CHAPTER 4

Management of Lagoons and Storage Structures for Swine Manure

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INTRODUCTION

Most swine buildings in South Carolina are designed to collect and transfer manure to an anaerobic lagoon or storage pond as a liquid. The two most popular collection and transfer systems are flush and pit-recharge.

Most new flush swine facilities have completely slotted or perforated floors (farrowing and nursery buildings) that allow manure to fall through the floor onto a sloped, concrete alley. Manure is flushed from below the slotted floor 4 to 12 times each day. An independent flush tank is used to clean manure from each row of pens. Most flush tanks are sized to release 250 to 500 gallons of water per flush. Flushed manure is collected in a cross channel and is conveyed to a 6 to 8 inch pipe that is used to gravity load the lagoon or storage pond. Recycled lagoon surface water (called ***supernatant***) is typically used to flush swine buildings.

Older swine buildings use an open flush gutter for finishing swine or breeding stock. Flushing schedules can range from a twice each day using a manual dump tank to a continuous stream. The resting and feeding area is a solid concrete floor that is manually scraped or cleaned with a high-pressure hose.

Most new swine facilities in South Carolina use a pit-recharge manure handling system developed by Barker and Driggers (1985). A pit-recharge manure handling system consists of an under-floor pit with an average depth of 24 to 30 in. The floor of the pit is generally sloped 1 inch per 20 ft toward a collection gutter that conveys manure to a drain that is located in a sump outside the building. The drain is plugged using a removable standpipe that is typically made of PVC. A slot is cut in the side of the standpipe to set the liquid depth in the building. The level is set so that the highest part of the pit floor is covered by 3 to 6 inches of water. In most cases, the pit is filled with recycled lagoon supernatant. The pit is typically emptied every 5 to 7 days. The manure is loaded into a lagoon or storage pond by gravity through a 6 to 8 inch pipe.

The objectives of this chapter are to: (1) describe the concepts used to size treatment lagoons and storage ponds, (2) describe the management requirements for lagoons and storage structures, (3) describe alternative storage structures, (4) describe methods to control odor from lagoons and storage structures, and (5) provide estimates of the quantity of plant nutrients that must be land applied from lagoons and storage structures.

TYPES OF BACTERIA IN MANURE

Selection of a type of storage structure and proper management requires an understanding of the basic types of bacteria that are present in manure. Bacteria growth can reduce the strength of some pollutants in manure (called ***treatment***). Uncontrolled growth of certain bacteria will provide some treatment, but will greatly increase the frequency and amount of odor.

Animal manure contains three types of bacteria: anaerobic, aerobic, and facultative. Anaerobic bacteria will only grow in manure that contains no oxygen. Aerobic bacteria can only thrive in manure with a sufficient level of dissolved oxygen. Facultative bacteria can live with or without oxygen. Most manure storage structures and treatment lagoons maintain the manure in an oxygen-free or anaerobic condition. Natural or mechanical aeration (addition of oxygen to manure) is required to promote the growth of aerobic bacteria. Aeration will suppress the growth of anaerobic bacteria.

The organic matter in manure can be decomposed by all three types of bacteria. The organic matter that can be decomposed is called the volatile solids. Volatile solids make-up the majority of the solids in manure (70 to 80%). Anaerobic bacteria can decompose a much larger amount of volatile solids per unit volume than aerobic bacteria. Aerobic lagoons require dissolved oxygen that must be added mechanically or by constructing a very shallow lagoon (3 to 4 ft deep) with a very large surface area. As a result, almost all animal manure lagoons are designed to use anaerobic bacteria.

Unfortunately, most of the gases and other compounds that are associated with the odor from animal manure are the result of anaerobic decomposition of the volatile solids. An anaerobic lagoon must be sized and loaded to limit the rate of anaerobic decomposition to control odor. The surface water of a lagoon will receive some natural aeration. Facultative and aerobic bacteria live in the surface water of a lagoon and can help reduce the occurrence of odor. A lagoon designed with a large surface area and the required anaerobic treatment volume will allow facultative bacteria to thrive in the first few feet of lagoon liquid. A treatment lagoon designed in this manner will help to reduce odor.

If animal manure is stored in a concentrated liquid form, such as a slurry at 5 to 10% total solids, the rate of anaerobic decomposition will be increased. Increased rates of decomposition will result in more odor. Concentrated liquid manure storages generally do not promote the growth of facultative and aerobic bacteria in the surface layer. As a result, uncovered, concentrated liquid manure storages can generate more odor than a properly designed and maintained lagoon.

ANAEROBIC TREATMENT LAGOONS AND STORAGE PONDS

Anaerobic treatment lagoons and storage ponds are the most common type of storage structures used to store swine manure in South Carolina. A treatment lagoon and storage pond may look the same, but the management requirements are different.

Most lagoons or storage ponds are constructed as an earthen basin. Earthen basins are earth-walled structures that are partially above or below grade and are designed and constructed to prevent ground water contamination. Common materials used for basin liners are clay-type soils, geosynthetic plastic, or concrete. If the soil near the basin is too porous, clay soil can be obtained from another site. However, the cost of a clay liner may exceed the cost of a synthetic liner if the clay must be transported a large distance (over 5 miles).

Proper installation and maintenance is required to seal the basin regardless of the type of liner used. Installation of a concrete pad and ramp is recommended at each agitation and pumping location to protect the basin seal during agitation and removal of solids. A contractor experienced in basin construction is required for the installation of all basin liners. Check with your NRCS (Natural Resources Conservation Service) office or hire a qualified professional engineer for help in evaluating site suitability, dike construction, bottom sealing, and basin wall side slopes. The requirements for locating and constructing earthen basins that are used as a treatment lagoon or storage for swine manure are given in sections 100.80 and 100.90 in the Standards for the Permitting of Agricultural Animal Facilities (R.61-43, SCDHEC).

Sizing Anaerobic Lagoons

Proper management of an anaerobic lagoon requires a basic understanding of the concepts used to size the lagoon. The components of an anaerobic lagoon are shown in Figure 4.1 and include the following:

- anaerobic treatment volume,
- manure and wasted water storage volume,
- sludge storage volume, and
- additional depth for the net rainfall (precipitation - evaporation), the 25-year, 24-hour rainfall event and a freeboard of 1 ft (ASAE EP403.2, 1998).

The lagoon operator must maintain these volumes and depths in order for the lagoon to function properly.

Three important levels are also shown in Figure 4.1 and are called the (1) minimum operating level, (2) design treatment level, and (3) maximum operating level. These three operating levels must be clearly identified on the earthen basin. The liquid level of a lagoon must be controlled (by pumping) to maintain the level between the design treatment level and the maximum operating level. The depth for freeboard and the 25-year, 24 hour storm must be maintained at all times.

Treatment Volume and Loading Rate

The treatment volume of a lagoon is determined based on the volatile solids loading rate (pounds of volatile solids per 1,000 cubic feet per day or lb VS/1,000 ft^3-day). The loading rate varies with climate (ASAE EP403.2, 1998). Larger loading rates can be used in warm climates than in cold climates. For example, in the coastal plains of South Carolina, the maximum loading rate that should be used is 5 lb VS/1,000 ft^3-day. However, in Iowa the maximum loading rate is 3.5 lb VS/1,000 ft^3-day. In North Carolina the maximum loading rate is about 4.5 lb VS/1,000 ft^3-day.

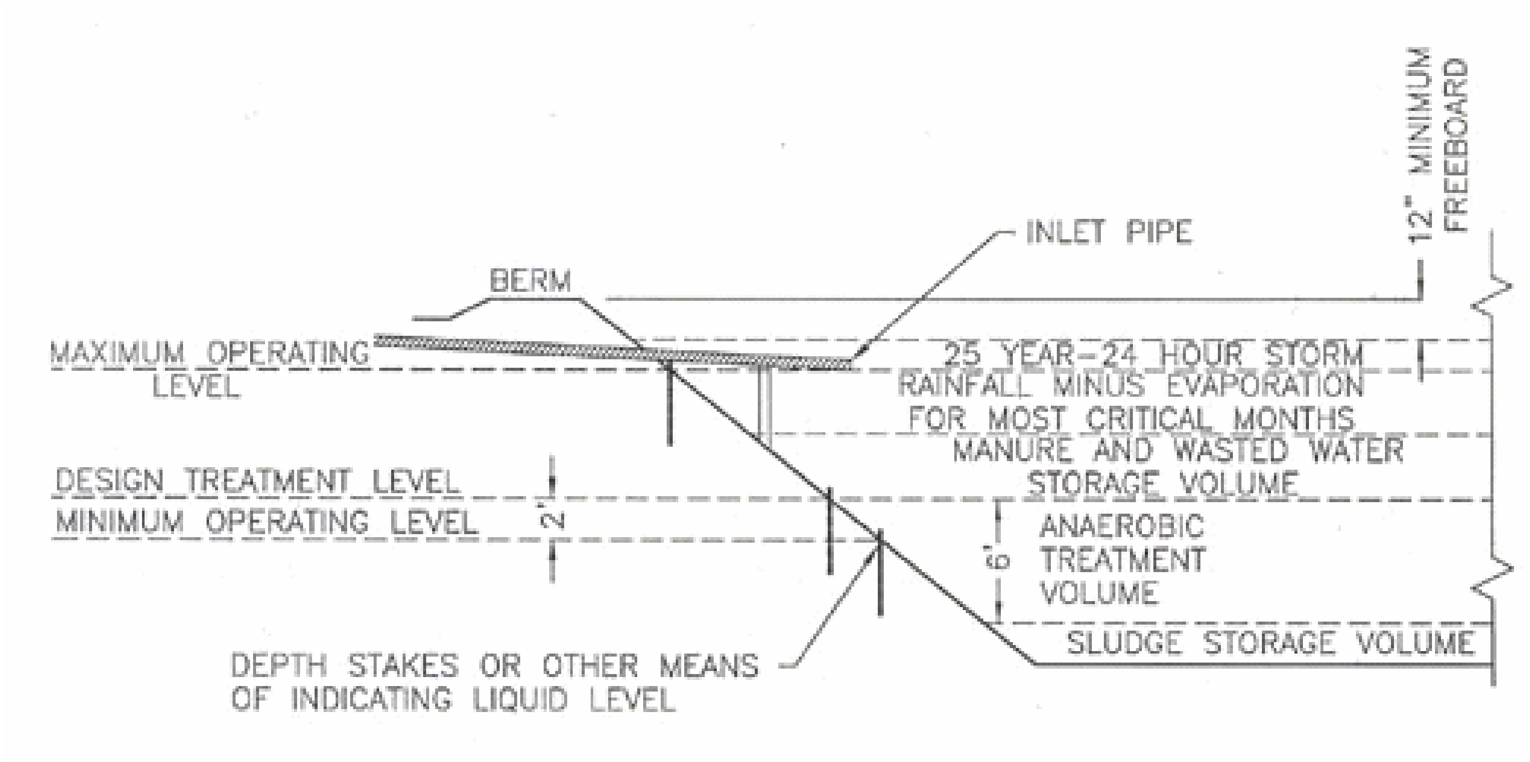

Figure 4.1. Components and operating levels for an anaerobic lagoon.

Effect of Loading Rate on Odor The loading rate has a large impact on the amount of odor that is generated from a lagoon as shown in Figure 4.2. The data indicates that at very high loading rates, such as 30 lb VS/1,000 ft^3-day, a significant odor will be produced near the lagoon 80% of the time. If the loading rate is only 1.9 lb VS/1,000 ft^3-day, the odor will be insignificant. These results show that one way to control odor is to use a very small loading rate. However, a lagoon sized based on a loading rate of 1.9 will be very large and expensive to build. The maximum recommended loading rate of 5.0 will have an odor near the lagoon 33% of the time. In South Carolina, the recommended loading rate to minimize odor is 3.8 lb VS/1,000 ft^3-day with an odor frequency of 20%.

The variation in odor frequency with loading rate given in Figure 4.2 also shows why the design treatment volume must be maintained. If solids or sludge are allowed to build up in the lagoon, the treatment volume will be greatly reduced. The decreased treatment capacity has the same effect as an increase in loading rate and will cause an increase in odor frequency.

The recommended treatment volumes for swine lagoons in South Carolina are given in Table 4.1. Most swine lagoons designed by the Natural Resources Conservation Service (NRCS) are sized to minimize odor (loading rate = 3.8 lb VS/1,000 ft^3-day).

Table 4.1. Lagoon treatment volumes based on South Carolina, NRCS standards (see Swine Manure Production and Nutrient Content, Table 3.1, for volatile solids data).

		Minimum Size [1]		Size to Minimize Odor [2]	
Farm Type	Average Weight lb/PU[3]	Lagoon Treatment Volume ft^3/AU[4]	Surface Area [5] ft^2/AU	Lagoon Treatment Volume ft^3/AU	Surface Area [5] ft^2/AU
Farrow-to-Wean	433 lb	900	150	1,184	197
Nursery	30 lb	1,700	283	2,237	373
Farrow-to-Feeder	522 lb	1,020	170	1,342	224
Feeder -to- Finish	135 lb	1,700	283	2,237	373
Farrow-to-Finish	1,417 lb	1,440	240	1,895	316

[1] Loading rate = 5.0 lb VS/1,000 ft^3 -day
[2] Loading rate = 3.8 lb VS/1,000 ft^3- day
[3] PU = production unit. For all farm types with sows, the production unit is a sow. For nursery farms, a production unit is a pig. For a finishing farm, a production unit is a hog. See the chapter 3 for more explanation.
[4] One animal unit AU = 1,000 pounds of live weight.
[5] Based on a treatment volume depth of 6 ft.

The treatment volume per animal unit (1,000 pounds of live weight) is not the only factor that must be considered. Lagoon designers also try to set the depth of the treatment volume at a minimum of 6 ft. Anaerobic bacteria will not thrive if the depth of the treatment volume is too shallow. The surface area per animal unit (ft^2/AU) shown in Table 4.1 is the treatment volume divided by 6 ft. Deeper structures may be designed depending on site conditions. South Carolina law requires a separation of 2 ft between the bottom of an earthen lined lagoon or storage structure and the water table (see R.61-43, section 100.90 (E)).

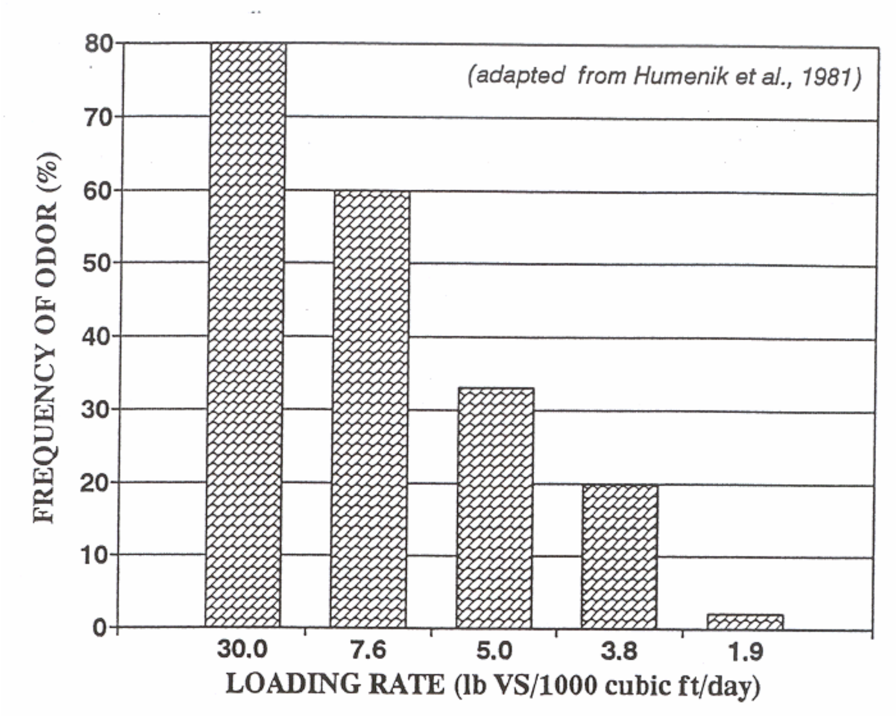

Figure 4.2. Effect of loading rate on odor production from lagoons and storages.

Effect of Loading Rate on Recycle Water Quality The final important consideration related to sizing treatment volumes based on loading rates is the quality of recycle water for recharging pits and flushing. The loading rate of a lagoon greatly effects the quality of the water that is typically recycled through the building to remove manure. The maximum loading rate that should be used if lagoon water is recycled through the building is 5.0 lb VS/1,000 ft^3-day (Barker and Driggers, 1985). Using a lower loading rate, such as 3.8 lb VS/1,000 ft^3-day, will provide recycle water that is relatively low in odor. Inadequately treated lagoon liquid, associated with high loading rates, can increase ammonia levels in the swine buildings and increase odor from the buildings. An old lagoon with excessive amounts of sludge should not be used as a source of recycle water.

Manure and Sludge Volumes

In most cases, lagoons in South Carolina are sized to provide 180 days of storage for manure (includes wasted water), and 10 years of sludge storage. However, the producer and the designer can modify these values on a case-by-case basis. The design volumes for manure and sludge are given in Table 4.2. It should be noted that sludge is a mixture of fresh and old manure solids that settle to the bottom of a lagoon.

The two major components of sludge are the fixed solids (solids like sand that will never decompose), and volatile solids that require a large amount of time to decompose (more than 5 to

10 years). The majority (90%) of the sludge can be removed by agitation and pumping with the appropriate type of equipment.

Table 4.2. Manure and sludge volumes for sizing lagoons and storage structures.

Farm Type	Average Weight lb/PU[3]	Manure and Wasted Water[1] ft^3/AU/180 days [4]	Annual Sludge Volume [2] ft^3/AU/year [4]
Farrow-to-Wean	433 lb	209	104
Nursery	30 lb	292	195
Farrow-to-Feeder	522 lb	223	119
Feeder -to- Finish	135 lb	292	195
Farrow-to-Finish	1,417 lb	268	165

[1] Includes manure plus waterer wastage, and washdown water, based on Table 3.2 in Swine Manure Production and Nutrient Content (chapter 3).
[2] Based on ASAE EP403.2 (1998).
[3] PU = production unit. For all farm types with sows the production unit is a sow. For nursery farms a production unit is a pig. For a finishing farm a production unit is a hog. See the chapter 3 for more explanation.
[4] One animal unit AU = 1,000 pounds of live weight.

Total Lagoon Volume

The total design volumes for swine lagoons are given in Table 4.3. These volumes are the sum of the treatment volume, 180 days of storage for manure and wasted water, and 10 years of sludge storage. In most cases, the NRCS designers in South Carolina use the largest value in the table (loading rate of 3.8 lb VS/1,000 ft3-day, and feeder-to-finish) to minimize the frequency of odor.

Table 4.3. Total lagoon volumes including 180 days of manure and wasted water storage and 10 years of sludge storage. (These values do not include the additional depth required for net rain, the 25-year, 24-hour storm, or required 1 ft free board.)

Farm Type	Average Weight lb/PU[3]	Minimum Size [1] Total Volume ft^3/AU[4]	Size to Minimize Odor [2] Total Volume ft^3/AU[4]
Farrow-to-Wean	433 lb	2,149	2,433
Nursery	30 lb	3,942	4,479
Farrow-to-Feeder	522 lb	2,433	2,755
Feeder -to- Finish	135 lb	3,942	4,479
Farrow-to-Finish	1,417 lb	3,358	3,813

[1] Loading rate = 5.0 lb VS/1,000 ft^3 -day
[2] Loading rate = 3.8 lb VS/1,000 ft^3- day
[3] PU = production unit. For all farm types with sows the production unit is a sow. For nursery farms a production unit is a pig. For a finishing farm a production unit is a hog. See the chapter 3 for more explanation.
[4] One animal unit AU = 1,000 pounds of live weight.

Net Rainfall, 25-year, 24-hour storm, and Freeboard
The additional depth needed to allow for precipitation and freeboard are given in Table 4.4. These are approximate values, and are intended for general planning purposes. More detailed weather information can be obtained at the local NRCS office for a particular location. In some cases, the required depth will be lower than shown in the table. In the mountains of the Upstate region of South Carolina the values could be larger due to high variations in local rainfall.

Table 4.4. Approximate depths to add to lagoons or storage structures for net rainfall, rain from a 25-year, 24-hour storm, and freeboard in South Carolina (NRCS field offices can provide more accurate values.)

Region	Net Rainfall Based on Winter Rainfall & Evaporation (inches)	Rainfall From a 25-year, 24-hour Storm (inches)	Total Depth to Add Including 1 ft Freeboard (ft)
Mountains	18	9	3.3
Upstate	13	7.5	2.7
Midlands	10	7	2.4
Coastal Plain	9	8	2.4

Sizing Manure Storage Ponds

A storage pond looks like a lagoon. However, they are typically not designed based on anaerobic treatment principles. Storage ponds are much smaller, and the potential for strong odor is greater than for a treatment lagoon.

Manure storages are sized to store all of the manure, waterer wastage, and washdown water for a defined storage period, as shown in Figure 4.3. Additional depth is also provided for precipitation and freeboard in the same way as for a lagoon (see Table 4.4). The entire storage contents are agitated and land applied. In cold climates, 8 to 12 months of storage is required because manure can only be used to fertilize crop or pasture land during the spring and summer. In South Carolina, manure storages are typically sized to contain 180 days (6 months) of manure since grains and forages can be grown much of the year. A land application plan that includes winter and summer crops or forest land can allow the storage period to be reduced. Whatever the case, it is important that the storage structure be sized to provide adequate storage when land application can not occur, and to allow for periods of wet weather. The minimum practical storage period for liquid manure is between 60 and 90 days.

The only operating level that is associated with a conventional storage pond is the maximum operating level as indicated in Figure 4.3. The contents of a storage pond are agitated so that both solids and liquids are removed during pumping and land application operations. The liquid level must not exceed the maximum operating level.

Design Volumes for Conventional Storages
Conventional storage structures can be used to store slurry or liquid swine manure. Design volumes for 180 days of storage are given in Table 4.5. Slurry manure storages are typically used

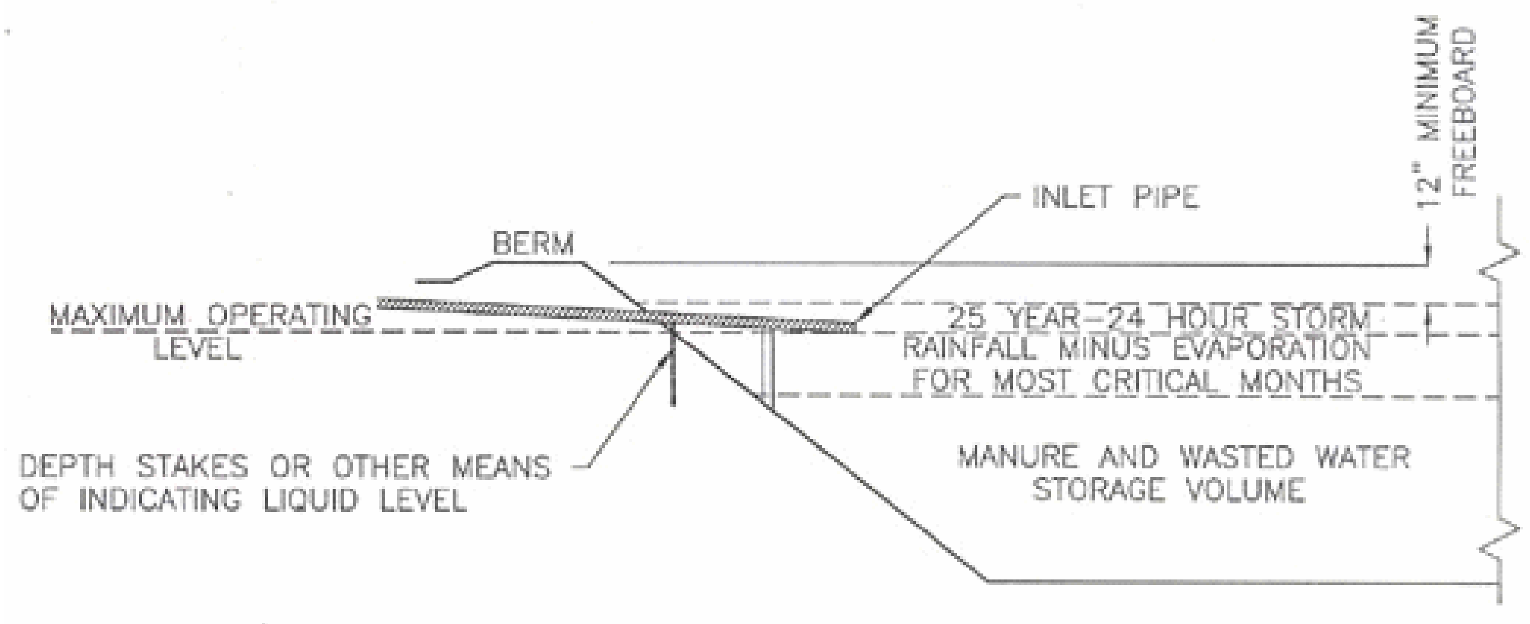

Figure 4.3. Components and Operating Levels for a Conventional Storage Pond

in the Upper Midwest and Canada and are included for comparison. Liquid manure storages are used with pit-recharge and flush systems and are about twice as large as a slurry storage. All manure storages are smaller than lagoons and can be less expensive to construct.

A slurry storage has very little dilution volume, and the effective loading rate is about 27 lb VS/1,000 ft^3-day. Consequently strong odors are frequent. A liquid manure storage has some dilution volume from the water added for flushing or pit-recharge. The loading rate is about 6 lb VS/1,000 ft^3-day. The strength and frequency of odor from a liquid storage is less than for a slurry storage, but the surface water is too strong to be recommended for recycling.

Design Volumes for Storage Structures Sized Based on Loading Rate

One way to reduce the odor frequency from a manure storage and to allow recycling of the surface water is to provide a treatment volume and the required 180 days of manure storage. This hybrid structure provides the treatment volume of a lagoon without the sludge storage volume as shown in Figure 4.4.

The two important levels are the design treatment level and the maximum operating level. The maximum operating level is the same as for a treatment lagoon and a conventional storage pond. The treatment level is the same as previously described for a lagoon. The liquid level is kept between these two levels except when solids are removed by agitating and pumping.

Recommended design volumes using loading rates of 5.0 and 3.8 lb VS/1,000 ft^3-day are given in Table 4.5. A liquid storage designed based on loading rate is 1.5 to 2 times as large as a conventional storage, but is about half the size of a traditional lagoon (based on volumes for feeder-to-finish). Therefore, a storage sized to reduce odor is less expensive to construct than a traditional lagoon. More storage structures have been built in South Carolina over the last few years due to the lower cost.

Table 4.5. Recommended design volumes for swine manure storage structures. (These values do not include the additional depth required for net rain, the 25-year, 24-hour storm, or required 1 ft free board.)

Storage Description	Minimum Volume for 180 days ft^3/AU[1]
Conventional Storage Structures [2]	
Slurry (TS = 5%, includes water for manure removal)	447
Pit-recharge or flush systems	1,224
Storage Structures Designed to Reduce Odor [3]	
Storage sized to limit loading rate to 5.0 lb VS/1,000 ft^3 - day.	1,992
Storage sized to limit loading rate to 3.8 lb VS/1,000 ft^3 - day.	2,529

[1] 1 AU = 1,000 lb live weight
[2] Sized based on manure and wasted water production from finishing swine.
[3] Additional volume is based on the volatile solids production of finishing swine.

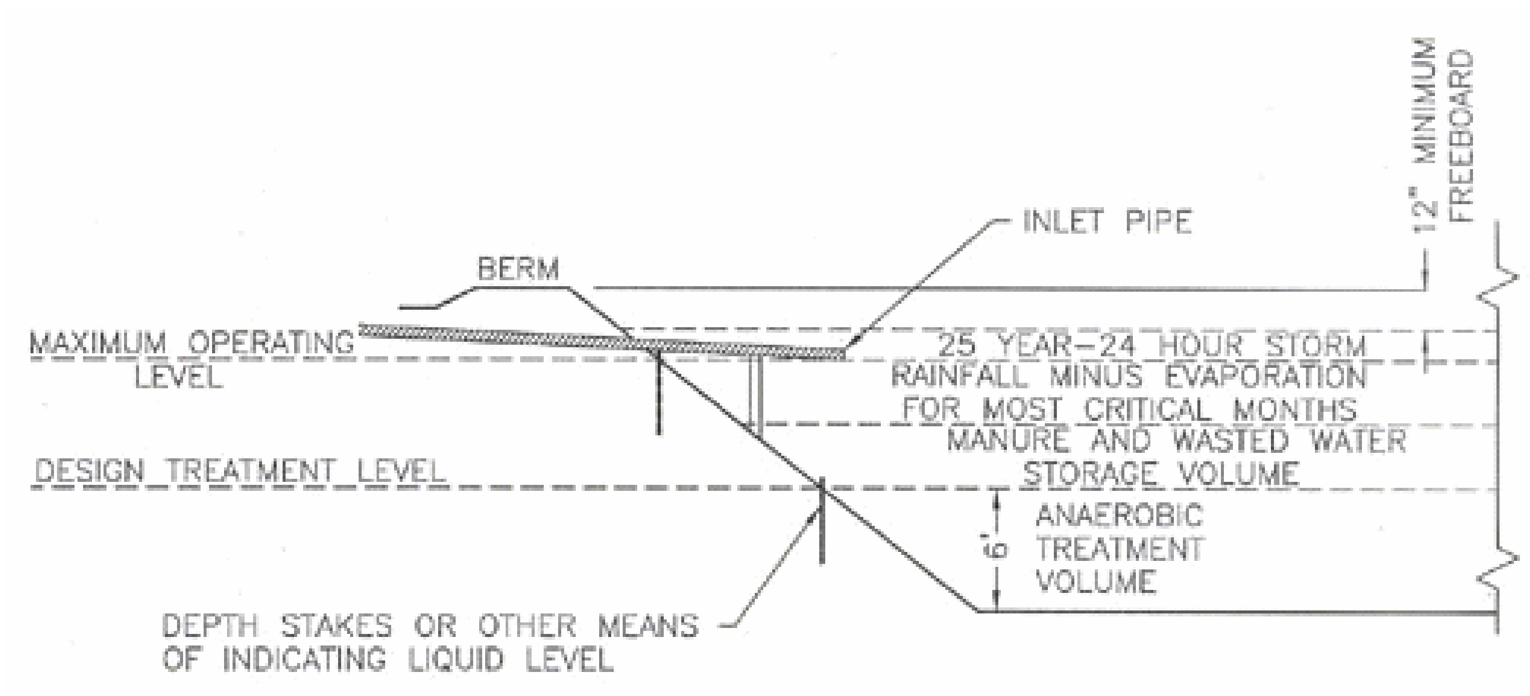

Figure 4.4. Components and operating levels for a liquid manure storage pond that includes a treatment volume for odor control.

Careful management of a storage structure is required to maintain the desired treatment volume for odor control. The management requirements for lagoons and storage structures are compared in the following section.

MANAGEMENT OF EARTHEN BASINS USED AS LAGOONS AND STORAGE PONDS

Anaerobic treatment lagoons and storage ponds are designed differently, but some of the same principles of management apply to each type of storage. Proper management includes: loading frequency, startup procedures, and removal of liquids and solids. The management requirements of lagoons and storages are compared in the following sections.

Loading

Anaerobic lagoons operate best if they are frequently loaded with small volumes of fresh manure. Flush systems are designed to remove manure from all of the buildings 4 to 12 times per day, and provide the ideal method of loading a lagoon. On swine farms that use pit-recharge buildings, it is customary to empty one building every day or every other day. This practice also promotes frequent feeding of the anaerobic bacteria and is part of good lagoon management.

Effects of Slug Loading
It is important to avoid loading large amounts of manure at one time. Such a practice is referred to as slug loading. Slug loading can temporarily increase the amount of odor generated on a farm, and can upset the environment for anaerobic bacteria. Slug loading can be caused by the following: (1) draining all of the recharge pits on a farm on one day, or (2) allowing manure to accumulate in recharge pits for an excessive amount of time.

Most pit-recharge swine buildings are designed to maintain a constant volume of manure and recycled lagoon water in the pit. As manure accumulates in the pit, the same volume of water flows out through a notch in the stand pipe that is used to plug the drain. If manure is collected in the pit for a long period of time, such as 2 to 3 weeks for 200 lb hogs, the volatile solids content of the pit will be 2 to 3 times greater than if manure was collected for only one week. High concentrations of solids in the pit can reduce the quality of the air in the building and promote slug loading. In general, recharge pits should be emptied every 5 to 7 days to prevent slug loading and to improve indoor air quality. In addition, storage time in the building for greater than 7 days may increase the population of flies (see chapter 10).

Loading of Storages
The loading frequency does not effect the operation of a slurry storage. However, if a liquid storage is sized based to limit the loading rate to 5 lb VS/1,000 ft^3-day or less, then loading frequency is the same as for a traditional anaerobic lagoon.

Maintenance of Earthen Basins

The maintenance of berms is the same for lagoons and storages. The most important factors are listed below.

- Establish a grass cover on all slopes and level surfaces of a new earthen basin as soon as construction is complete. Do not wait until loading begins. Fescue or common bermudagrass is often used as a vegetative cover.
- Maintain the vegetative cover by frequent mowing and annual fertilization. Fertilize based on soil test recommendations.
- Do not allow trees or bushes to grow on the berm. Mowing, spraying with herbicide, or chopping can be used to control woody vegetation. Do not allow the herbicide to enter the lagoon. The chemicals may kill the bacteria that treat manure.
- Install a fence around the lagoon or storage to keep animals and people out. Make sure that gates and drive ways are provided to facilitate maneuvering of liquid and solids manure handling equipment.
- Place warning signs around the perimeter of the fence.
- Inspect the entire lagoon or storage basin during the initial filling and at least monthly after startup. The key items to look for are listed below.
    1. Record the liquid level. If the level is close to the maximum operating level (see Figures 4.1, 4.3, and 4.4), then remove a portion of the manure and land apply.
    2. Inspect the surface of the lagoon or storage for undesirable vegetative growth and floating debris. Remove all floating debris and clean up all trash around the berm.
    3. Inspect the inlet pipes, and the recycling pump and piping. Look for leaks at piping joints, cracks in the pipes, and accumulation of minerals or debris that can plug the pipes.
    4. Inspect both sides of the berm. Look for evidence of settling, cracking, or holes in the berm. Do not allow rodents to make burrows in the berm. Also, look for slumps or bulges on the side slopes, erosion of the berm due to lack of vegetation or wave damage, gaps in riprap on interior slopes, and wet areas on the back slope. If any of these conditions are observed, obtain technical assistance from the individuals who designed and constructed the earthen basin. Do not dig into the dam of an earthen basin for any reason. Obtain the services of a technical expert.
    5. Check for proper operation of recycling and irrigation pumps. Check for leaks around fittings, and overall pump operation. Grinding noises and excessive vibration often indicate that repair or replacement is required. Perform all scheduled maintenance of the irrigation pump after pumping the contents down to the low operating level. Consider maintaining an inventory of spare parts, and have an extra recycling pump available.
    6. Check the gutters and all surface water diversion channels that are designed to carry rainwater away from the lagoon or storage. Make sure that adequate vegetation is growing in diversion channels. Remove debris from diversion channels and gutters.
    7. If solid manure or animals are kept outside on a feedlot, make sure that the runoff rainwater does not enter the diversion channels. Runoff rainwater from outside animal lots or piles of separated solids must be collected and stored in a lagoon or storage basin.

8. Inspect the entire manure storage system during or immediately following a period of heavy rain.

Startup Procedures and Indicators of Proper Function

The purpose of a startup procedure is to promote the growth of the anaerobic and facultative bacteria that will be used to treat the manure. The following startup procedures apply for traditional anaerobic lagoons and liquid storages that will be used as a source of recycled water for manure removal.

- Begin loading a new lagoon or liquid storage in the spring or early summer, if possible, to take advantage of the increased bacterial activity associated with warm temperatures. Bacterial activity is 3 to 4 times greater in the summer than in winter.
- Fill new lagoons and liquid storages with a minimum of 4 ft of water. Do not begin recycling water until the depth is 5 to 6 ft. This will provide the required treatment volume.
- Add manure slowly, and gradually increase the amount of manure added over the first 4 months of operation. This will allow the population of bacteria to increase as the loading increases and will help to reduce odor. The natural increase in loading rate that occurs as the buildings are populated and animals grow is typically sufficient for new buildings. Phase out the old manure system, and phase in the loading of manure if a new lagoon is added to a set of existing buildings.
- The desired bacterial population can be increased by filling 0.25% of the full lagoon volume with sludge and water from another properly functioning lagoon. This procedure is called seeding and should occur at least 2 weeks before loading begins.
- Periodically check the pH of the surface liquid of the lagoon or liquid storage. If the lagoon pH falls below 6.7, add agricultural lime (pulverized) at the rate of 1 pound per 1,000 cubic feet of liquid volume until the pH rises above 7.0. The ideal pH range is between 7.5 and 8.0. As the lagoon ages, the pH will become stable.

The indicators of proper lagoon function are color, odor, and the presence of bubbling.

- Color is a good indicator of proper lagoon function. As the microbial activity of a new lagoon stabilizes, the color will change from light green, to dark green and then to brown or pink. This color change will often take a year. Swine lagoons will often develop a pink tint as a result of purple sulfur bacteria. These bacteria are desirable because they control the hydrogen sulfide concentration which is a significant source of odor. A black color or a grainy scum layer is an indication of overloading. These lagoons may have an unpleasant odor, and sludge will build up at a high rate. Once the sludge layer occupies a large portion of the treatment volume foul odors can be a common occurrence.
- Odor should be low once the lagoon achieves a brown or slightly pink color. Unpleasant odors can be expected when the lagoon has a dark green color during the startup period. If foul odors persist during warm weather, then a problem in the design may exist. Obtain technical assistance if this occurs.
- A properly functioning lagoon with a mature culture of anaerobes will bubble. Bubbling should increase during warm weather and is an indicator of proper function.

Liquid Management for Lagoons and Storage Ponds

Accumulation of rain water, manure, waterer wastage, and building washdown water will cause the liquid level of a lagoon or manure storage to rise. The liquid level of a traditional lagoon or liquid storage that is sized to reduce odor is maintained by pumping surface water and applying it to crop, pasture, or forest land using an irrigation system. *The liquid level of a slurry storage is never controlled in this manner. All of the manure is managed as an agitated slurry*.

The liquid level is to be maintained between the design treatment level and the maximum operating level as indicated in Figures 4.1 and 4.4. The maximum operating level includes all of the defined storage volumes except the depth for the 25-year, 24-hour storm and the freeboard. *Therefore, in most regions of South Carolina the liquid level should never be allowed to come within 20 inches of the lowest edge of the top of the basin*. The minimum operating level for a treatment lagoon is a 4 ft depth that is above the sludge layer as shown in Figure 4.1. The lagoon should be pumped down to the minimum operating level in the late summer or fall of the year. This will assure that sufficient storage volume is allowed for the hurricane season and winter rainfall without compromising the required depth for the 25-year, 24-hour storm and 1 ft freeboard. Additional requirements for the management of the liquid level are given below.

- Visible markers must be established at the minimum operating level, the design treatment level, and the maximum operating level. The depth of liquid between each marker should be indicated. The minimum operating level for a liquid storage that is sized to control odor is the design treatment volume (compare Figures 4.1 and 4.4).
- Do not pump the liquid level below the minimum operating level unless sludge is being removed.
- Locate the floating intake of the pump about 18 inches below the liquid surface and as far away from the pipes that are used to load the lagoon as possible.
- Provide several “windows” of time for the application of surface water by growing warm and cool season crops. Consider combinations of corn, coastal bermuda, soybeans, wheat, oats, fescue, and commercial forest land to take full advantage of the long growing season in South Carolina. Water from a lagoon or liquid storage can be applied (in proper amounts) at planting and on a growing crop. Using split applications can increase the frequency of land application and better match the nutrient needs of some crops (see chapter 5). A good mix of crops will make the liquid level of a lagoon or liquid storage easy to manage.

Solids Management for Lagoons and Storages

Solids management is the most important, but most overlooked, factor in the maintenance of lagoon function. It is also critical for the operation of manure storages. Agitation of solids and liquid prior to removal is very important. Good agitation makes the nutrient content of the manure more uniform.

Agitation Equipment

The techniques used to agitate and remove solids are essentially the same for all earthen basins. The main difference is in how often solids removal is required. The most common types of equipment used to agitate solids in earthen basins are: the inclined shaft, propeller-type agitator (Figure 4.5), and an inclined-shaft centrifugal chopper-agitator pump (Figure 4.6). Most agitation equipment is tractor PTO driven.

Agitation pumps should have a semi-open or open impeller to allow for better solids handling. Some pumps also have a chopper near the pump intake. Chopper-agitator pumps generally have pumping rates in the range of 3,000 to 6,000 gpm (gallons per minute) and require a 90 to 140 hp tractor to operate.

Most prop-type agitators and chopper agitator pumps have an effective range of 50 to 75 feet. The agitation and pumping equipment should be moved around the perimeter of the lagoon or storage (about every 100 ft) to ensure good solids removal. Start agitation and removal near the inlet pipes since a large fraction of the solids are deposited near the inlet. The maximum solids content that can be agitated and pumped is 12%.

Agitated lagoon sludge or agitated liquid storage ponds can range from 1 to 3% solids. Swine manure stored as a slurry can range in solids content from 4 to 8%. Most irrigation pumps that are used for land application of manure can easily handle manure with a solids content less than 4%. A pump with a semi-open impeller is recommended for slurries (4 to 8% solids).

Both prop-type agitators and agitation pumps are typically lowered down an embankment or concrete ramp. During agitation, the discharge from an agitator pump must be directed away from the sidewalls and toward the center of the earthen basin to prevent damage to the clay liner. Prop-type agitators must be positioned so that the blades are below the liquid surface and in a manner that will prevent scouring of the clay liner. Lowering agitation equipment down an exposed synthetic liner will cause the liner to tear. Also, the high discharge pressures from agitation pumps can damage exposed liners. Concrete agitation and pumpout ramps and pads are recommended at each pumping location for all new lagoons and storages, but are essential for structures with a synthetic liner.

Prop-type agitators that are suspended from the 3-point hitch are also available. They are generally less expensive than the models that are mounted on wheels. However, these “boom type” agitators are shorter and do not extend as far out into a lagoon or storage pond.

Solids Management for Lagoons

Lagoons are quite different from storages since the structure is designed to treat the volatile fraction of the manure solids by anaerobic decomposition. The solids that are stored near the bottom of a lagoon by settling are called sludge.

Measurements taken from swine lagoons in South Carolina indicate that 73% of the volatile solids are destroyed if sludge is held in a lagoon for 1 year. If sludge is held in the lagoon for 5 years, approximately 80% of the volatile solids are destroyed (Barth and Kroes, 1985). Holding sludge longer than 5 years only provides a small amount of additional treatment. About 0.0486 cubic feet of sludge will accumulate in the bottom of a lagoon for every pound of total manure solids added (ASAE EP403.2, 1998). The volumes per year per animal unit are given in Table

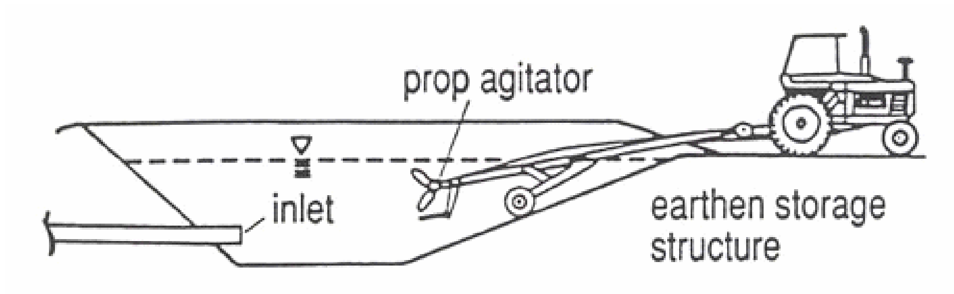

Figure 4.5. A propeller-type agitator (from the Liquid Manure Applications Design Manual, NRAES-89).

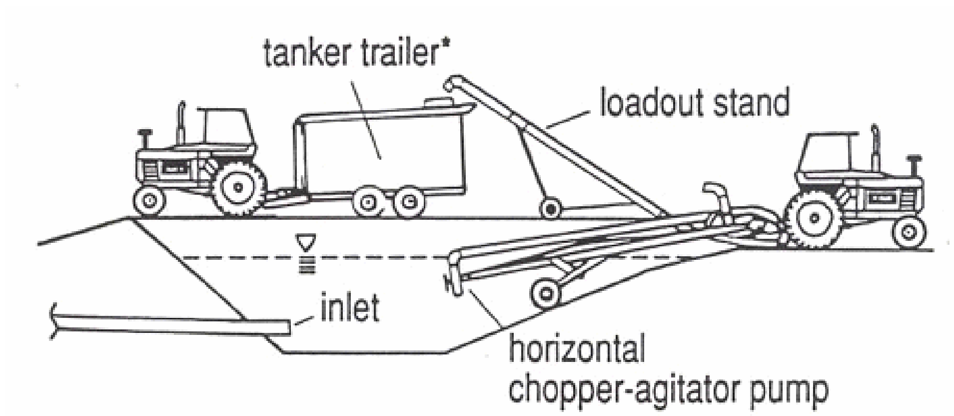

Figure 4.6. A centrifugal chopper-agitator pump (from the Liquid Manure Applications Design Manual, NRAES-89).

4.2. Most lagoons in South Carolina are sized to provide 10 years of sludge storage. However, it is recommended that a portion of the sludge be removed every 3 to 5 years. It is easier, and often less expensive, to remove sludge more frequently than to wait to remove 10 to 20 years of sludge at one time.

Sludge build up can create odor problems. However, not all of the sludge should be removed. The sludge layer contains the culture of the bacteria that break down the organic matter in fresh manure. Lagoons that are designed with significant sludge storage volumes (as indicated in Tables 4.2 and 4.3) only need removal of 50% of the sludge volume every 5 years. If sludge is not removed from the lagoon for 10 years or more, approximately 75% of the total sludge volume should be removed.

The techniques used to remove sludge from a lagoon depends on how and where the nutrients will be used. The removal of sludge will increase the amount of land that is needed for land application every 5 years. In most cases, the cropland that normally receives the surface water is not sufficient for the application of sludge at agronomic rates. If sludge must be hauled to fields that can not be irrigated, sludge removal procedures should be modified to increase the concentration of solids. The techniques that are used to remove and land apply sludge from lagoons are summarized below.

- Sludge can be mixed with lagoon water and applied to cropland using a traveling gun irrigation system with a large-bore nozzle or a towed-hose direct injection system if sufficient land is available close to the swine facilities. A propeller-type agitator is often used in this process, but a high-volume chopper-agitator pump is also an excellent choice. It is important to provide several hours of agitation before the mixture of sludge and lagoon liquid is land applied. Agitate 2 to 4 hours before land application. It is also important to provide continuous agitation while the mixture is being land applied. The irrigation pump is used to remove the material from the lagoon and for land application. The agitation and pumping equipment need to be moved around the perimeter of the lagoon as the sludge is removed. Be sure to agitate and pump near the pipe(s) that are used to load the lagoon since sludge tends to buildup near the inlet pipe(s).

- In many cases, the cropland that can be irrigated is not sufficient to properly utilize the additional nutrients in sludge. Cropland or commercial forest land that is a few miles away from the swine farm will be needed. The amount of water in the sludge must be reduced to decrease the transportation and application costs. One way of increasing the solids content of sludge is to pump off most of the lagoon water above the sludge layer and irrigate the water onto nearby cropland. The remaining water and sludge can be agitated and pumped into tank-type spreaders or transfer trucks. A high-volume (5,000 gpm) centrifugal chopper-agitator pump or propeller-type agitator will need to be operated for 4 to 12 hours prior to removal of the sludge. Agitate and pump at several locations around the perimeter of the lagoon to assure good sludge removal.

- Renovation of an older lagoon may require the use of a dragline or sludge barge. This is the most expensive alternative and is accomplished by hiring a contractor.

Solids Management for Storages

Manure storages can be used to store swine manure as a liquid or a slurry. Slurry storages have a high solids content (4 to 8% total solids) and are always well agitated before being emptied to remove solids and liquids. Therefore, solids are removed every time manure is removed from a slurry storage. Liquid manure storages that are not used as a source of recycle water for flushing or pit-recharge should also be agitated prior to pumping to remove solids.

Liquid storages that are sized to limit the volatile solids loading rate (as shown in Table 4.5) are essentially operated as lagoons with intensive solids management. The surface water of the lagoon can be pumped periodically to prevent over filling in the same manner as a lagoon. However, the majority of the solids and liquids should be agitated and land applied at least twice each year if 180 days of manure storage is provided. If it is desired to agitate and remove solids once each year, provide 365 days of manure and wasted water storage volume.

The techniques used to remove solids from manure storages depends on the methods used for land application. Manure from a slurry storage is generally land applied using tank-type spreaders or towed-hose direct injection. Agitated manure from a liquid manure storage is often land applied using a large-bore nozzle with a traveling gun irrigation system or towed-hose direct injection. The concepts for these techniques are summarized below.

- Six months of slurry in an earthen storage basin will require 4 to 12 hours of agitation prior to pumping using a propeller-type agitator or a chopper-agitator pump. If an agitation pump is used, direct the discharge stream below the liquid surface and toward the center of the earthen basin. Agitated manure is pumped into a liquid manure spreader or transfer trailer for land application. Periodic agitation is often required as the storage is emptied if a single pump is used. A propeller-type agitator is operated continuously, while the manure is removed with a centrifugal pump that is equipped with a semi-open or open impeller. The inlet to the suction line of the pump is positioned near the agitator. Repositioning of the agitation and pumping equipment along the perimeter is needed for large storages.

- Solids in a liquid manure storage can be agitated using a propeller-type agitator or chopper-agitator pump. The agitation time needed will depend on the amount of solids that have accumulated. Plan on 1 to 3 hours of agitation time per pumping location. After agitation is complete, continue mixing with the agitation equipment and remove the mixture of solids and liquids using the irrigation pump and apply to cropland using the irrigation system or towed-hose direct injection. Agitate and pump manure from the liquid manure storages at several locations around the perimeter. Be sure to agitate and remove solids near the locations where manure enters the storage. The main difference between a liquid storage and a lagoon is that most of the solids from a storage should be removed every 180 days. Therefore, agitation and pumping will continue until most of the contents of the storage is removed and land applied. Generally, it is difficult to remove the last foot of material.

- If the liquid storage is used as a source of recycle water to clean the buildings, plan on adding 3 to 4 feet of fresh water to the storage or use fresh water to fill flush tanks or recharge pits until a treatment volume has been reestablished. In general, the frequent removal of solids from liquid storages will require more fresh water to be used per year than for an anaerobic lagoon.

- In some cases, sufficient cropland is not available close to the swine facilities to utilize all of the plant nutrients in the liquid and solids removed from a liquid storage. Therefore, irrigation or towed-hose direct injection may not be feasible for application of the solids. In this case, a large portion of the liquids can be applied without agitation to the nearby cropland. The remaining liquids and solids are agitated and loaded into tank-type spreaders as previously described for slurry manure. Removal of the majority of the liquid layer will reduce the number of loads that need to be transported to remote fields.

Causes of Failure in Earthen Basins

Earthen basins can fail from improper design, improper construction, or improper operation. All failures result in the discharge of wastewater from the structure and can pollute the environment. Failure can occur by leakage through the berm or bottom of the basin, overflow of the structure, or breach of the berm. Proper design and construction of the liner and berm is the responsibility of the individuals that design and construct earthen basins. However, prevention of overflow and maintenance of the integrity of the storage structure is the responsibility of the swine producer. Items that can cause a failure of an earthen basin are listed below.

- Failure to keep the liquid level below the maximum operating level as shown in Figures 4.1, 4.3, and 4.4. Overflow of the structure not only is against the law, but it can also cause gullies to be formed in the back slope of the dam. Gullies will weaken the berm and can lead to a breach in the dam.
- Failure to protect the basin liner from damage by agitation and pumping equipment, and scouring from the inlet pipe. The inlet pipe should be installed out far enough so that fresh manure always falls onto the liquid surface and not the side slope of the berm (Figure 1).
- Failure to inspect and maintain the earthen basin to discover small problems before they become big problems.
- Modification of the basin by producers without using proper soils and placement techniques. A new pipe must be installed based on proper design and construction techniques. Obtain the services of a qualified engineer and construction company.

Solid-Liquid Separation

Solid-liquid separation is more common on dairy farms than swine farms. However, the use of solid-liquid separation in swine manure handling and treatment systems is likely to increase in the future. Solid-liquid separation can assist in the management of an anaerobic lagoon in the following manner: (1) reduce the volatile solids loading rate, (2) reduce the required treatment volume for lagoons, and (3) reduce or eliminate sludge build up. Reduction in the loading rate and prevention of sludge build up can help reduce the frequency of odor on a swine farm. Solid-liquid separation can also be used to reduce the VS loading on a storage structure. Solid-liquid separation can be achieved using a mechanical separator or gravity settling basin. Since manure is separated into a solid and liquid fraction, both liquid and solid land application equipment is required.

Most mechanical separators work by screening out particles that are larger than the screen opening. Examples of mechanical separators include the screw press, rotating screen, stationary screen, and vibrating screen. Very little data has been published on the effectiveness of treating swine manure with mechanical separation (Zhang and Westerman, 1997). The screw press can remove 15% of the total solids and 20% of the volatile solids from liquid swine manure if it is pre-thickened by gravity (Chastain et al., 1998). The solids removed by a screw press are 24 to 28 % total solids, will pile easily and have low odor. The rotating screen separator can remove 18% of the total and volatile solids. However, the solids have the consistency of a slurry with a solids content of 6 to 8%. Therefore, solids separated using a rotating drum separator are often collected in a tank. Use of a screw press or rotating screen will provide about an 18% reduction in VS loading rate and about a 30% reduction in sludge accumulation in a lagoon. A centrifuge can be used to remove 70% of the solids from swine manure and will eliminate sludge build up, but it is very expensive (Chastain et al., 1998).

Gravity settling basins have been used for years for flush dairy buildings and to remove solids from feedlot runoff. However, gravity settling basins and settling tanks are not common on swine farms. Gravity settling basins can remove 50% of the total and volatile solids (Zhang and Westerman, 1997; Chastain and Vanotti, 1998). Addition of a flocculant (polymer or alum) can increase the solids removal of a settling basin to 70% (Chastain and Vanotti, 1998). Gravity settling basins can be used to cut the loading rate of a lagoon by 50 to 70% and eliminate sludge build up problems in lagoons. Settling basins should be designed to provide 30 to 60 minutes of settling time. The solids removed from a settling basin can vary in solids content from 3 to 10%. Therefore, gravity separated solids are generally handled as a slurry. Basin designs that allow the solids to drain and to dry can yield solids in the range of 10 to 18%.

MANURE STORAGE TANKS

Very few swine farms in South Carolina use tanks to store manure (see Figures 4.7 and 4.8). However, they will most likely become more common as new treatment systems are developed and put into use on farms. Manure tanks can be constructed above or below ground. Storage tanks can be used to store slurry or liquid manure. Liquid manure from tanks is typically not used as a source of flush or pit-recharge water unless a large fraction of the solids are removed. Additional details on storage alternatives is provided in the following publications (see reference list):

Liquid Manure Application Systems Design Manual (NRAES-89), and
Livestock Waste Facilities Handbook (MWPS-18).

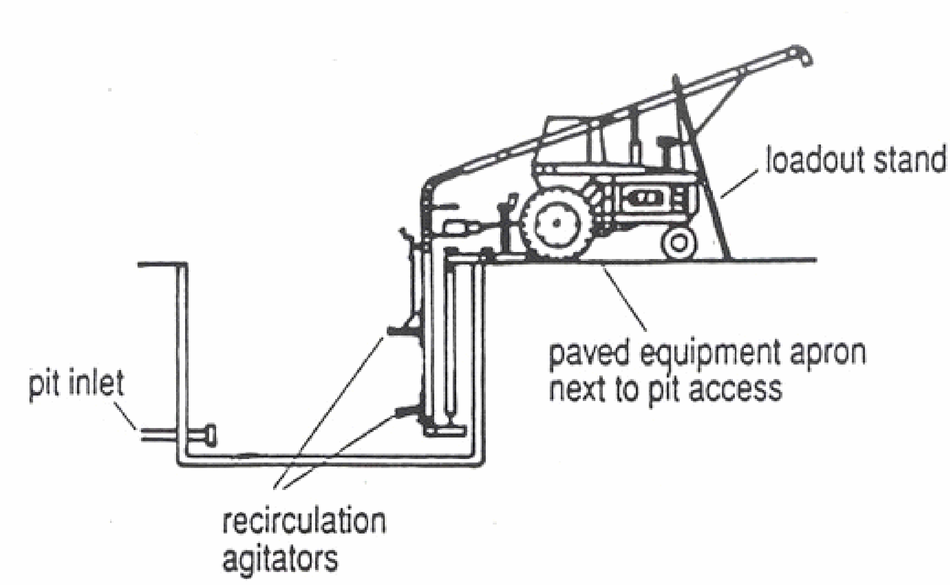

Figure 4.7. A below-ground storage tank (from Liquid Manure Application Systems Design Manual, NRAES-89).

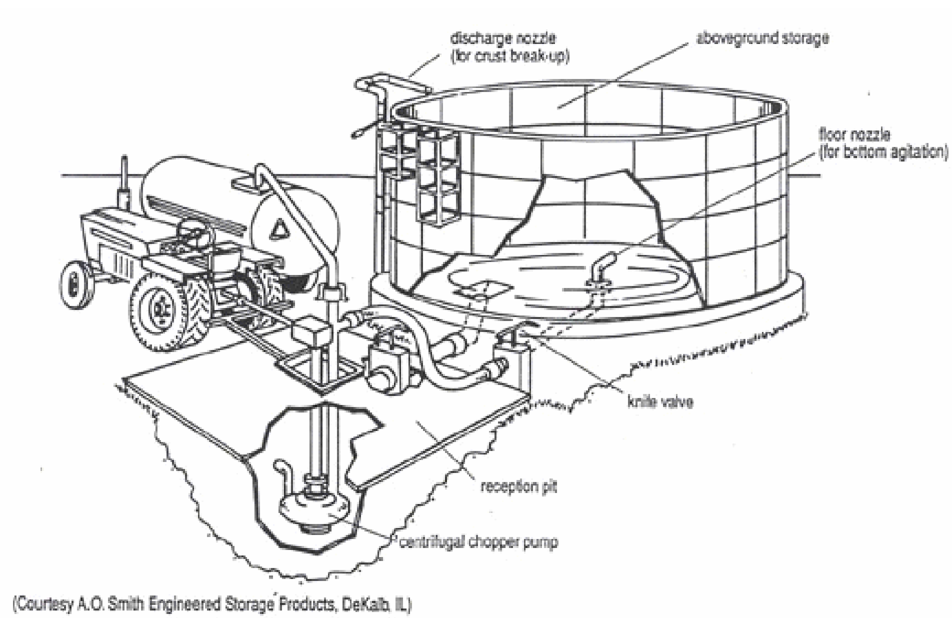

Figure 4.8. An above-ground storage tank and agitation system (from Liquid Manure Application Systems Design Manual, NRAES-89).

Below-Ground Storage Tanks

Below-ground tanks can be built below the slotted floor of a swine building or to the side of the building. Runoff from outside lots should not be stored in a covered below-ground concrete tank due to the relatively high cost. The same is true for a concrete tank beneath slotted floors. Many below-ground storage tanks are used as a reception pit to collect manure from multiple buildings. The manure is agitated and pumped into an above-ground storage structure or an earthen basin.

Storage depth may be limited by soil depth over bedrock, water table elevation, and possibly, effective lift of a pump. Tanks must be designed to withstand all anticipated earth, hydrostatic, and live loads.

Manure is typically transferred to a below-ground storage tank using gravity flow through a 6 to 8 inch pipe. Provide a continuous 1% slope for 6 inch pipes, and a 1/2% slope for 8 inch pipes. Excessive pipe slopes will cause solids to settle out and could cause clogging. The maximum bend in the pipe should be no more than 45 °.

Above-Ground Storage Tanks

Above-ground manure tanks are large-diameter tanks resembling silos. They are more expensive than earthen basins or below-ground tanks. However, they provide an alternative where basins are limited by space, high ground water, close proximity to surface water or the presence of shallow creviced bedrock. Because of the higher cost, runoff should be minimized and flush systems should not be considered if an above-ground storage tank is needed.

Above-ground liquid storages are from 10 - 25 ft high and 30 -160 ft in diameter. They are made of concrete stave, reinforced concrete, and steel. Leaks from joints, seams, or bolt holes can be unsightly, but most small leaks quickly seal with manure. The joint between the foundation and the sidewall can be a problem with improper construction. The reliability of the dealer and construction crew are as important as the tank material in assuring an environmentally safe structure.

Manure is typically loaded into an above-ground storage tank by collecting manure from all of the swine buildings in a common below-ground tank that is used as a reception pit. The reception pit is sized to contain the manure volume from the largest building on the farm. The manure is agitated with a centrifugal chopper pump that has a semi-open impeller and is driven by a vertical shaft and a 5 to 10 hp electric motor. A pair of check valves are required in the pipe that is used to load the above-ground storage to prevent manure from flowing back into the reception pit.

Agitation and Unloading

Agitation of the manure in a tank prior to unloading is very important. Agitation makes the nutrient content of the manure more uniform and makes solids removal easier to accomplish. Agitate slurry and liquid manure tanks by diverting part or all of the pumped liquid through an agitator nozzle. The liquid stream breaks up floating mats of solids, stirs settled solids, and makes a more uniform mixture. Agitate and pump as much manure as possible, then agitate the remaining solids and dilute with additional water if necessary. Diluting wastes to 90% water (or 10% solids) may be necessary.

Above and below-ground storage and manure tanks are usually agitated with a submerged centrifugal chopper pump. For silo-type storages, pumps can be mounted on or next to the storage foundation. Large diameter tanks may have a center agitation nozzle. Locate agitation sites no more than 40 ft apart in below-ground tanks without partitions.

The agitated manure can be land applied using tank-type spreaders, towed-hose direct injection, or a large-bore traveling gun irrigation system. A center-pivot irrigation system can be used to apply liquid manure with a solids content less than 1%. The nozzle diameter of the sprinklers needs to be about one quarter of an inch (0.25 in).

Safety

Protect tank openings with grills and/or covers and enclose open manure tanks with a fence at least 5 ft high to prevent humans, livestock, or equipment from accidentally entering. Provide removable grills over openings used for agitation and pumping. Install railings around all pump docks and access points for protection during agitation and clean-out. Provide wheel chocks and tie downs for pumps and tractors.

Toxic gases that are released during the agitation of manure in storage tanks can be deadly to both humans and animals. People should not be near an enclosed pit during the agitation of a manure storage unit. *Do not allow anyone to enter a manure tank without a self-contained breathing apparatus, and place warning signs around tank.*

ODOR CONTROL FOR MANURE STORAGES

Slurry manure storages are not designed to provide manure treatment. However, slurry manure in a storage will decompose anaerobically and has the potential to release strong odors.

Covers

Covering a manure storage tank or earthen basin can reduce odors from storages to negligible levels. The amount of ammonia released from covered and uncovered manure storages was measured by researchers in Europe (see Table below). Ammonia is only one of 150 compounds that can cause odor, but it is easy to measure. A reduction in ammonia release can be used to indicate a reduction in odor release from a manure storage.

Dairy cow manure will form a crust if minimal water is added to a storage. Such a crust serves as a biological cover and has been shown to reduce odor emissions from dairy storages by 75%. Hog manure will almost never crust. Many different types of materials have been used to cover swine manure storages. Some of the most promising cover materials are: barley straw, vegetable oil, vegetable and barley straw mixtures, polystyrene floatation panels with barley straw, peat moss, concrete, floating tarps, air supported hypalon covers, floating foam pellets, floating permeable mats, and structurally supported panels.

Table 4.6. Reduction in Odor Emissions Using Covers

Type of Cover	Reduction in Ammonia Emissions
Sealed lid	95%
Floating straw	50 - 80%
Floating pellets	70%
Natural crust (dairy manure typically)	75%
Uncovered	0%

The most cost effective cover has yet to be determined, but the straw, air-supported sealed structures, and floating panels appear to be fairly inexpensive. Smaller storage structures, or structures with a smaller exposed surface area, are obviously less expensive to cover than an earthen basin with a surface area of an acre or more. A Canadian study reported that the cost of barley straw covers was $41/1,000 square feet/year, and would last for one month before the straw began to sink. Polystyrene panels were used as floating supports to increase the useful life of the straw cover to two months. The polystyrene floatation increased the annual costs to $76/1,000 square feet/year. Waste storages do not freeze during a typical South Carolina winter. Therefore, the cost of straw covers in South Carolina would be expected to be double or triple the cost determined by Canadian researchers. An air-supported, hypalon tarp was used to cover the waste storage for a 200 sow farrow-to-finish operation (also in Canada). The cost of the covering system was $28 per sow and was very effective at reducing odor.

Anaerobic Digestion

A covered earthen basin or tank can be designed and operated as an anaerobic digester. An anaerobic digester uses the same anaerobic bacteria to treat manure as a lagoon but at a higher rate. Loading rates for anaerobic digesters are typically in the range of 10 to 25 lb volatile solids per 1,000 ft^3 per day. Therefore, the treatment volume for an anaerobic digester is one fifth to half the size of a lagoon. A recent study by the authors indicated that a covered earthen basin or covered lagoon digester is the most practical type for use in South Carolina.

A covered lagoon digester can be described as an earthen basin that is sized at a much higher loading rate (10 to 25 lb VS/1000 ft^3 -day). The higher loading rate results in a much smaller treatment volume and has a much greater potential for the generation of foul odors. A cover and biogas collection system solves the odor problem and yields another product - biogas. Biogas contains 550 to 595 Btu of energy per cubic ft. The energy is from methane that is a byproduct of anaerobic decomposition. Biogas is 60 to 70% methane. The remainder is mostly carbon dioxide (28 to 29%) and small but significant amounts of hydrogen sulfide and other odorous compounds. Biogas must be burned to eliminate its odor. If desired, the biogas can be used as a fluctuating, but significant source of energy.

The ideal temperature for anaerobic digestion is 95°. The temperature in an unheated covered lagoon digester will vary with the average outside temperature. During the winter months anaerobic digestion is slow. However, the warm climate in South Carolina results in only about 45 days per year when biogas production is greatly reduced.

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. Well stabilized solids that are removed from a digester also have a lower odor than lagoon solids or swine slurries. As a result, odor is less of a concern during land application.

Aeration

Low-rate aeration can be accomplished with a 2-7.5 hp motor per storage since the amount of air needed to control the population of anaerobes is much lower than the amount of air needed to treat the wastewater aerobically. Use of low-rate aeration will favor the growth of facultative microbes (microbes that can live with or without air) and can provide some reduction in strength as well as control odor (the anaerobes produce the foul smelling compounds).

QUANTITY OF PLANT NUTRIENTS FOR LAND APPLICATION

The quantity of plant nutrients that need to be accounted for in a land application plan will vary with the type of manure storage or treatment system used. South Carolina regulations require swine producers to have the forms of manure (liquid versus agitated solids and liquid) that are land applied analyzed for plant nutrient content each year (see chapter 3). Records must also be kept on the quantity of manure applied to each field (see chapter 7). The total amount of plant nutrients that are used for fertilization can be calculated from the manure analysis records and the volume records. The total amount of land needed can be determined based on fertilization recommendations and soil test data as explained in chapter 5.

The amount of plant nutrients produced by a swine farm in a year is calculated from the manure nutrient analysis and volume data. The calculations are explained in the following example.

Example 4.1
A swine producer has 3 feeder-to-finish buildings that hold 880 hogs each. The average number of hogs on the farm at any time is 2,640 (880 hogs x 3 buildings). A pit-recharge manure handling system is used to remove manure from the buildings, and the manure is stored and treated in an anaerobic lagoon. The swine producer sampled the surface water of the lagoon and had it analyzed by the Ag. Services Laboratory at Clemson University. The results from the laboratory are shown below.

Plant nutrients in swine lagoon surface water (from Table 3.3, chapter 3)

Nutrient Content	Incorporated PAN	Surface PAN	P_2O_5	K_2O
lb/1,000 gal	3.6	4.2	2.8	6.1

The total volume of lagoon surface water that must be pumped per year is the sum of the following annual volumes: manure, wasted water, and net rain fall (annual rainfall - evaporation). Records from the farm indicate that 1,823,342 gallons are irrigated onto crop and pasture land each year. The swine producer used the following steps to calculate the total pounds of plant nutrients to be used for fertilization each year.

Step 1. Select the correct estimate of plant available nitrogen.
Since irrigation will be used to land apply the lagoon water, the incorporated PAN estimate of 3.6 lb PAN/1,000 gal should be used.
Step 2. Divide the annual manure volume in gallons by 1,000 to determine the volume factor.
1,823,342 gal ÷ 1,000 = 1,823.34 = volume factor
Step 3. Determine the amount (in pounds) of a particular plant nutrient to apply by multiplying the nutrient content (lb /1,000 gal) by the volume factor.

lb of nutrient per 1,000 gal x Volume Factor = Total Amount of Nutrient to Apply (lb)

The amount of each plant nutrient that is to be land applied per year is calculated as follows.

3.6 lb PAN /1,000 gal x 1,823.34 = 6,564 lb PAN/year
2.8 lb P_2O_5 /1,000 gal x 1,823.34 = 5,105 lb P_2O_5/year
6.1 lb K_2O /1,000 gal x 1,823.34 = 11,122 lb K_2O/year

The same type of calculations can be performed for any type of manure storage system. The requirements are measurements of the volume and nutrient content of the manure.

Swine producers and waste system designers often need an estimate of the nutrients that must be land applied before a farm is constructed or expanded. In many cases, sludge has never been removed from a lagoon and data are needed to plan for the application of lagoon sludge. Estimates of the nutrients produced per production unit are given in Tables 4.7 through 4.10 for lagoon water, lagoon sludge, slurry manure tanks, and liquid manure storage ponds. These tables are only for planning purposes. The nutrient content of all forms of swine manure must be determined by laboratory analysis for each farm. The volume estimates must be verified by application records.

The use of the tables will be demonstrated for lagoon sludge using our feeder-to-finish example.

Example 4.2
A swine producer has 3 feeder-to-finish buildings that hold 880 hogs per building. The average number of hogs on the farm at any time is 2,640. The producer needs to estimate the additional plant nutrients in lagoon sludge that must be land applied in five years. It is assumed that the sludge will be incorporated on the day of application.

The producer estimated the quantity of plant nutrients using Table 4.8 as shown below.

8.4 lb PAN/hog	x	2,640 hogs	=	22,176 lb PAN
27.9 lb P_2O_5/hog	x	2,640 hogs	=	73,656 lb P_2O_5
3.7 lb K_2O/hog	x	2,640 hogs	=	9,768 lb K_2O

Example 4.3
How many pounds of PAN would need to be utilized if direct injection is used as the application method for the situation in Example 4.2?

Step 1. An estimate of PAN for direct injection is not given in Table 4.8. Therefore, equation 3.4 (page 3-8) must be used with Table 3.4 to calculate the PAN estimate using the tabulated values for ammonium-N and organic-N.

Step 2. The ammonium availability factor (from Table 3.4 and equation 3.3) for direct injection is 1.0. Therefore the PAN per hog for direct injection is calculated as follows:

3.6 lb NH_4^+-N/hog + 0.6 x 9.2 lb organic-N/hog = 9.1 lb PAN/hog

Step 3. Calculate the amount of plant available nitrogen from sludge that must be utilized.

9.1 lb PAN/hog x 2,640 hogs = 24,024 lb PAN using direct injection.

Therefore, 8% more nitrogen is available to crops if direct injection is used for this type of material. If the ammonium-N had made up a larger portion of the nitrogen the difference would have been greater.

Table 4.7. Quantities of plant nutrients in swine lagoon water (supernatant) to be land applied each year per production unit. A production unit (PU) is a sow, pig, or hog.

Farm Type	Volume, [1] gal/PU/yr	NH_4^+-N	Organic-N	Incorp. [2] PAN	Surface [3] PAN	P_2O_5	K_2O
		Pounds Per Production Unit Per Year [4]					
Farrow-to-Wean	1,532/sow	5.2/sow	2.1/sow	5.4/sow	NA	4.3/sow	9.4/sow
Nursery	153.5/pig	0.52/pig	0.22/pig	0.55/pig	NA	0.43/pig	0.94/pig
Farrow-to-Feeder	1,987/sow	6.7/sow	2.8/sow	7.0/sow	NA	5.5/sow	12.1/sow
Feeder -to-Finish	691/hog	2.3/hog	0.97/hog	2.4/hog	NA	1.9/hog	4.2/hog
Farrow-to-Finish	6,603/sow	22.4/sow	9.2/sow	23.4/sow	NA	18.4/sow	40.2/sow

[1] Volume includes annual manure production, wasted water (20% of manure volume), and annual net rainfall on surface.
[2] Incorporated available nitrogen estimate.
[3] Surface spread available nitrogen estimate.
[4] See Table 3.3 in chapter 3 for concentrations used to develop this table.

Table 4.8. Plant nutrients in swine lagoon sludge to be land applied every five years. A production unit (PU) is a sow, pig, or hog.

Farm Type	Volume, [1] gal/PU	NH_4^+-N	Organic-N	Incorp. [2] PAN	Surface [3] PAN	P_2O_5	K_2O
		Pounds Per Production Unit Per Five Years [4]					
Farrow-to-Wean	1,011/sow	6.1/sow	15.7/sow	14.3/sow	12.5/sow	47.8/sow	6.4/sow
Nursery	131.3/pig	0.80/pig	2.0/pig	1.8/pig	1.6/pig	6.2/pig	0.83/pig
Farrow-to-Feeder	1,037/sow	8.5/sow	21.6/sow	19.8/sow	17.2/sow	65.9/sow	8.8/sow
Feeder -to-Finish	590/hog	3.6/hog	9.2/hog	8.4/hog	7.3/hog	27.9/hog	3.7/hog
Farrow-to-Finish	5,247/sow	32.0/sow	81.3/sow	74.4/sow	64.8/sow	248/sow	33.0/sow

[1] Volume includes annual manure production, wasted water (20% of manure volume), and annual net rainfall on surface.
[2] Incorporated available nitrogen estimate.
[3] Surface spread available nitrogen estimate.
[4] See Table 3.3 in chapter 3 for concentrations used to develop this table.

Table 4.9. Quantity of plant nutrients from a tank used to store swine slurry. A production unit (PU) is a sow, pig, or hog.

Farm Type	Volume, [1] gal/PU/yr	NH_4^+-N	Organic-N	Incorp. [2] PAN	Surface [3] PAN	P_2O_5	K_2O
		Pounds Per Production Unit Per Year [4]					
Farrow-to-Wean	2,111/sow	32.5/sow	29.4/sow	43.6/sow	33.9/sow	72.6/sow	30.0/sow
Nursery	203/pig	3.1/pig	2.8/pig	4.2/pig	3.2/pig	7.0/pig	2.9/pig
Farrow-to-Feeder	2,699/sow	41.6/sow	37.5/sow	55.8/sow	43.3/sow	92.9/sow	38.3/sow
Feeder -to-Finish	916/hog	14.1/hog	12.7/hog	18.9/hog	14.7/hog	31.5/hog	13.0/hog
Farrow-to-Finish	8,831/sow	136/sow	123/sow	183/sow	142/sow	304/sow	125/sow

[1] Volumes calculated based on 5% TS from the storage and 9.2% TS for fresh manure (see chapter 3).
[2] Incorporated available nitrogen estimate.
[3] Surface spread available nitrogen estimate.
[4] Concentrations used in calculations (TS = 5%) based on a data base developed by the author and are given below.

	NH_4^+-N	Organic-N	P_2O_5	K_2O
lb / 1,000 gal	15.4	13.9	34.4	14.2

Table 4.10. Quantity of plant nutrients from a liquid swine manure storage pond. These estimates include the nutrients from the solids and liquids. A production unit (PU) is a sow, pig, or hog.

Farm Type	Volume, [1] gal/PU/yr	NH_4^+-N	Organic-N	Incorp. [2] PAN	Surface [3] PAN	P_2O_5	K_2O
		Pounds Per Production Unit Per Year [4]					
Farrow-to-Wean	8,039/sow	31.3/sow	33.0/sow	44.8/sow	35.5/sow	90.8/sow	49.0/sow
Nursery	557/pig	2.2/pig	2.3/pig	3.1/pig	2.5/pig	6.3/pig	3.4/pig
Farrow-to-Feeder	9,691/sow	37.8/sow	39.7/sow	54.1/sow	42.7/sow	110/sow	59.1/sow
Feeder -to-Finish	2,506/hog	9.8/hog	10.3/hog	14.0/hog	11.1/hog	28.3/hog	15.3/hog
Farrow-to-Finish	26,307 /sow	103/sow	108/sow	147/sow	116/sow	297/sow	160/sow

[1] Volume includes annual manure production, wasted water (20% of manure volume), and annual net rainfall on surface.
[2] Incorporated available nitrogen estimate.
[3] Surface spread available nitrogen estimate.
[4] See Table 3.3 in chapter 3 for concentrations used to develop this table.

SUMMARY

Anaerobic lagoons and storage ponds can look the same, but the management of solids and liquids are very different. Swine producers must understand how the structure was designed to understand how to effectively control odor and utilize plant nutrients in the solids and liquids. The methods used to treat and store swine manure can have a significant effect on the amount of N, P, and K that must be utilized properly in a nutrient management plan.

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