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Lagoon Management – Pork Industry Handbook
Michigan State University Extension Service
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pork industry handbook

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Michigan State University Extension

Lagoon Management

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Introduction

A lagoon is a basin, typically earthen, used to treat and store manure from pork production facilities. A lagoon appears similar to an earthen liquid manure storage; however, it serves the added function of dilution and treatment. The difference is in the length of storage, in the amount of dilution added, and in the fact that a lagoon is never completely emptied. Lagoons are used extensively in the United States. They rely on bacteria to stabilize organic material. Most lagoons used in the swine industry are either anaerobic (bacteria existing in the absence of oxygen) or facultative (combination of anaerobic and aerobic bacteria) treatment units. However, in lagoons considered to be facultative, free oxygen is rarely found below the top few inches of liquid. Aerobic lagoons (bacteria requiring oxygen) also can be used to treat swine manure. However, some means of mechanically supplying the oxygen is typically required.

The lagoon can be used in a variety of manure treatment systems. Properly designed and managed lagoons have a number of attractive features:

- stabilization and reduction of organic matter
- reduction in concentration for some nutrients
- adaptability to a wide range of climatic and topographical situations
- compatibility with liquid manure handling and or collection systems
- reasonable capital and operating costs
- reasonable management requirements
- infrequent sludge removal
- somewhat tolerant of shock loading.

Lagoons are especially compatible with hydraulic flush manure removal and pit recharge systems. Many pork production systems recycle lagoon effluent as the flush or pit recharge liquid.

Before selecting or finding a location for a lagoon, the entire manure management system (manure collection and transport, lagoon, land application equipment, crops and land to receive lagoon nutrients) should be planned and evaluated. If any of the elements do not support the complete design, either an alternative site or an alternative manure management system should be considered.

Lagoon Design

Lagoon Design Standards

Lagoons treat manure biologically with several types of bacteria working together to decompose organic material. The rate of bacterial decomposition is governed by lagoon temperature. The long-term rate of manure addition to a lagoon should not exceed the rate at which stabilization can occur. The rate that lagoons can reasonably treat manure is termed loading rate. Loading rate can be defined as the amount of manure that will be added per volume of lagoon per day.

Lagoons must be designed to meet a predetermined loading rate criteria. The loading rate for anaerobic lagoons can be expressed as 1) pounds of volatile solids per cubic foot of lagoon volume per day, 2) pounds of chemical oxygen demand (COD) per cubic foot of lagoon volume per day or 3) pounds of live animal weight per cubic foot of lagoon. Anaerobic lagoon loading rates vary throughout the United States as a function of mean annual air temperature. As temperature increases, loading rates can increase because the bacteria are more active and can treat larger quantities of manure. This defines the minimum design volume for an anaerobic lagoon. A final anaerobic lagoon design must include this volume plus additional volume to store manure, accumulated sludge, precipitation and lot runoff for desired amounts of time.

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Several anaerobic lagoon design procedures are in use in the United States. These include American Society of Agricultural Engineers (ASAE) Engineering Practice 403.1, USDA Soil Conservation Service Practice 359 and design procedures developed by individual state Cooperative Extension Services. It is advisable for producers to seek professional assistance from someone who is familiar with local conditions and regulations before designing and locating lagoons. This service may be provided by your Cooperative Extension Service, USDA Soil Conservation Service or consulting engineers.

The aerobic lagoon design is based on the amount of oxygen required to stabilize the organic material in the manure. One often used rule is to supply sufficient oxygen through mechanical aeration to satisfy 50% of the daily COD inflow. Design of mechanically aerated lagoons should be left to experienced professionals. Aerobic lagoons without mechanical aeration require a very large surface area in order for sufficient natural aeration to take place, and usually they are not economically feasible.

Consequences of Inadequate Design

If lagoons receive more manure than the bacteria are capable of "digesting," significant odor and rapid sludge accumulation will occur. During winter, biological activity in anaerobic lagoons is dramatically reduced. In warmer seasons, bacteria must digest the undigested portion of manure added during the winter plus the manure being added in the summer. This situation can lead to temporary lagoon overload and objectionable odors in the spring. It is a good practice to be conservative when designing anaerobic lagoons. Some excess capacity is desirable. As herd size is increased, lagoon capacity should be increased as well.

Need for Permits

States may require permits for lagoon construction and/or operation. Always check with the appropriate regulatory agency in a state before lagoon construction. Several states have established criteria for lagoon design volume and construction. Some states require verification of lagoon sealing before initial operation.

Multiple Stage Lagoons

Anaerobic lagoon systems can be designed with either single or multiple stages. Either design practice is acceptable under certain circumstances. Advantages for multiple stage lagoons include:

- Less floating debris on the second or third stages. This can reduce the potential for clogging flush recycle and irrigation pump intakes and irrigation sprinklers.
- Maintenance of a fixed minimum design and sludge storage volume in the initial cell if recycling and effluent removal are accomplished from second and third stages. This can help ensure that the lagoon system is never "over pumped" and that an adequate concentration of bacteria is present to treat incoming manure. This allows a more stable operation which helps to minimize odors.

Disadvantages of multiple stage lagoons include:

- Increased surface area for a given lagoon depth and volume.
- Increased construction cost.
- Potential for overloading the first cell which can lead to odors.

The need for multiple stage lagoons can depend on the amount of precipitation, the relative frequency for removing excess lagoon liquid and the intent of recycling lagoon liquid as flush water. Many operations in the Southeast only use single stage lagoons since precipitation is high and need for liquid removal is frequent. The dilution/removal process develops a reasonably clean recycle liquid. In some locations, two and even three stage lagoons have been used to an advantage. In three stage lagoons, the first stage is designed as the primary treatment unit. This cell is designed for stabilization of organic material or odor control. A relatively small, second-stage, constant-volume, constant-head cell serves the function of containing a supply of reasonably clean recycle liquid (most of the floating scum retained in primary lagoon). Excess effluent from the second cell flows into the third stage. The third stage is primarily a storage lagoon and liquid is periodically removed for land application. The third stage should have sufficient volume to store all lagoon system inputs (manure addition, precipitation, etc.) for a selected amount of time.

Sealing Lagoons

Lagoons must be sealed to prevent seepage that would lead to ground water contamination. A lagoon is considered sealed in most states if its lower boundaries (bottom and sides) have a hydraulic conductivity not greater than 10^{-7} cm/sec (0.0034 inches/day). A lagoon can be sealed with properly installed clay soil or by using an industrial liner. Appropriate state regulatory agencies should be contacted before lagoon design and construction to determine lagoon sealing requirements. Some states require verification of lagoon seal and/or a leak detection system. It is critical that lagoon seals be adequately maintained. Access by livestock to lagoon banks should be prohibited.

Livestock manure is a good soil sealant (except in very coarse sand or gravel); nevertheless, try to locate the lagoon in the most impervious soil. Cooperative Extension Service or Soil Conservation Service personnel can help you determine a soil's suitability for lagoon construction.

Sites where the bottom of the structure would be in sand or within 10 feet of limestone should be avoided. However, it may be possible to seal the bottom with plastic liners, a swelling-type clay, 6 inches of compacted topsoil or 4 inches of disked-in livestock manure. Also, if located in a high water table or shallow soil area, consider constructing lagoon above grade.

Site Factors to Consider

Lagoon location is one of the most critical aspects of successful lagoon operation. A considerable amount of thought should be given to the design and siting of a lagoon. Because anaerobic and facultative lagoons can produce objectionable odors on a seasonal basis, they should be located with appropriate separation distances from residences, schools, businesses, churches and other places of assembly. In some situations visual (vegetative or structural) barriers should be installed. The following is a partial list of factors that should be considered:

1. Geology and soil type, depth to water table, depth to bedrock, proximity to karst limestone areas. Proximity of groundwater, and the presence of soils with sufficient clay to seal and provide a barrier against seepage to groundwater are important considerations in locating a lagoon.
2. Sufficient land area and cropping systems to accommodate the nutrients to be periodically removed.
3. Type of agriculture in vicinity.
4. Proximity to residences, wells, streams, ponds, churches, schools and businesses.
5. Visibility of lagoon by neighbors and passers-by.
6. Odor production and movement. Because odors will be produced by the swine facilities and the lagoon, consideration should be given to prevailing wind direction, and air drainage patterns when winds are calm and humidities are

high. Odors remain concentrated and follow flow lines similar to water during periods of high humidity and low air movement.

7. Develop and document a defensible site selection procedure. Given the possibility of future litigation, a defined site selection procedure should be used in selecting a site, and that procedure should be followed and documented. It can then be used as supporting evidence should the location be legally challenged. Successful defense of a legal case against a livestock production facility generally requires that all local, state, and federal regulations are followed.
8. Likelihood of future nearby housing development.

Co-treatment of Domestic Waste

In general, domestic waste cannot be added to livestock lagoons. Some states prohibit this practice. Contact your local Department of Health for more information. Appropriate state regulatory agencies should be contacted if this practice is being considered.

Pretreatment of Manure Entering Lagoons

Reasons for Pretreating

The "health" of an anaerobic lagoon is controlled primarily by the loading rate. As a rule, reducing the organic loading rate reduces the potential for odors. Where consideration is given to increasing herd size and it is impractical to enlarge the lagoon to allow for the increased loading, the organic strength of the manure flowing into the lagoon should be reduced. Settling basins and mechanical separators can achieve solids and volatile solids reductions of 40% to 50% in the liquid entering lagoons. This reduction in organic loading will decrease the potential for odor.

Settling Basins

Settling basins are typically earthen or concrete lined ponds that are designed to promote the settling of the heavier manure particles. These units are frequently only two to six feet deep. The design goal is to reduce the fluid velocity to less than 1 foot per second. Liquid flows from one end of the basin to the other before exiting. It may be beneficial to use a baffle around the discharge pipe to retain floating solids. The material in the basin is removed periodically as the solids concentration increases and the retention time decreases.

Make settling basins large enough to have a usable depth of at least 2 ft with another 1 to 2 feet of depth available for sludge storage.

For flush systems: size the basin for a detention of at least 30 minutes. For example, if two 500 gallon flush tanks dump during each 30 minute period, the usable tank volume should hold at least 1000 gal (137 cu ft). In this case, the tank would have a surface area of 137 cu ft/2 ft = 68 sq ft. A tank configuration of 7 ft x 10 ft or larger would provide this.

For pit recharge and liquid manure pit systems, size the settling basin to hold the manure from the largest pit that will drain into it. For example, a building pit which is 8 ft wide x 100 ft long x 4 ft deep will require a settling basin that has a volume of at least 3200 cu ft, plus an additional foot or two for storage of settled solids.

Settling basins can be designed to simply overflow with solids removed frequently with liquid manure handling equipment. If elevation permits, settling basins can be fitted with a removable overflow pipe plug so that liquid can be drained to the lagoon either intermittently or continuously. They also can be designed with a small opening which is always open to allow liquids to slowly drain away from the settled solids. Solids can be removed with a front-end loader. In this case, provide an access ramp with no more than 1:12 slope.

Mechanical Separation

Mechanical separators can be used to process the flushed liquid from swine production facilities. Several types of separators are on the market including stationary sloping screens, continuous belt sloping screens, vibrating screens, centrifuges and auger press screens. As with most mechanical devices, maintenance and management must be considered. Many mechanical separators require daily cleaning and flow adjustment. To achieve optimum performance, the flow to the separator must be reasonably consistent. Frequently the flow from the production facilities is directed into a holding/mixing tank and then pumped to the separator at a regulated flow. It is possible to produce separated solids with a solids content greater than 25%. The separated solids can be directly applied to land, composted for possible commercial markets or used as a cattle feed ingredient. For use as a cattle feed ingredient the separated solids should be mixed with a forage material and ensiled.

Anaerobic Lagoon Management

Lagoon Startup

Startup of anaerobic lagoons should be planned so as to minimize biological stress. This will allow the lagoon to produce necessary bacteria, and in doing so to improve its capability to treat manure. Anaerobic bacteria are slow growing. It can take more than a year to increase bacteria populations to desired concentrations. An anaerobic lagoon usually takes over a year to reach maturity. Until it reaches maturity, elevated odor may be detected. This is especially true in colder climates and if the lagoon is loaded too rapidly. There are several factors that a producer should consider when initiating use of an anaerobic lagoon:

1. The volume of the lagoon defined as the minimum design volume should be filled with water before introducing manure. For a multiple stage lagoon with the first stage holding the minimum design volume the entire first stage should be filled.
2. Lagoons should be started in the late spring or summer if at all possible. This allows the bacteria opportunity to become established since they grow and reproduce faster at warmer temperatures.
3. The amount of manure loaded into a lagoon should be gradually increased over two to three months (3-6 months if done in cooler times of the year). This typically can be accommodated easily if the lagoon is placed into operation at the same time that the sows are placed on the site. The manure load will gradually increase as the nursery and finishing units are populated. If a new lagoon is constructed to treat an existing manure flow, the amount of manure added per day should be brought to full load over a period of several months.

Berm/Bank Management

Lagoon banks and berms must be managed to prevent or minimize erosion and deterioration by establishing grass on lagoon banks and berms. Provisions for mowing grass should be made for berms and the outside slopes of lagoons. This will allow periodic inspection which should be made to ensure that no seepage is occurring. Livestock should not be allowed access to the inside or outside slopes of lagoons. Large weeds, shrubs and trees should not be grown on lagoon banks or berms. Root penetration and subsequent decay could initiate leakage. Aquatic weeds contribute to stagnant water where mosquitoes can breed. Rodent populations should be eliminated from lagoon banks. Burrowing by rodents can lead to lagoon leakage on exposed sides.

Odor Control

During the winter, biological activity in lagoons is reduced and organic matter is incompletely digested. As the lagoon warms in the spring, bacteria are presented with excess organic matter to stabilize. At this time, very vigorous activity is observed on the lagoon surface and large amounts of biogas are produced. This typically is referred to as lagoon "turnover." During a turnover, highly offensive gases can be produced, the result of incomplete digestion. One means of reducing odor production potential is using lower loading rates, especially during winter months and early spring.

A number of commercial products have been marketed that advertise the ability to either reduce or control odors. These materials include masking agents, chemicals that can temporarily bind ammonia, chemicals that inhibit urease production and, therefore, ammonia production, bacteriocides, chemicals that neutralize odor, chemicals that stimulate bacterial growth and biological preparations that contain "special" strains of bacteria. However, most of these products have not been scientifically evaluated and proven to be effective; even so, there are numerous reports from producers attesting to the partial effectiveness of some of these products. Considering all of the materials available, those that contain active bacterial cultures hold the most promise for helping the lagoon's bacteria to limit odor. The producer should be very wary of any unsupported claims by vendors of odor control products. Chemicals that may have positive results in one situation may not be effective in seemingly similar situations.

Periodic Removal of Lagoon Liquid

Lagoons located in all but the most arid of climates will accumulate liquid over time. Most lagoons are designed for a given amount of storage. This storage volume should be sufficient to allow liquid removal to coincide with beneficial nutrient use on crops. Lagoons should not be pumped below the minimum design volume. This ensures that sufficient volume is available for adequate manure treatment and to retain the necessary active bacterial culture. The minimum design volume depth should be noted by the lagoon designer on a design drawing. A grade stake or similar marking device should be positioned in the lagoon so that those responsible for pumping the lagoon will know when to stop pumping. Typically, 40% to 50% of the active lagoon volume should be left in the lagoon.

Remove lagoon liquid in the colder climates only during the warmer summer months. To allow sufficient bacterial populations to develop, large amounts of lagoon liquid (more than 25% of total volume) should not be removed in the late fall. For warm, humid climates, lagoon liquid can be removed throughout the year if an acceptable land application site is available.

If the lagoon system has multiple cells in series (one cell emptying into another) the effluent pumped should not come from the first stage. The intake for the removal pump should be located as far as possible from the inflow line to allow for maximum treatment. Frequently, the pump intake line is placed on a float with the pipe submerged approximately one foot below the liquid level to avoid clogging the pumps and pipe with floating debris.

Fate of N, P and K and Pathogens

Most of the nitrogen that enters a lagoon is converted to ammonia. The nitrogen in the urine will convert to ammonia rapidly while the nitrogen in the organic matter will transform over many months. A relatively small amount of the total amount of nitrogen added to a lagoon is retained in the sludge, even though the nitrogen concentration in the sludge can be quite high. Much of the ammonia nitrogen will volatilize from the surface of the lagoon over time. The amount of volatilization that occurs increases as air movement above the lagoon surface, pH and lagoon temperature increase. Typically as much as 70% to 80% of the nitrogen converts to ammonia and is volatilized. Lesser amounts of ammonia volatilization will occur in cooler climates.

Much of the phosphorus added to lagoons will attach to particles and accumulate in lagoon sludge. Therefore, phosphorus loss over time is minimal. Most of the potassium remains in solution. In arid climates where there is a net evaporative loss over the year or where recycling of lagoon liquid for flushing is practiced, potassium concentrations can become quite high.

Other than the nutrient loss discussed above the only other major nutrient removal mechanism is land application of lagoon liquid. Due to the wide variation in lagoon designs and climatic conditions, it is extremely difficult to predict nutrient concentrations. The best practice is to always have representative lagoon samples analyzed before pumping lagoon liquid. This information is essential in matching nutrient application with agronomic uptake to avoid excess nutrient applications that could result in water contamination.

Pathogens can survive anaerobic conditions for extended periods of time. Coliforms, streptococci, *Escherichia coli*, enterococci, *Salmonella* species, and *Serpulina hyodysenteriae* and many other microorganisms have been identified in swine lagoons. Research has even indicated the development and perpetuation of specific strains of pathogens for a given lagoon. However, most pathogens have significant population reductions within 30 days. Table 1 indicates some possible ranges of removal of certain organisms in lagoons. Most microbial populations are less than 10^4 organisms per milliliter. Lower lagoon organic loading rates have been suggested as a means of reducing the potential of pathogen survival.

Table 1. Percentages of populations of microbial species in raw manure remaining in lagoon liquid.

Organism	% Remaining
Fecal coliform	1 - 10
Total coliform	0.2 - 2
Enterococci	0.001 - 0.05
Fecal Streptococci	0.005 - 15

Recommendations to minimize potential pathogen risks to humans and swine include:

1. Instruct workers to practice proper personal hygiene.
2. Locate recycle intake lines in a lagoon as far from flush manure inflow lines as possible.
3. Prevent swine from making contact with recycled lagoon liquid.
4. Operate lagoons as designed.
5. Design lagoons appropriately.

Recycling of Lagoon Liquid for Flushing

Production facilities that use anaerobic lagoons often use either flushing or pit-recharge systems to collect and transport manure. To reduce the amount of water added to the system and consequently reduce the quantity of lagoon liquid to be land applied many producers recycle lagoon liquid. This has proven to be cost effective. There will be fewer problems from trash clogging pump intake lines if the recycle liquid is taken from a second or third stage.

Crystal Buildup in Recycle Lines

Struvite (magnesium ammonium phosphate) or similar crystalline materials frequently occur in recycle systems. This material develops in pumps and/or at points of restriction and turbulence in the pipeline. The material starts as a soft scum that adheres to the pipes and pumps. Once the material solidifies, additional crystal growth can be rapid and can completely block even large pipes. There is no proven method for totally preventing these crystals. To minimize difficulties associated with struvite the following should be considered:

1. Use only smooth wall plastic pipe.
2. Minimize joints and elbows.
3. Keep pipe flow velocities well below 5 feet per second.
4. Keep pipes and pumps as free of particles as possible.
5. Minimize suction lift on the pump.
6. Pump housings should be directly grounded to prevent any stray voltage that could contribute to crystal growth.

Some producers have installed parallel piping systems that can be used to circulate acid. Typically muriatic (hydrochloric) acid (30% (20°) technical grade) is used. Extreme caution must be exercised when handling acid. Eye protection and gloves should always be used. Muriatic acid should be diluted using one gallon of acid to nine gallons of water before use. The diluted acid should be placed in a plastic reservoir and a pump used to circulate the acid through the piping system until it is free of struvite. After one or more uses the acid may lose its effectiveness depending on the amount of crystal to dissolve. The acid/salt solution should be disposed of properly by pumping it to the lagoon.

Lagoon Effluent as Input to Constructed Wetlands

Constructed wetlands are shallow (12 in. to 18 in. water depth), essentially level earthen basins that are designed for wastewater treatment. Such units are man-made as opposed to natural wetlands. Constructed wetlands are populated with aquatic plants such as cattail and bullrushes. The plants serve to provide surface area for bacteria and as a filter to remove nutrients and organic matter through a variety of physical, chemical and biological processes. Constructed wetlands can be used to further treat effluent from lagoons if the solids and ammonia concentrations are not too high. The maximum ammonia concentration that aquatic plants are known to tolerate is approximately 100 parts per million. Effluent from even secondary lagoons often has ammonia concentrations higher than 100 ppm. Therefore, some dilution of lagoon liquid is typically required before discharge into constructed wetlands.

The producer should seek professional assistance for the design and management of constructed wetlands. It is important to realize that the effluent or discharge from constructed wetlands typically will not meet state and federal standards that will allow for direct discharge into streams. Therefore, the effluent must be collected for recycle or land application. The primary benefit of a constructed wetland is that the reduction of nutrients means less land will be required for land application of effluent.

There has been little definitive research on the long-term effectiveness of constructed wetlands for further treating swine lagoon liquid. Producers using this system should have an alternative means of treating this manure should the system fail.

Troubleshooting

There are a number of activities that the producer should consider to help maximize the performance of lagoons and minimize problems. Among these activities include:

1. Make frequent inspections of lagoon banks and berms to note any potential problems such as overtopping, excessive vegetation, rodent burrowing and bank erosion.
2. Annual analyses of lagoon contents for TKN (Total Kjeldahl Nitrogen), NH_3-N, P and K can be a good indicator of lagoon performance. If these fertilizer nutrients are not obtained through laboratory analysis, a simple field measurement of electrical conductivity (EC) can be used as an indicator of lagoon health. EC is a measurement of salt or mineral levels in lagoon water, and excessive levels can inhibit bacterial activity.
3. Avoid slug loading lagoons as much as possible. This practice is critical during the late fall, winter and early spring to prevent excessive odor during the spring and early summer. Smaller daily or weekly loadings result in best performance.

Cost of Lagoon Management

There are definite costs associated with managing lagoons. The most obvious cost is for the periodic removal of excess lagoon liquid. The cost can be reduced by diverting unnecessary runoff from the lagoon and recycling lagoon liquid for flushing. Recycling lagoon liquid for use in flushing swine buildings can lead to problems with salt deposition in recycle lines.

Costs of renting or owning and operating lagoon effluent application equipment are significant, but must be considered as a cost of staying in business just as feed costs are a cost of staying in business. Cash flow analyses for the production enterprise should include these costs.

Another possible expenditure for lagoon management is the cost to operate a settling basin or mechanical separators. This cost should be compared with the benefits realized from reducing the lagoon organic loading rate and potential use of the separated solids.

The cost of maintaining lagoons should also be considered. For most situations where good construction practices were followed this only involves periodic mowing or removal of excess vegetation. However, lagoon berms and banks may need occasional repair.

When lagoon sludge accumulations reduce the working volume of the lagoon to the point where odor becomes a problem, the sludge will have to be removed. This can be a major expenditure. Thought should be given to potential sludge removal while designing the surface dimensions of the lagoon. The producer should also consider the cost of operation should the lagoon not be in service during sludge removal.

Lagoon systems should be designed keeping construction and operating costs in mind.

Rejuvenation of Existing Lagoons

After lagoons have been in use for 10 to 20 years, they may have sludge accumulations that require removal. As the sludge level increases, the loading rate on the remaining lagoon volume can increase to the point where biological overloading occurs. In addition, the lagoon can be a source of constant odor and can even become too thick to recycle as flush liquid. The only way to effectively rejuvenate a lagoon is to remove the settled sludge. Sufficient land to receive the sludge must be available. The sludge will be rich in phosphorus, nitrogen and other nutrients. Land application rates should be determined after sludge samples have been analyzed.

There are three techniques for sludge removal. The first is to use agitation equipment (pumps and prop agitators) to resuspend the sludge and pump the sludge while the contents are thoroughly mixed. The sludge can be expected to resettle rapidly once agitation is terminated. Most agitation equipment has an effective radius of only 75 ft to 100 ft. Sludges with solids contents up to 8% can be pumped through large pipe lines, but large capacity solids pumps are required. Friction loss in pipelines can be higher than for pumping water. Pumped sludge can best be applied using large diameter irrigation guns or with manure tank wagons or trucks.

A second technique for removing sludge is to use a specially designed floating dredge. The dredge is systematically moved across the lagoon. A pump located on the dredge moves the sludge to a second pump on the lagoon bank. From the second pump the sludge is pumped to the application site.

A third method for rejuvenating a lagoon is to pump the liquid above the sludge into another lagoon or onto land and allow the sludge to dry. It can take several months for sludge to dry sufficiently to be removed by tracked equipment. This technique is often impractical to use in humid climates.

In many cases it is appropriate to contract for commercial sludge removal due to the special purpose equipment that is required.

Aerobic Lagoon Management

Description of Aerobic Lagoons

Aerobic lagoons require free oxygen to sustain the aerobic bacteria. The required oxygen concentration can be achieved by either designing the lagoon to have a large surface area or to use mechanical aerators. For mechanically aerated lagoons, the liquid depth is typically 10 feet or deeper. For naturally aerated lagoons in warm climates the maximum accepted loading rate is 50 pounds of biochemical oxygen demand (BOD_5) per acre per day. For cold climates, the loading rate should be reduced to 35 pounds of BOD_5 per acre per day. The BOD_5 production rate for swine is approximately 3.1 pounds per 1000 pounds of live animal weight per day. A typical design criteria is to have sufficient oxygen capability to satisfy 50% of the chemical oxygen demand (COD). The COD production rate from swine is approximately 8.4 pounds of COD per 1000 pounds of live animal weight per day. This is a design of approximately 12,000 pounds of live weight per acre for a naturally aerated lagoon (1 acre for each 7 to 8 sows in the herd for a farrow to finish operation).

Aerator Operation

Aerators should be sized to provide sufficient oxygen to minimize odor production potential and promote aerobic decomposition of organic matter. Aeration is typically accomplished using floating aerators which have oxygen transfer capabilities in the range of 1.5 to 2.0 pounds of oxygen per horsepower-hour in lagoon liquid. The producer is advised to request oxygen transfer data from manufacturers before purchase of aeration equipment. A parallel design criteria is to have minimum aerator capacity of one horsepower per 1,000 square feet of surface area to promote mixing.

Removal of Sludge

Aerobic lagoons will develop excess sludge accumulations over time as compared to anaerobic lagoons. When sludge accumulation begins to impact treatment efficiency, the material should be removed.

Land Application of Lagoon Liquid

Lagoon Nutrients/Analysis

Lagoon liquid contains significant amounts of nutrients. Land application programs must be based on an accurate laboratory analysis of lagoon liquid. Concentrations of nutrients can change for a given lagoon throughout the year. Therefore, a lagoon sample should be taken and analyzed before land application. Rarely do two lagoons have identical nutrient analyses. Producers should be careful when considering the use of analysis information from other than the lagoon in question. The concentration of nutrients in lagoon sludge can be several times higher than in lagoon liquid. Care should be taken to collect samples representative of what will be pumped/removed.

Several states offer inexpensive laboratory analysis of lagoon liquid. Where this service is not available, commercial laboratories should be used. The following parameters should be included in an analysis: total Kjeldahl nitrogen, ammonia nitrogen, phosphorus, potassium and pH. Micronutrient analysis information also may be useful. Samples should be refrigerated or frozen after collection and delivered to the lab in this fashion. Warm samples can lead to ammonia volatilization and inaccurate nitrogen results.

Record Keeping

As with most business operations, good records must be maintained as part of the overall management program. The records program should include the following at minimum:

- history of lagoon analysis
- application dates, identification of area receiving lagoon liquid and application rates
- crop type and yield
- soil test
- application of chemicals and commercial fertilizer.

The use of information on crop yield, soil tests, application timing and rate will improve management of lagoon liquid. Lagoon liquid should be considered as a nutrient source and used beneficially. This strategy will reduce any potential of groundwater pollution.

Appropriate Application Rates

Application rates of lagoon liquid should be based on satisfying crop nutrient requirements. Application rates are typically governed by nitrogen; however, some states limit phosphorus application as well. In order to determine the appropriate application rate two types of information are needed: lagoon liquid analysis and estimate of crop nutrient requirements throughout the growing season. In some situations the soil nutrient content and previous history of site (production of legumes, etc.) also should be considered. Multiple, light applications of lagoon liquid on a site are generally superior to few large application events in terms of crop performance. When estimating effective nutrient application rates it is important to remember that a large portion (typically 70% to 90%) of the nitrogen in lagoon liquid is in the ammonium nitrogen form. Some of the ammonia will volatilize during and immediately following application.Consult with local Cooperative Extension Service personnel regarding appropriate assumptions for ammonia volatilization rates in their location.

Protection of Groundwater

Nitrogen readily transforms from ammonia to nitrate in most soils. If nitrogen is overapplied, the potential exists for elevating the nitrate concentration of groundwater providing rainfall is great enough for percolation to beneath the root zone. Limit applications of lagoon liquid to crop uptake requirements. Special care is required for fields that have been tile drained.

Injection of Lagoon Liquid into Irrigation Systems

In some situations lagoon liquid may be applied by injecting this liquid into permanent irrigation systems that are used to apply water for crop production. For this type of system backflow/anti-siphon devices must be installed to preclude the chance of contamination of the fresh water supply.

Maintaining Lagoon Liquid Levels in Arid Climates

In situations where evaporation significantly exceeds rainfall there may be the need to add additional water to lagoons to maintain sufficient lagoon volume to promote proper bacterial activity. This can be handled by periodically using fresh water to flush facilities or the simple addition of water to the lagoon system. If lagoon levels are too low, reduced biological activity can occur thereby contributing to odor production. In addition, the salt concentration can become so elevated as to inhibit bacteria activity. Therefore, in arid climates it may be appropriate to periodically test the lagoon liquid for electrical conductivity. Readings above 8,000 micromhos per centimeter can indicate reduced bacteria activity. Additions of freshwater (precipitation) will reduce this problem.

Covering Lagoons

Anaerobic lagoons have been successfully covered using special designs of industrial fabrics and flotation devices. The intent of the floating covers is to minimize odors by decreasing diffusion of gases into the atmosphere. Before making a decision to cover an anaerobic lagoon on the basis of potential odor control, the producer must satisfy himself that there will be sufficient odor reduction from the complete facility to warrant such an action. The biogas harvested can be used as a fuel for stationary engines, absorption cooling and hot water heating. Biogas production is very dependent on lagoon temperature and loading rate. Summer production rates often are two to three times the winter biogas production rates. Biogas production from lagoons that have winter temperatures below 50°F usually is too low for practical economic use.

Due to the cost and technology required to design and manage a floating cover system, professional assistance should be used. Major drawbacks to biogas production are the storage and use of a relatively corrosive, low-energy content gas in conventional engines and burners and the added management and labor for the energy system.

Future regulations may limit the emission of certain gases (such as NH_3, CH_4 and CO_2 to the atmosphere and increase the use of lagoon covers).

As with most business decisions, economics must be thoroughly considered. The cost of designing and installing a floating cover and biogas system are significant. There must be a valid economic incentive for installing a floating cover system. This motivation should be either the potential profit/cost savings to be realized from energy harvest, the value to the producer of possibly gaining relief from odor or a combination of these two reasons.

Lagoon Terminology

The American Society of Agricultural Engineers has developed two standards that define appropriate terminology for manure management These standards are identified as ASAE S466, Nomenclature/Terminology for Livestock Waste/Manure Handling Equipment and ASAE S292.4, Uniform Terminology for Rural Waste Management. The following definitions relative to lagoon management have been taken from ASAE S466 and ASAE 292.4 with the permission of the American Society of Agricultural Engineers:

Aerobic bacteria: Bacteria that require free elemental oxygen for their growth. Oxygen in chemical combination will not support aerobic organisms.

Aerobic decomposition: Reduction of the net energy level of organic matter by aerobic microorganisms.

Aeration: A process causing intimate contact between air and a liquid by one or more of the following methods: (a) spraying the liquid in the air, (b) bubbling air through the liquid, and (c) agitating the liquid to promote absorption of oxygen through the air liquid interface.

Aeration unit: A tank or lagoon in which sludge, wastewater, or other liquid is aerated.

Anaerobic bacteria: Bacteria not requiring the presence of free or dissolved oxygen. Facultative anaerobes can be active in the presence of dissolved oxygen, but do not require it.

Anaerobic decomposition: Reduction of the net energy level of organic matter by anaerobic microorganisms in the absence of oxygen.

Bacteria: A group of universally distributed, rigid, essentially unicellular procaryotic microorganisms. Bacteria usually appear as spheroid, rod-like or curved entities, but occasionally appear as sheets, chains, or branched filaments.

Biochemical oxygen demand (BOD): The quantity of oxygen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions. Normally 5 days at 68°F unless otherwise stated. A standard test used in assessing the biodegradable organic matter in municipal wastewater.

Biogas: Gaseous product of anaerobic digestion that consists primarily of methane and carbon dioxide.

Chemical oxygen demand (COD): A measure of the oxygen-consuming capacity of inorganic and organic matter present in water or wastewater. It is expressed as the amount of oxygen consumed from a chemical oxidant in a specified test. It does not differentiate between stable and unstable organic matter and thus does not necessarily correlate with biochemical oxygen demand.

Composting: Biological degradation of organic matter under aerobic conditions to a relatively stable humus-like material called compost.

Denitrification: The reduction of oxidized nitrogen compounds (such as nitrates) to nitrogen gas or nitrous oxide gas.

Detention pond: An earthen structure constructed to store runoff water and other wastewater until such time as the liquid may be recycled onto land. Sometimes called holding ponds or waste storage ponds.

Detention time: The time wastes are subjected to a stabilization process or held in storage.

Digestion: Usually refers to the breakdown of organic matter in water solution or suspension into simpler or more biologically stable compounds, or both. In anaerobic digestion organic matter may be decomposed to soluble organic acids or alcohols and subsequently converted to such gases as methane and carbon dioxide. Complete decomposition of organic solid materials to gases and water by bacterial action alone is never accomplished.

Dissolved oxygen (DO): The molecular oxygen dissolved in water, wastewater, or other liquid, usually expressed in milligrams per liter, parts per million, or percent of saturation.

Earthen storage basin: An earthen structure usually with sloping sides and a flat floor, constructed to store semisolid, slurry or liquid manure. Also called a waste storage pond.

Effluent: The discharge of wastewater or other liquid, treated or untreated.

Electrical conductivity: A measure of a solution's ability to carry an electrical current; varies both with the number and type of ions contained by the solution.

Escherichia coli (E. Coli): One of the species of bacteria in the intestinal tract of warm-blooded animals. Its presence is considered indicative of fresh fecal contamination.

Facultative bacteria: Bacteria which can use either free oxygen or reduced carbon compounds as electron acceptors (as in organic substrates like sugars, starches, etc.) in their metabolism.

Fertilizer value: An estimate of the value of commercial fertilizer elements (N, P, K) that can be replaced by manure or organic waste material. Usually expressed as dollars per ton of manure or quantity of nutrients per ton of manure.

Fixed solids: The portion of the total solids remaining as an ash or residue when heated at a specific temperature and time (usually 600°C or 1112°F for at least one hour).

Food to microorganisms ratio (F/M): The weight ratio of biodegradable organic matter (BOD) to microorganisms.

Flushing system: A system that collects and transports or moves waste material with the use of water such as in washing of pens and flushing livestock systems.

Grassed infiltration area: An area with vegetative cover where runoff water infiltrates into the soil.

Gravity separation systems: Structures which utilize gravity to collect more dense particulate solids by allowing them to settle out of highly liquid manure. The structure may be of any shape but with a relatively shallow depth.

Infiltration rate: The rate at which water enters the soil or other porous material under a given condition, expressed as depth of water per unit time, usually in millimeters per hour.

Influent: Water, wastewater, or other liquid flowing into a reservoir, basin, or treatment plant, or any unit thereof.

Lagoon: An earthen structure for the storage and biological treatment of wastewater. Lagoons can be aerobic, anaerobic, or facultative depending on their loading and design.

Land application: Application of manure, sewage sludge, municipal wastewater and industrial wastes to land either for ultimate disposal or for reuse of the nutrients and organic matter for their fertilizer value.

Leaching: (1) The removal of soluble constituents such as nitrates or chlorides from soils or other material by water. (2) The removal of salts and alkali from soils by irrigation combined with drainage. (3) The disposal of a liquid through a nonwatertight artificial structure, conduit, or porous material by downward or lateral drainage, or both, into the surrounding permeable soil.

Loading rate: The quantity of material added per unit volume or unit area per unit time.

Mechanical solids separation: The process of separating suspended solids from a liquid-carrying medium by trapping the particles on a mechanical screen or sieve, or by centrifugation.

Sedimentation tank: A unit in which water or wastewater containing settleable solids is retained to remove by gravity a part of the suspended matter. Also called sedimentation basin, settling basin, settling tank or settling terrace.

Seepage: (1) Percolation of water through the soil. (2) The slow movement of water through small cracks, pores, interstices, of a material. (3) The loss of liquid by infiltration from a canal, reservoir, manure tank or manure stack. It is generally expressed as flow volume per unit time.

Settleable solids: (1) That matter in wastewater which will not stay in suspension during a preselected settling period, such as one hour. (2) In the Imhoff cone test, the volume of matter that settles to the bottom of the cone.

Settling basins: A relatively long-term separation structure, larger in size than a settling tank. Solids collection is by mechanical means once the liquids evaporate or have been drained away.

Settling tank: A relatively short-term separation structure, smaller in size than a settling basin. The liquid is allowed to fully drain away for solids removal by mechanical means.

Solids content: (1) The sum of the dissolved and suspended constituents in water or wastewater. (2) The residue remaining when the water is evaporated away from a sample of sewage, other liquids, or semi-solid masses of material and the residue is then dried at a specified temperature (usually 103°C or 217.4°F for 24 h); usually stated in milligrams per liter or percent solids.

Static inclined screen: A screen, mounted on an incline, over which manure passes as it flows by gravity from a top head box. The liquid passes through the screen due to its flow momentum and surface tension, while solids continue over and flow off the end of the screen.

Surface aerator: A partially submerged impeller whose action results in vigorous agitation and air entrainment. The impeller may be mounted on floats in a storage structure with varying liquid levels or fixed in a constant liquid system. Power may be supplied by an electric or hydraulic motor coupled directly to the impeller.

Suspended solids: (1) Solids that are in water, wastewater, or other liquids, and which are largely removable by filtering or centrifuging. (2) The quantity of material filtered from wastewater in a laboratory test, as prescribed in APHA Standard Methods for the Examination of Water and Wastewater.

Vibrating screen: A circular or square shallow container with a replaceable screen bottom. The assembly is vibrated both vertically and horizontally. Manure flows into the container, where liquids pass through the screen and the solids are collected to the side of the container.

Volatile solids: That portion of the total solids driven off as volatile (combustible) gases at a specified temperature and time (usually 600°C or 1112°F for at least 1 h).

Volatile suspended solids (VSS): That portion of the suspended solids driven off as volatile (combustible) gases at a specified temperature and time (usually 600°C or 1112°F for at least 20 min).