of crop residue.

[b] Biocover layer may require periodic replacement. Actual life unknown.

[C] Odor reduction will depend on the amount of liquid surface covered. A fully covered lagoon digester will provide odor reduction of about 95%.

and costs about $1.43 per square yard. However, if one considers the material and energy costs associated with multiple, annual applications of straw or corn stalks, the cost of the geotextile cover may be comparable to a biocover.

Combination of a geotextile with a layer of plant residue will increase the cost to about $2.05 per square yard, and will provide a small increase in odor reduction.

Impermeable covers are the most expensive to install at $4 to $11 per covered square yard or more. However, they provide the greatest amount of odor control and the longest useful life.

The cost for biogas handling for covered lagoon digesters and the energy requirements for the inflatable dome are not included in the values provided in Table 2.

The amount of electric energy required to maintain dome inflation is a small operating cost that should be considered and would be calculated based on blower size.

In the future, a covered lagoon could provide a cost benefit. A portion of the biogas could be used for energy on-farm. Also, it may be possible to receive payment for the carbon credit that will be provided by methane capture and incineration.

SUMMARY

Covers for manure storages can be divided into two categories—permeable and impermeable. Permeable covers allow rainwater to pass through the cover and gases are released at a very slow rate. Impermeable covers are made of plastic, do not allow rainwater to enter the storage directly, and contain all gases produced by anaerobic decomposition.

Permeable covers are made from either crop residues such as straw, non-woven geotextile fabrics, or both. Permeable covers can provide 40% to 80% reduction in odor production from a manure storage structure. Initial costs are lower than for impermeable plastic covers, but they require more frequent replacement.

Impermeable covers can be either floating or air-supported. Odor reduction is more consistent than for a permeable cover and can be as high as 95%. However, the cost is 3 to 7 times more than a permeable cover.

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