CHAPTER 4

Management of Lagoons and Storage Structures For Dairy Manure

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INTRODUCTION

Most dairy buildings in South Carolina are designed to collect and transfer manure to an anaerobic lagoon or storage pond as a liquid or slurry. The two most popular collection and transfer systems are tractor scrape and flush. The floors of many milking centers are cleaned by scraping, with a high-pressure hose, or by flushing.

The objectives of this chapter are to: (1) describe the concepts used to size treatment lagoons and manure storages, and (2) describe the management requirements for 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 dairy manure (83%). 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.

TREATMENT LAGOONS AND STORAGE STRUCTURES

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

Most lagoons and 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 dairy manure are given in the Standards for the Permitting of Agricultural Animal Facilities (R.61-43, SCDHEC).

Sizing and Management of 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 to 2 ft (ASAE EP403.2, 1998).

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

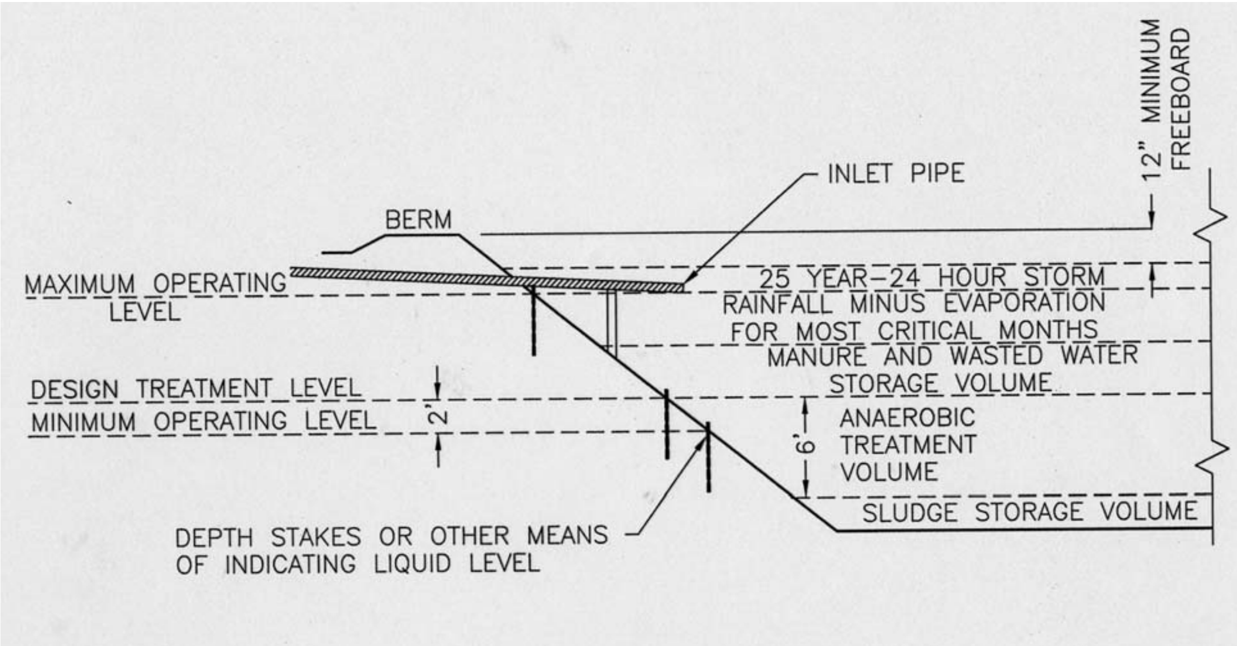

Figure 4.1. Schematic of volumes and operating levels for an anaerobic treatment lagoon.

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.

Effect of Loading Rate on Odor The loading rate has a large impact on the amount of odor that is generated from a lagoon. At very high loading rates, such as 30 lb VS/1,000 ft^3-day, a significant odor will be produced near a lagoon 80% of the time. If the loading rate is only 1.9 lb

VS/1,000 ft^3-day, the frequency of odor will be insignificant. Therefore, one way to control odor is to use a very small loading rate. However, a lagoon sized based on a small loading rate 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.

The variation in odor frequency with loading rate is the reason 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 treatment volume 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. Deeper structures may be designed depending on site conditions.

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 flushing. The loading rate of a lagoon greatly affects the quality of the water that is 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). Inadequately treated lagoon liquid, associated with high loading rates, can increase ammonia levels in the 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.

Total Lagoon Volume

The total design volumes for dairy lagoons are given in Table 4.1. These volumes are the sum of the treatment volume, 180 days of storage for manure and milking center waste, and 10 years of sludge storage.

Table 4.1. Volumes for sizing dairy treatment lagoons.
Loading rate = 5.0 lb VS/1000 ft^3-day
These values do not include the additional depth required for net rain, the 25-year, 24-hour storm, and required free board.

	Tractor Scrape & Manual Parlor Wash down		Total Flush		Milking Center Only Manual Wash down		Milking Center Only Flush	
Number of Milkings per day	2X	3X	2X	3X	2X	3X	2X	3X
Treatment Volume (ft^3/AU)	2380	2380	2380	2380	180	268	180	268
Waste Volume, 180 days (ft^3/AU)	529	621	864	1123	184	275	518	778
Sludge Storage, 10 years (ft^3/AU)	3060	3060	3060	3060	230	344	230	344
TOTAL VOLUME (ft^3/AU)	5969	6061	6304	6563	593	888	928	1390

Design Volumes for Lagoons without Sludge Storage

A traditional treatment lagoon (ASAE EP403.2, 1998) includes a volume for sludge storage. However, typical sludge volumes of 10 years require about the same liquid volume as the anaerobic treatment volume and increase the cost of construction significantly. A lagoon can be designed to exclude long-term sludge storage. However, the majority of the sludge must be agitated and removed each year. Careful management is required to maintain the desired treatment volume for odor control. The management levels for this hybrid structure are shown in Figure 4.2.

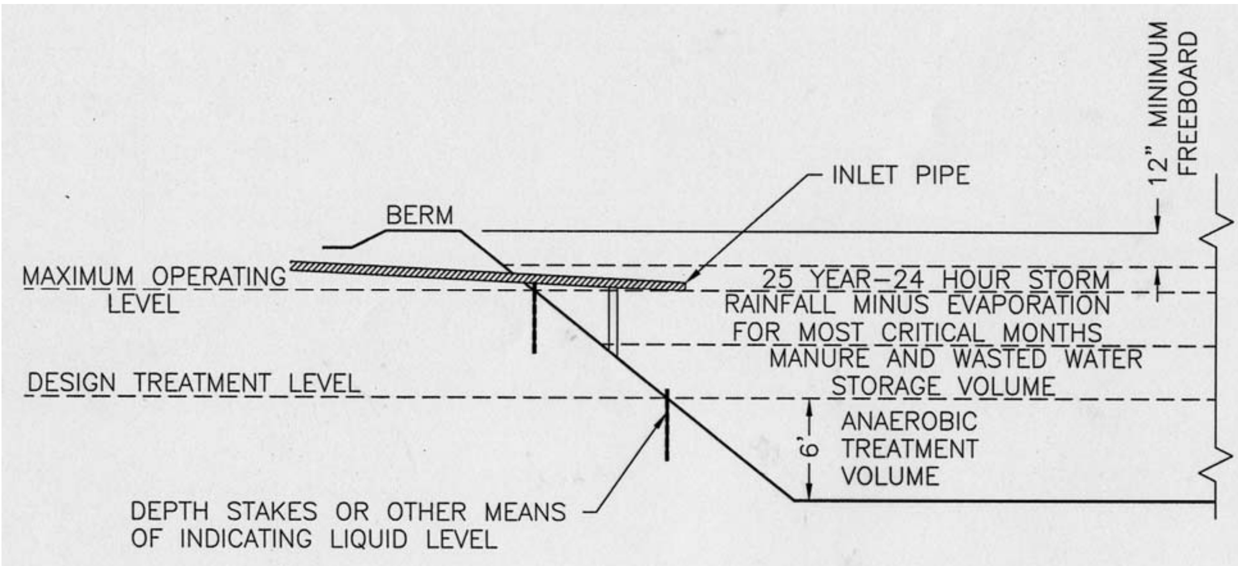

Figure 4.2. Schematic of volumes and operating levels for a treatment lagoon that does not include sludge storage.

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. 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 a loading rate of 5.0 lb VS/1,000 ft^3-day are given in Table 4.2.

Net Rainfall, 25-year, 24-hour storm, and Freeboard

The additional depth needed to allow for precipitation and freeboard are given in Table 4.3. These are approximate values, and are intended for general planning purposes. More detailed 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 4.2. Volumes for sizing dairy treatment lagoons that do not include sludge storage.
Loading rate = 5.0 lb VS/1000 ft^3-day, agitated sludge must be removed 1 to 2 times per year These values do not include the additional depth required for net rain, the 25-year, 24-hour storm, and required free board.

	Tractor Scrape & Manual Parlor Wash down		Total Flush (Freestall barns and Milking Center)		Milking Center Only Manual Wash down		Milking Center Only Flush	
Number of Milkings per day	2X	3X	2X	3X	2X	3X	2X	3X
Treatment Volume (ft^3/AU)	2380	2380	2380	2380	180	268	180	268
Waste Volume, 180 days (ft^3/AU)	529	621	864	1123	184	275	518	778
TOTAL VOLUME (ft^3/AU)	2909	3001	3244	3503	364	543	698	1046

Table 4.3. 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

* Note: Lagoons permitted after June 28, 2002 will require 2 ft of freeboard. So an additional 1 ft of depth must be added to these values.

Startup Procedures and Indicators of Proper Lagoon Function

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 2 to 3 times per day, and provide the ideal method of loading a lagoon. On dairy farms where manure is removed using a blade and tractor, manure is typically removed from the buildings and transferred to the lagoon 1 to 3 times per day. This practice also promotes frequent feeding of the anaerobic bacteria and is part of good lagoon management.

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.

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.

- 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.
- 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. 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. Addition of water for dilution can be beneficial. 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

Accumulation of rain water, manure, and wash down water will cause the liquid level of a lagoon to rise. The liquid level of a treatment lagoon is maintained by pumping surface water and applying it to crop, pasture, or forestland using an irrigation system.

The liquid level is to be maintained between the design treatment level and the maximum operating level as indicated in Figures 4.1 and 4.2. 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 the required ft freeboard (typically 1 ft). Additional requirements for the management of the liquid level are given below.

- <u>Visible markers must be established at the minimum operating level, the design treatment level, and the maximum operating level</u>. The depth of liquid between each marker should be indicated. Do not pump the liquid level below the minimum operating level of a lagoon unless sludge is being removed.
- Locate the floating intake of the pump 18 to 24 inches below the liquid surface and as far away from the pipes that are used to load the lagoon as possible.
- <u>Provide several "windows" of time for the application of surface water</u> by growing warm and cool season crops. Consider combinations of corn, coastal bermuda, soybeans, wheat, oats, fescue, and commercial forestland to take full advantage of the long growing season in South Carolina. Water from a lagoon 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 easier to manage.

Solids Management for Lagoons

<u>Solids management is the most important, but most overlooked, factor in the maintenance of lagoon function.</u> Lagoons are 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 and that will not decompose readily or at all are called sludge.

Most lagoons in South Carolina are sized to provide 10 years of sludge storage. <u>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 years of sludge at one time.</u>

Agitation Equipment

The most <u>common types of equipment used to agitate solids in earthen basins are: the inclined shaft, propeller-type agitator (Figure 4.3), and an inclined-shaft centrifugal chopper-agitator pump (Figure 4.4).</u> Most agitation equipment is tractor PTO driven. Some pumps also have a chopper or propeller near the pump intake. Agitation equipment generally requires a 90 to 140 hp tractor to operate.

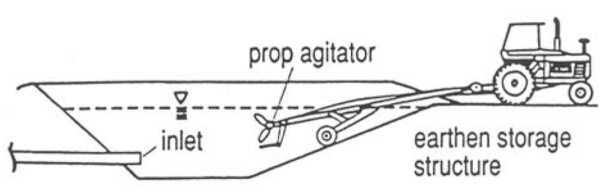

Figure 4.3. A propeller-type agitator (from the Liquid Manure Applications Design Manual, NRAES-89).

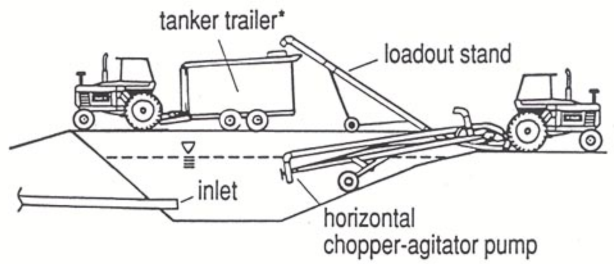

Figure 4.4. A centrifugal chopper-agitator pump (from the Liquid Manure Applications Design Manual, NRAES-89).

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 (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 about 12%.

Agitated lagoon sludge can range from 1 to 10% solids. Most irrigation pumps that are used for land application of manure can handle manure with a solids content less than 4%. A pump with a semi-open or open impeller is recommended for slurries (4 to 12% 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 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 earthen basins, 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.

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 (Table 4.1) only need removal of 50% of the sludge volume every 5 years.

Lagoons that are sized without sludge storage (Table 4.2) 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 once each year if 180 days of manure storage is provided.

If the lagoon was not designed to include sludge storage, plan on adding 3 to 4 feet of fresh water to the basin or use fresh water to fill flush tanks until the 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 a traditional anaerobic lagoon that includes sludge storage.

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 dairy 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 dairy farm will be needed. The amount of water in the sludge should 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 a few 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.

Sizing and Management of Manure Storages

Manure storages are sized to store all of the manure, waterer wastage, and washdown water for a defined storage period. Additional depth is also provided for precipitation and freeboard in the same way as for a lagoon (see Table 4.3). The entire storage contents are agitated and land applied once or more times per year. 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 cannot occur, and to allow for periods of wet weather.

Manure storage structures can be made of a variety of materials. The most common type is the lined earthen basin or storage pond. However, above and below ground concrete or glass-lined steel tanks can also be used.

Design Volumes for Dairy Manure Storages

Conventional storage structures can be used to store slurry or liquid dairy manure. Design volumes for 90, 180, and 365 days of storage are given in Table 4.4. All manure storages are smaller in volume than lagoons. If a lined earthen basin is used they can be less expensive to construct. Manure storages are not recommended for use with flush dairies and should never be used with recycle flush systems.

Table 4.4. Recommended design volumes for dairy manure storage structures.
These values do not include the additional depth required for net rain, the 25-year, 24-hour storm, and required free board.

	Sand-laden Manure Only	10% Slurry Manure Only	Tractor Scrape & Manual Parlor Wash down		Milking Center Only Manual Wash down	
Number of Milkings per day	NA	NA	2X	3X	2X	3X
Storage for 90 days (ft^3/AU)	147	208	259	347	92	138
Storage for 180 days (ft^3/AU)	293	416	518	693	184	275
Storage for 365 days (ft^3/AU)	595	843	1051	1405	372	558

Storage Pond

Storage ponds look like lagoons. However, they are not designed based on anaerobic treatment principles and they cannot be used as a source of recycle water for flushing. Storage ponds are much smaller, and the potential for strong odor is greater than for a treatment lagoon. However, odor production is typically reduced by a natural crust that typically forms on dairy manure storages. Odor production is the greatest during agitation and unloading.

The only operating level that is associated with a conventional storage pond is the maximum operating level as indicated in Figure 4.5. 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.

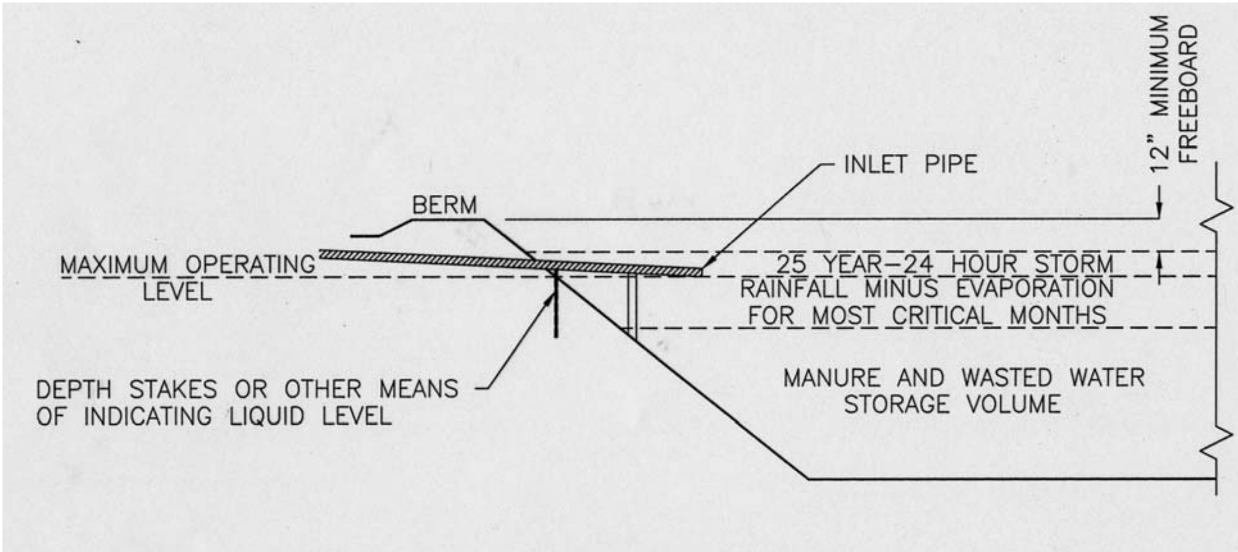

Figure 4.5. Schematic of volumes and operating level for a storage pond.

Manure Storage Tanks and Pits

Very few dairy farms in South Carolina use tanks to store manure (see Figures 4.6 and 4.7). However, they may 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 water unless a large fraction of the solids are removed. Unloading and level management is the same as for a storage pond. Additional details on storage alternatives is provided in the following publications: Liquid Manure Application Systems Design Manual (NRAES-89), and Livestock Waste Facilities Handbook (MWPS-18).

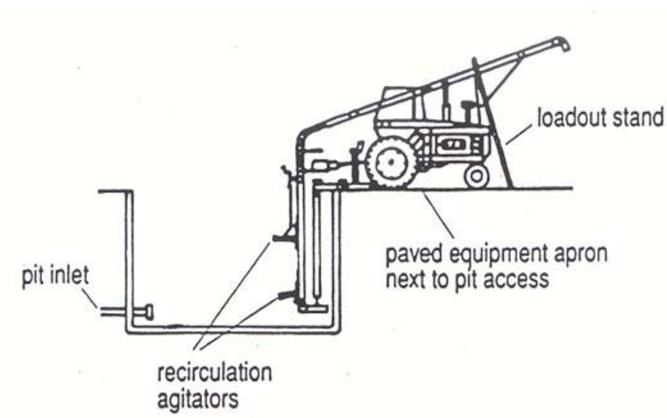

Figure 4.6. A below-ground storage pit (from Liquid Manure Application Systems Design Manual, NRAES-89).

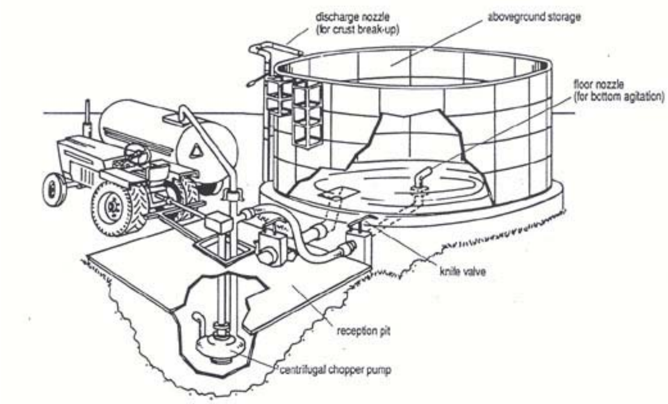

Figure 4.7. An above-ground storage tank and agitation system (from Liquid Manure Application Systems Design Manual, NRAES-89).

Below-Ground Storage Tanks Below-ground tanks can be built below the slotted floor of a dairy 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 (as shown in Figure 4.6). 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.

Liquid manure is typically transferred to a below-ground storage tank using gravity flow through 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 (Figure 4.7) 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 storages are from 10 to 25 ft high and 30 to 160 ft in diameter. They are made of concrete stave, reinforced concrete, and glass-lined 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 is 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 dairy 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 is required in the pipe that is used to load the above-ground storage to prevent manure from flowing back into the reception pit.

Tank 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 the tank. 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.*

Agitation and Unloading Storage Structures

Manure storages have a high solids content (4 to 9% total solids) and should always be well agitated before being emptied. 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 or by using a prop-type agitator as shown previously in Figures 4.3 and 4.4. 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 as indicated in Figure 4.7. Large diameter tanks may have a center agitation nozzle. Locate agitation sites no more than 40 ft apart in below-ground tanks without partitions.

Manure from a storage is generally land applied using tank-type or v-bottom 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.

Solids near the bottom of an earthen storage pond will require about 4 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 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. Agitation and pumping will continue until most of the contents of the storage are removed and land applied. Agitation pumps that include a propeller agitator are also available and are a good option for dairy storage ponds. Generally, it is difficult to remove the last foot of material.

Special Considerations for Storage and Handling of Sand-Laden Manure

Most organic freestall bedding materials absorb moisture but add little weight to dairy manure. With adequate dilution manure from heavily bedded freestall barns can be agitated and pumped relatively easily with conventional manure pumps. This is not the case for freestall barns that use sand bedding.

Sand has a density of about 150 lb/ft^3 which is over twice as much as undiluted dairy manure (62 lb/ft^3). Therefore, sand adds considerable weight to the manure with no water absorbing characteristics. The density of sand-laden dairy manure varies with the type of sand used and the amount of sand used per stall per week. The average density of sand-laden manure, based on data from Michigan State University (Stowell and Bickert, 1995), is 75 lb/ft^3. Sand-laden manure weights about 21% more than dairy slurry and heavy duty equipment is required for spreading and pumping.

The solids content of most slurry dairy manure is in the range of 8 to 12% solids. Sand-laden dairy manure that is scraped from a freestall barn will have a solids content in the range of 25 to 38%. However, it will have a consistency of a thick milkshake and it cannot be stacked. It must be handled and stored as a heavy, viscous slurry that is quite different from conventional dairy manure. Some basic considerations and guidelines are summarized below. Detailed recommendations on the storage and handling of dairy manure are given in the following publications:

- Storing & Handling Sand-Laden Dairy Manure, Michigan State University, Extension Bulletin E-2561, East Lansing MI, 48824-1039,
- Effective Means of Handling Sand-Laden Dairy Manure, Cornell University Pro-Dairy Program (available at http://www.ansci.cornell.edu/prodairy/), and
- Handling Sand-Laden Dairy Manure from Barn to Storage, Cornell University Pro-Dairy Program (available at http://www.ansci.cornell.edu/prodairy/).

Dilution The amount of water added to sand-laden dairy manure is one of the controlling factors in the performance of a handling and storage system. The sand in undiluted manure does not settle away from manure quickly. This type of manure is best handled with a rubber-tire scraper, manure auger, or positive displacement pump. If it is desired to keep the manure as thick as possible then do not include milking center waste water in any type of storage for manure and exclude as much precipitation as possible. Provide a separate waste system for the milking center and divert all runoff and roof drainage away from the storage. If large quantities of water are added to the manure then the sand will settle away from the manure and will accumulate on the bottom of a storage structure. Large amounts of rain can also cause settling problems in storage.

Agitation and Pumping Positive displacement pumps can be used to transfer undiluted sand-laden manure to a storage. However, the higher capacities associated with centrifugal pumps are typically needed to empty a storage. The main exception is a PTO driven manure auger that can be used to unload smaller capacity storages (a few weeks to 3 months of manure). Sand-laden manure will decrease the life and the flow rate of all types of pumps.

The manure must have at least a slurry consistency to be removed using a centrifugal pump with an open impeller. Also, the manure must be agitated continuously using a rugged propeller-type agitator that will provide the required subsurface agitation. The prop-type agitator can be a separate piece of equipment or it can be included as a part of the pumping equipment. A source of additional dilution water may be required. If a separate structure is used to treat and store milking center waste water then it can be pumped into the storage periodically during the unloading process to maintain a slurry consistency.

Storage Design A storage for sand-laden manure should be designed to provide:

- a concrete bottom that is designed to hold the added weight of heavy equipment,
- several concrete agitation ramps around the perimeter of the structure,
- concrete buck walls if a portion of the solids are to be removed using a front-end loader,
- a wide push-off area with safety fencing if the storage will be loaded by scraping with a tractor,
- a sump if a stationary pump or auger is used to unload the majority of the manure, and
- a concrete access ramp to allow entrance of heavy loaders when needed.

Due to the difficulties associated with sand removal a treatment lagoon should never be used with sand-laden dairy manure. If an efficient manure and sand separation system is used for primary treatment an anaerobic lagoon can be used to treat the effluent.

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, 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. Fire ant hills in or near the berm should also be eliminated. 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 (for flush systems).
    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.

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 dairy 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, 4.2, and 4.5. 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.
- 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 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 dairy farm. 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 may be 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. A brief summary of solids and plant removal efficiencies for mechanical separators treating dairy manure is given in Table 4.5

Table 4.5. Comparison of mechanical separator performance for dairy manure.

Type of Separator	Influent TS (%)	Removal Efficiency (%)				TS in Solids (%)	Reference
		TS	VS	TKN	P_2O_5		
Incline Screen	4.6	49	NR	NR	NR	12	A
	3.83	60.9	62.8	49.2	53.1	20.3	B
	NR	45.5	50.1	17.1	11.0	23.1	C
Vibrating Screen	1.0 – 1.7	8 - 16	NR	NR	NR	5.7 – 14.8	D
	1.0 – 1.8	12 - 13	NR	NR	NR	18 - 19	A
Rotating Screen	1.1 – 3.0	4 - 14	NR	NR	NR	6.4 – 8.1	D
Screw Press	1.0 – 10.1	14.9 - 47	NR	NR	NR	26 – 34	E

NR = not reported,
A = Zhang and Westerman (1997),
B = Chastain et al. (2001),
C = Fulhage and Hoehne (1998),
D = Hegg at al. (1981), and
E = Converse et al. (1999),

Gravity settling basins have been used for years to remove solids from flushed dairy manure and feedlot runoff. Gravity settling can remove 15 to 59% of the total solids and 31 to 57% of the volatile solids depending on the solids content of the influent dairy manure (Figure 4.8). Addition of a flocculant (polymer) can increase the solids removal of a settling basin to 76%

(Chastain et al., 2001). Gravity settling basins can be used to significantly reduce the loading rate of a lagoon and eliminate sludge build up problems in lagoons. Settling basins should be designed to provide 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%.

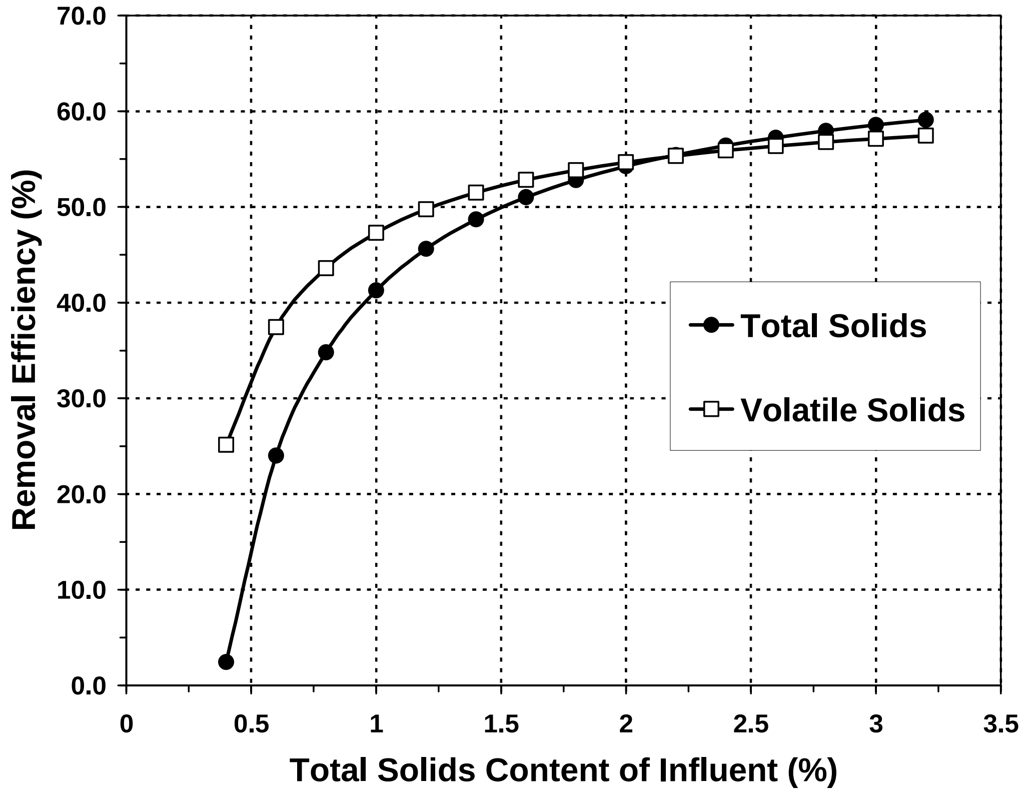

Figure 4.8. Total and volatile solids removal efficiencies for gravity settling of dairy manure (settling time = 60 min, excludes the use of sand bedding)

SUMMARY

Anaerobic lagoons and storage ponds can look the same, but the management of solids and liquids are very different. Dairy producers must understand how the structure was designed to understand how to effectively control the liquid level, sludge accumulation, and utilize plant nutrients in the solids and liquids. The methods used to treat and store dairy 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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