Chapter 2: System Components and Operation—Type A

Animal waste management systems are composed of structures and devices that collect, transport, recycle (flush), treat, store, and land apply the waste products resulting from the production of animals. As an operator of such a system, you will become knowledgeable of these system components and their proper operation and maintenance. Improper operation of any of these components could lead to a spill or runoff of the wastes, both of which are violations of state law discussed further in Chapter 8.

Type A animal waste management systems rely primarily on an anaerobic lagoon and soil/plant systems for the treatment of animal waste. These systems are generally used to treat animal waste generated by animals that produce a low-fiber waste, such as swine and poultry. These systems generally include the following components: anaerobic lagoon; pumps, pipes, and associated appurtenances that convey the waste from the point of generation to the final treatment/disposal site; flushing systems; solids separation equipment; irrigation equipment; and land application site and crops.

Lagoons are earthen structures that function as digestors where bacteria decompose organic matter. Anaerobic lagoons are used in the swine and poultry industry because of their efficiency and cost advantages. Anaerobic means the waste is treated without aeration or mixing devices. A properly sized and operated lagoon reduces organic material (which is the source of the majority of the odor), reduces the nitrogen concentration of the waste, and allows solids to settle out. Most of the phosphorus will accumulate in the sludge in the bottom of the lagoon.

An undersized lagoon increases the need for more intensive management and pumping frequency. It also increases odor potential and nutrient (nitrogen and phosphorus) levels of water that leaves the lagoon, either as flush water or as irrigation water to a field. An undersized lagoon also increases the rate of sludge (solids) buildup in the lagoon and requires more frequent sludge removal.
Describe the six specific volumes for an anaerobic lagoon.

The capacity of an anaerobic lagoon (as shown in Figure 2-1) includes volumes designed for:

1. **Sludge**—organic solids which cannot be further degraded by anaerobic bacteria and accumulates in the bottom of a lagoon.

2. **Permanent liquid treatment**—the amount of liquid which should always be present in a lagoon for optimal bacterial activity.

3. **Temporary liquid storage**—this volume should be based on the amount of wastewater, rainfall, and extra washwater that will enter the lagoon during periods when liquid cannot be irrigated onto a growing crop.

4. **25-year, 24-hour storm**—the most rainfall likely to occur in a 25-year period over a 24-hour duration (5 to 9 inches of rainfall for North Carolina).

5. **Heavy rainfall factor**—as a minimum must be equal to or greater than the depth of a 25-year, 24-hour storm on the lagoon surface to allow for excessive prolonged rainfall periods.

6. **Freeboard**—the required distance from the top of the lagoon dam or dike elevation (at its lowest point) to the highest allowed waste liquid elevation (at least 1 foot). This distance is in addition to the 25-year, 24-hour storm and the heavy rainfall factor.

*Note: Heavy rainfall factor not required for lagoons designed before September 1, 1996. Although not required, it is recommended to maintain storage to accommodate the heavy rainfall factor. See your original lagoon design or a technical specialist for more information.*

The **Permanent Storage Volume** is the sum total of the sludge storage volume and the permanent liquid treatment volume.

**Liquid Level Gauging Device**

Lagoons must have permanent markers inside the lagoon to assist with liquid level management. These show the absolute maximum and minimum operating levels to indicate when pumping is needed and when
pumping should stop. The markers should be routinely cleaned so you can easily observe the available storage. The marker’s location relative to the lagoon storage design can be seen in Figure 2-1. Lagoon level management will be discussed later in this chapter.

Figure 2-1. Schematic of an anaerobic waste treatment lagoon (note that this drawing is not to scale).

LAGOON DESIGN AND CONSTRUCTION

Proper lagoon design and construction is required to meet the requirements of N.C. Dam Safety Laws. A failure of your lagoon dam could affect the life, health, property, and public well-being of others in varying degrees, depending on the size and location of the dam. If your dam is over 15 feet in height or your lagoon has greater than 10 acre-feet of capacity, you are subject to the dam safety regulations. Proper design
and construction will also minimize the risk to surface water or groundwater as a result of lagoon overflow or seepage.

Lagoons should not be placed in low areas or wet areas where the potential exists for groundwater seepage into the lagoon. You should also check for areas where subsoil drainage tile has been installed. Either situation could cause the lagoon to remain full of water, regardless of how much irrigation pumping is done. If located within a floodplain, lagoons must be designed to prevent inundation during a 100-year flood event.

**LINERS**

Lagoon liners are used to reduce the permeability (seepage) of the bottom and sidewalls of the lagoon. This prevents or restricts the potential for downward and lateral seepage of the wastes from the lagoon. The types of lagoon liners used are:

- **Clay**—can usually be found near site; requires careful installation with proper compaction at the proper moisture content.

- **Bentonite**—is blended with existing soil; has to come from sources outside North Carolina; freight is expensive.

- **Synthetic membrane**—normally some type of plastic; requires careful installation by experienced contractor; easy to damage.

The need for a liner depends on the soils that are used for the construction of the lagoon. Natural Resources Conservation Service SNCTC Technical Note 716 (Revision 1) has guidelines for proper design.

**PIPES**

Pipes are important because they convey the waste from the animal confinement houses to the lagoon and from the lagoon to the fields for irrigation. Pipes are also used to recycle lagoon water used to flush the waste from the houses.
Factors that should be considered when choosing pipes include:

- **Material**—the pipe should be made of a durable material that can withstand contact with the waste. Plastic or concrete is usually more durable than metal.

- **Size**—the pipe must be large enough to carry the volume of waste without backup in the house. Recycling pipes that are too small can cause problems with pumps and motors. Pipes that are too large can allow solids buildup which may clog the pipe.

- **Slope**—pipes that carry waste from the swine and poultry houses to the lagoon should be on a slope of approximately 1 percent or greater to reduce the potential for solids buildup which may clog pipes.

- **Location**—pipe discharges should be located where they will not cause problems, such as: erosion of the lagoon liner or embankment, interference with traffic around the lagoon, or interference with diversion of surface water away from the lagoon. Pipes should not be installed in the embankment without proper engineering considerations. Pipes through embankments must have anti-seep collars or other devices. Pipes that are above ground must be properly supported with piers, posts, or a cradle to prevent sagging. To reduce odors, the pipe must discharge below the liquid surface. This also helps to minimize potential lagoon liner damage.

As the operator, you should know where all pipes are located at your facility. You should make a map of your facility with all pipes clearly marked. The map should show the types of pipes, size, and the type of water each pipe carries (such as flush water, drinking water for animals, and drinking water for office). A color code system for the pipes will help separate the types of pipes and their uses.

Breaks in piping are a common cause of discharges of animal waste. You should keep extra repair pipes and valves in the event of a break. During repair of any pipe which carries waste, some temporary means must be used to ensure that all wastes and flush waters still reach the lagoon or holding pits. Commonly, a small dug trench is used for such temporary situations, being careful not to damage the lagoon liner. It is crucial to...
know where all pipes are so that repair equipment does not cause further pipe breakage.

Frequent inspections of the piping system, including walking the areas where there are underground pipes, cannot be over emphasized. This should be done at least as frequently as you evaluate the lagoon level.

**LAGOON MAINTENANCE**

Proper lagoon liquid management should be a year-round priority. It is especially important to manage levels so that you do not have problems during extended rainy and wet periods.

Maximum storage capacity should be available in the lagoon for periods when the receiving crop is dormant (such as wintertime for bermudagrass) or when there are extended rainy spells such as the thunderstorm season in the summertime. This means that at the first signs of plant growth in the late winter/early spring, irrigation according to a farm waste management plan (see Chapter 3) should be done whenever the land is dry enough to receive lagoon liquid. This will make storage space available in the lagoon for future wet periods. In the late summer/early fall the lagoon should be pumped down to the low marker (see Figure 2-1) to allow for winter storage. Every effort should be made to maintain the lagoon close to the minimum liquid level as long as the weather and waste management plan will allow it.

Waiting until the lagoon has reached its maximum storage capacity before starting to irrigate does not leave room for storing excess water during extended wet periods. Overflow from the lagoon for any reason except a 25-year, 24-hour storm is a violation of state law and subject to enforcement action.

The routine maintenance of a lagoon is necessary to ensure the structure does not erode or otherwise allow the wastes to leak or discharge. Routine maintenance involves the following:

- Maintenance of a vegetative cover for the dam. Fescue or common bermudagrass are the most common vegetative covers. The vegetation should be fertilized each year, if needed, to maintain a vigorous stand. The amount of fertilizer applied should be based...
on a soils test, but in the event that it is not practical to obtain a soils test each year, the lagoon embankment and surrounding areas should be fertilized with 800 pounds per acre of 10-10-10, or equivalent.

- Brush and trees on the embankment must be controlled. This may be done by mowing, spraying, chopping, or a combination of these practices. This should be done at least once a year and possibly twice in years that weather conditions are favorable for heavy vegetative growth.

*Note: If the vegetation is controlled by spraying, the herbicide must not be allowed to enter the lagoon water. Such chemicals could harm the bacteria in the lagoon that are treating the waste.*

Maintenance inspections of the entire lagoon should be made during the initial filling of the lagoon and at least weekly. Items to be checked should include, as a minimum, the following:

- Waste Inlet Pipes, Recycling Pipes, and Overflow Pipes—look for:
  1. separation of joints
  2. cracks or breaks
  3. accumulation of salts or minerals
  4. overall condition of pipes

- Lagoon surface—look for:
  1. undesirable vegetative growth
  2. floating or lodged debris
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- Embankment—look for:
  1. settlement, cracking, or holes on embankment and around pipes
  2. side slope stability—slumps or bulges
  3. wet or damp areas on the back slope
  4. erosion due to lack of vegetation or as a result of wave action
  5. rodent damage
  6. tree damage

Larger lagoons may be subject to liner damage due to wave action caused by strong winds. These waves can erode the lagoon sidewalls, thereby weakening the lagoon dam. A good stand of vegetation will reduce the potential damage caused by wave action. If wave action causes serious damage to a lagoon sidewall, baffles or rip-rap in the lagoon may be used to reduce the wave impacts.

Any of these features could lead to erosion and weakening of the dam. If your lagoon has any of these features, you should call an appropriate expert familiar with design and construction of waste lagoons. There is a resource list in Appendix A of experts in your area. You may need to provide a temporary fix if there is a threat of a waste discharge. However, a permanent solution should be reviewed by the technical expert. Any digging into a lagoon dam with heavy equipment is a serious undertaking with potentially serious consequences and should not be conducted unless recommended by an appropriate technical expert.

- Transfer Pumps—check for proper operation of:
  1. recycling pumps
  2. irrigation pumps

Check for leaks, loose fittings, and overall pump operation. An unusually loud or grinding noise, or a large amount of vibration, may indicate that the pump is in need of repair or replacement. Follow manufacturers’
specifications for routine pump maintenance, and record all maintenance and service performed on pumps in a log book.

*Note: Pumping systems should be inspected and operated frequently enough so that you are not completely “surprised” by equipment failure. You should perform your pumping system maintenance at a time when your lagoon is at its low level. This will allow some safety time should major repairs be required. Having a nearly full lagoon is not the time to think about switching, repairing, or borrowing pumps. Probably, if your lagoon is full, your neighbor’s is full also. You should consider maintaining an inventory of spare parts or pumps.*

- Surface water diversion features are designed to carry all surface drainage waters (such as rainfall runoff, roof drainage, gutter outlets, and parking lot runoff) away from your lagoon and other waste treatment or storage structures. The only water that should be going in your lagoon is that which comes from your flushing (washing) system pipes and the rainfall that hits the lagoon directly. You should inspect your diversion system for the following:
  1. adequate vegetation
  2. diversion capacity
  3. ridge berm height

The only exception to this is if you maintain animals or waste piles outside in such a manner that runoff from the concentrated animal area or waste area may enter surface waters. You should consult with a technical specialist to see what best management practices are needed for these situations. One possible practice is to catch the contaminated runoff water in the lagoon.

Identified problems should be corrected promptly. You should inspect your diversion during or immediately following a heavy rain. If technical assistance is needed to determine proper solutions, consult with appropriate experts.
You should record the level of the lagoon just prior to when rain is predicted, and then record the level again 4 to 6 hours after the rain (this assumes there is no pumping). This will give you an idea of how much your lagoon level will rise with a certain rainfall amount (you must also record your rainfall for this to work). Knowing this should help in planning irrigation applications and storage. If your lagoon rises excessively, you may have an inflow problem from a failing surface water diversion or there may be seepage into the lagoon from the surrounding soil.

**LAGOON OPERATION**

**Startup:**

1. Immediately after construction, establish a complete sod cover on bare soil surfaces to avoid erosion.

2. Fill new lagoon permanent storage volume at least half full of water before waste loading begins, taking care not to erode lining or embankment slopes.

3. Drainpipes into the lagoon must have pipe extender on the end of the pipe to discharge near the bottom of the lagoon during initial filling, or another means of slowing the incoming water to avoid erosion of the liner and minimize odors.

4. When possible, begin loading new lagoons in the spring to maximize bacterial establishment (due to warmer weather).

5. It is recommended that a new lagoon be seeded with sludge from a healthy working waste treatment lagoon in the amount of 0.25 percent of the full lagoon liquid volume. This seeding should occur at least two weeks prior to the addition of wastewater.

6. Maintain a periodic check on the lagoon liquid pH. If the pH falls below 7.0, dose with agricultural lime at the rate of 1 pound per 1000 cubic feet of lagoon liquid volume and thoroughly mix until the pH rises above 7.0. Optimum lagoon liquid pH is between 7.5 and 8.0.
7. A dark color, lack of bubbling, and excessive odor signals inadequate biological activity. Consultation with a technical specialist is recommended if these conditions occur for prolonged periods, especially during the warm season.

**Loading:**

The more frequently and regularly that wastewater is added to a lagoon, the better the lagoon will function. Flush systems that wash waste into the lagoon several times daily are optimum for treatment. Pit recharge systems, in which one or more buildings are drained and recharged each day with all buildings being recharged once per week, also work well.

- Practice water conservation (water reuse)—minimize building water usage and spillage from leaking waterers, broken pipes, and washdown through proper maintenance and water conservation. This reduces fresh water consumption, and reduces the volume of wastewater that ultimately must be stored in the lagoon and land applied.

- Minimize feed wastage and spillage by keeping feeders adjusted. This will reduce the amount of solids entering the lagoon.

**Management:**

- Maintain lagoon liquid level between the permanent storage volume level and the full temporary storage level.

- Place highly visible markers or stakes on the lagoon bank to show the minimum liquid level and the maximum liquid level (Figure 2-1).

- Start irrigating at the earliest possible date in the spring based on nutrient requirements and soil moisture so that temporary storage will be maximized for the summer thunderstorm season. Similarly, irrigate in the late summer/early fall to provide maximum lagoon storage for the winter.
• The lagoon liquid level must never be closer than 1 foot plus the 25-year, 24-hour storm storage to the lowest point of the dam or embankment. For lagoons constructed after September 1, 1996, storage for the heavy rainfall factor must also be maintained.

• Do not pump the lagoon liquid level lower than the permanent storage level unless you are removing sludge.

• Do not lower the lagoon liquid level below the seasonal groundwater table (see your system design or contact the local office of the Natural Resources Conservation Service for this level).

• Locate float pump intakes approximately 18 inches underneath the liquid surface and as far away from the drainpipe inlets and embankments as possible.

• Prevent additions of bedding materials, long-stemmed forage or vegetation, molded feed, plastic syringes, or other foreign materials into the lagoon.

• Frequently remove solids from catch basins at end of confinement houses or wherever they are installed.

• Maintain strict vegetation, rodent, and varmint control over the entire embankment.

• Do not allow trees or large bushes to grow on lagoon dam or embankment.

• Remove sludge from the lagoon either when the sludge storage capacity is full or before it fills 50 percent of the permanent storage volume. The treatment volume must always have at least 4 feet of depth that is free of sludge.

• If animal production is to be terminated, the owner is responsible for obtaining and implementing a closure plan to eliminate the possibility of a pollutant discharge. An alternative to closure may be to maintain a certified waste management plan and operate the system according to that plan, even though there is no additional manure input. You should consult the regional office of DWQ...
Rate of lagoon sludge buildup can be reduced by:

- proper lagoon sizing,
- mechanical solids separation of flushed waste,
- gravity settling of flushed waste solids in an appropriately designed basin, or
- minimizing feed wastage and spillage.

Lagoon sludge that is removed annually rather than stored long-term will:

- have more nutrients,
- have more odor, and
- require more land to properly use the nutrients.

Removal techniques:

- Hire a custom applicator.

- Mix the sludge and lagoon liquid with a chopper-agitator impeller pump; pump through large-bore sprinkler irrigation system onto nearby cropland and soil incorporate.

- Dewater the upper part of lagoon by irrigation onto nearby cropland or forageland; mix remaining sludge; pump into liquid sludge applicator; haul and spread onto cropland or forageland and soil incorporate.

- Dewater the upper part of lagoon by irrigation onto nearby cropland or forageland; dredge sludge from lagoon with dragline or sludge barge; berm an area beside lagoon to receive the sludge
so that liquids can drain back into lagoon; allow sludge to dewater; haul and spread with manure spreader onto cropland or forageland and soil incorporate. You should consult your waste management plan, farm conservation plan, or local Soil and Water Conservation district office to see if the specific fields used for sludge application can be disturbed with soil incorporation equipment.

Regardless of the method, you must have the sludge material analyzed for waste constituents just as you would your lagoon water. The sludge will contain different nutrient and metal values from the liquid. The application of the sludge to fields will be limited by these nutrients, as well as any previous waste applications to that field, and crop requirement. Waste application rates will be discussed in detail in Chapter 3.

When removing sludge, you must also pay attention to the liner to prevent damage. Close attention by the pumper or drag-line operator will ensure that the lagoon liner remains intact. If you see soil material or the synthetic liner material being disturbed, you should stop the activity immediately and not resume until you are sure that the sludge can be removed without liner injury. If the liner is damaged it must be repaired as soon as possible.

Sludge removed from the lagoon has a much higher phosphorus and heavy metal content than lagoon liquid. Because of this it should be applied to land with low phosphorus and metal levels, as indicated by a soil test, and incorporated to reduce the chance of erosion. Note that if the sludge is applied to fields with very high soil-test phosphorus, it should be applied only at rates equal to the crop removal of phosphorus (see Chapter 3).

The application of sludge will increase the amount of odor at the waste application site. Extra precaution should be used to observe the wind direction and other conditions which could increase the concern of neighbors. Injection or incorporation of sludge will help reduce odors.
Crystal Buildup in Recycle Lines

Struvite (magnesium ammonium phosphate) or similar crystalline material frequently occurs in lagoon liquid recycle pipes. This material develops in pumps and/or at joints of restriction and turbulence in the pipeline. The material starts as a soft scum that adheres to the pipes and pumps. However, once the material solidifies additional crystal growth can be rapid and can completely block even large pipes. There is no proven method of totally preventing these crystals.

To minimize difficulties associated with struvite the following should be considered:

1. Use only smooth-walled plastic pipe.
3. Keep pipe flow velocities well below 5 feet per second.
4. Keep pipes and pumps as free of particulates 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. There are several acids (including muriatic or hydrochloric acid) that have been used somewhat successfully to decrease struvite buildup. Extreme caution must be exercised when handling acid. Eye protection and gloves should always be used. Diluted acid solutions 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 into the lagoon.
POSSIBLE CAUSES OF LAGOON FAILURE

Lagoon failures result in the unplanned discharge of wastewater from the structure. Types of failure include leakage through the bottom or sides, overtopping, and breach of the dam. Assuming proper design and construction, the owner has the responsibility for ensuring structure safety. Items which may lead to lagoon failures include:

- Modification of the lagoon structure—an example is the placement of a pipe in the dam without proper design and construction. (Consult an expert in lagoon design before placing any pipes in dams.)

- Lagoon liquid levels—high levels are a safety risk.

- Failure to inspect and maintain the dam.

- Excess surface water flowing into the lagoon.

- Liner integrity—protect from inlet pipe scouring, damage during sludge removal, or rupture from lowering lagoon liquid level below groundwater table.

- Rodent and tree damage to lagoon embankments.

Note: Lagoon water should not be allowed to overtop dam. If lagoon water does overtop the dam, the moving water during overtopping will soon cause gullies to form in the dam. Once this damage starts, it can quickly cause a large discharge of wastewater and possible dam failure. A technical specialist’s or professional engineer’s advice should be sought for information on repair.

INNOVATIVE AND NEW MANAGEMENT PRACTICES

Describe some methods that could be used to enhance waste treatment.

There are several methods of improving or enhancing the handling and treatment of animal wastes. Many of these methods involve the separation of solids and liquids within the animal waste system. The producer may benefit through decreased costs in sludge and solids removal from lagoons, decreased nitrogen concentrations in wastewaters and the increased flexibility in the land application of wastes depending on the enhancement method used.
**SOLIDS SEPARATION**

Removal of fresh solids from manure slurries and flush water will reduce the pollutant content of manure, prolong the life of storage structures, improve the effectiveness of biological treatment, and minimize odors. Beneficial uses of the recovered solids include bedding materials, animal feed supplements, composts, and soil amendments. Solids separation can be done with mechanical or gravity devices.

**Mechanical**

Mechanical separators of animal waste include: inclined screens, vibrating-screens, belt presses, and screw presses. Manure is collected in a sump sized to store the largest combination of flush tank capacities or pit storage accumulations. A submersible or stationary bottom-impeller lift pump mixes the manure and liquids into a slurry and pumps it across the separator where the liquid drains off. These devices are effective in removing at least 30 percent of all solids, and produce a product with a moisture content between 30 and 35 percent. Separators with few moving parts, such as inclined screens and vibrating-screens, are more effective when large amounts of water are moved through the devices, such as in flushing systems. Most mechanical separators require daily cleaning and flow adjustments. Screens will need to be replaced periodically when the solids removal is decreased.

**Gravity**

A gravity settling basin may be less costly while removing 50 percent or more of the solids from liquid manure. Solids can be settled and filtered by a shallow basin (2 to 3 feet deep) with concrete floors and walls and a porous dam or perforated pipe outlet. Basins should allow access by a front-end loader to remove solids every 1 to 2 months.

An alternative is an earthen settling basin for 6 to 12 months storage of solids. The basin top width should be no more than 100 feet with a length-to-width ratio near 3:1 and a liquid depth of 8 to 10 feet. The basin contents should be thoroughly agitated and removed for land spreading either by a liquid manure spreader or slurry irrigation. If an earthen basin is used, the operator must make the necessary inspections discussed earlier in this chapter for anaerobic lagoons. The dam structure and waste level
must be constantly monitored, and the dam structure maintained to allow visual inspection for structural deterioration.

A third alternative consists of a large rectangular metallic or concrete settling tank with a 3:1 length-to-width ratio with an 8-foot depth. Tank volume depends on a peak-flow wastewater detention time of 10 to 30 minutes. Most solids in livestock manure settle in about 10 minutes although some additional settling occurs for hours. Tank inlets and outlets are baffled and solids are removed by automated skimmers and scrapers. Unless substantial solids storage is added to the settling tank volume, tank cleaning will need to occur frequently. Small solids collector basins at the end of flushing floors can be effective at removing solids, but typically require daily maintenance if they are to function efficiently as a solids separation system. Solids are removed by shovel and placed into a hopper or spreader for land application.

The use of solid/liquid separators will improve the waste handling and treatment efficiencies of many livestock operations. With the removal of manure solids, the storage life of a structure will be increased and costs can be saved due to the decreased need for sludge removal. The buildup of phosphorus, copper, and zinc will be reduced. In some instances where lagoons are undersized or are not effectively treating waste, solids removal may reduce the waste load to a level where proper anaerobic treatment can occur. The buildup of solids in transfer pipes and pumps will also be reduced.

Solids and liquids from mechanical and gravity separators can be utilized in many different fashions, many of which allow the producer to develop a value-added by-product. Due to the relatively low moisture content, separated solids may easily be composted or fermented as a feed supplement. Composting of manure solids will create temperatures high enough to kill off bacteria while producing a stabilized soil amendment or bedding source for dairy-free stall barns. The liquid fraction from a separator contains most of the manure fertilizer value. With large fibers and solids removed, this liquid can be treated in an aerobic or anaerobic lagoon and pumped efficiently for proper land application. Dried manure solids can generally be stored and handled without offensive odors.
In summary a solid/liquid separator may accomplish the following:

- reduce the volume of manure storage needed;
- improve anaerobic digestion;
- reduce concentrations of phosphorus, copper, and zinc in sludge and effluents;
- reduce pipe clogging problems;
- produce value-added by-products;
- allow the use of irrigation or direct soil injection equipment;
- reduce pumping horsepower needed and increase pumping distances; and
- allow a greater hauling distance for solids as compared to liquid slurry or lagoon sludge (due to better dewatering).

**Composting**

Composting biologically stabilizes organics like manure into a humus-like material. The opportunity exists for livestock producers to compost on farm manures, separated manure solids, vegetative matter, or by-products from other agricultural or nonagricultural sources. In some cases, composting may be a less expensive waste reduction process than alternative storage and treatment methods. The final composted product has less odor and breeds fewer flies than raw manure. The volume and weight is less than raw manure, thus requiring less cost to haul and spread the compost. Also, the heat generated by the composting process destroys pathogenic organisms and weed seeds in the manure.

Factors such as particle size, aeration, moisture content, carbon-to-nitrogen (C:N) ratio, and temperature are critical to efficient composting. The raw material particle size determines the porosity of the pile, which affects aeration. Optimum moisture contents range from 50 to 60 percent. C:N ratios should range from 20:1 to 30:1. Temperatures generated by microbial activity should reach 130° to 160°F. Temperature can be most
affected by aeration and moisture content. Composting can occur in windrows, with aeration provided by mechanical turning, or in static piles or bins with forced aeration.

The drier the collected manure or material is, the more compatible composting will be. Farmers considering investing in manure storage should find that composting is a competitive option. The equipment, methods, and handling practices are similar to those used for other farm operations. Care should be taken at composting sites to protect groundwater and surface water impoundments. Before initiating a composting operation, the supply of raw materials and demand for the finished product must be reliably established.

AEROBIC TREATMENT

The main advantages of aerobic (with oxygen) lagoons are that bacterial treatment tends to be more complete than anaerobic treatment and the end products are relatively odorless. In naturally aerobic lagoons or oxidation ponds, oxygen needed for treatment diffuses across the water surface. Mechanically aerated lagoons combine the odor control advantages of aerobic digestion with relatively small surface area requirements. Aerators are used mainly to control odors in sensitive areas and nitrogen removal where land available for manure application is limited. A major limitation for mechanically aerated lagoons is the expense of continually operating electrically powered aerators. Aerobic lagoons also produce more sludge than anaerobic lagoons because more of the manure is converted to microbial biomass. Suitable land must be available to accept the sludge with its associated nutrients, although it may be possible to dewater this sludge (see above) and move the solids off the farm for application at other farms or for other treatment such as composting.

MULTISTAGE LAGOONS

Two-stage lagoons have certain advantages over the typical single, primary lagoon. A two-stage anaerobic lagoon system has the same total liquid volume as a single primary lagoon. The first lagoon contains the design treatment volume and the sludge storage volume, while the second lagoon provides temporary storage prior to land application. A two-stage lagoon allows a maximum liquid level to be maintained in the primary lagoon for the most efficient stabilization of incoming wastes. The result...
is a more stable operation, which helps to minimize odors. More than two lagoons in series are rarely beneficial.

Pumping from a second-stage lagoon also reduces the solids pickup common to primary lagoons due to seasonal water turnovers, floating debris, and biological mixing. Because of the reduced solids, the second stage of a two-stage anaerobic lagoon system appears to have up to 25 percent less nitrogen in the lagoon liquid and up to 50 percent less phosphorus than a single primary lagoon with the same total volume. A second-stage lagoon, since it functions only as storage, may be pumped down completely. There only needs to be an upper level marker in this lagoon.

Disadvantages of multistage lagoons include:

- increased surface area to meet storage volume requirements, and
- increased construction cost.

**ODOR CONTROL PRODUCTS**

A number of commercial products have been marketed that advertise the ability to either reduce or control odors. These materials include:
1. (1) masking agents,
2. (2) chemicals that can temporarily bind ammonia,
3. (3) chemicals that inhibit urease production and, therefore, ammonia production,
4. (4) chemicals that neutralize odor,
5. (5) chemicals that stimulate bacterial growth, and
6. (6) bacterial preparations that contain “special” strains of bacteria. However, most of these products have not been scientifically evaluated and proven to be effective. Nonetheless, there are numerous reports from producers attesting to the partial effectiveness of some of these products. A livestock 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.

Describe methods that can be used to minimize odors.
Describe the need for a properly designed irrigation system.

A properly designed irrigation system provides the operator the opportunity to uniformly apply wastewater at agronomic rates without direct runoff from the site. However, a “good design” does not guarantee proper land application. The performance of a well-designed system can be ruined by poor management; likewise, a poorly designed system can sometimes provide good performance with proper, intensive management. You should be familiar with your system components, range of operating conditions, and maintenance procedures and schedules to keep your system in proper operating condition.

If irrigation equipment was in place prior to September 1, 1996, detailed design specifications for the irrigation system were not required to be included in the certified waste management plan. As a result, you may not have been provided specifications and management guidelines needed to ensure proper operation of your system. A brief description of system components and general operational procedures for common types of wastewater irrigation systems follows. Contact the irrigation designer or technical specialist who certified your waste management plan to obtain details and manufacturer specifications for your system. This information will be required when you apply for your General Permit (see Chapter 8).

There are two primary types of wastewater irrigation systems: stationary and traveling sprinklers.

Stationary Sprinkler Systems

Stationary systems for land application of lagoon liquid are usually permanent installations (lateral lines are PVC pipes permanently installed below ground). One of the main advantages of stationary sprinkler systems is that these systems are well suited to irregularly shaped fields. Thus, it is difficult to give a standard layout, but there are some common features between systems. To provide proper overlap, sprinkler spacings are normally 50 to 65 percent of the sprinkler wetted diameter. Sprinkler spacing is based on nozzle flow rate and desired application rate. Sprinkler spacings are typically in the range of 80 feet by 80 feet using single-nozzle sprinklers. Other spacings can be used and some systems are designed to use gun sprinklers (higher volume) on wider spacings. A typical layout for a permanent irrigation system is shown in Figure 2-2.
Most permanent systems use Class 160 PVC plastic pipe for mains, submains, and laterals and either 1-inch galvanized steel or Schedule 40 or 80 PVC risers near the ground surface where an aluminum quick coupling riser valve is installed. In grazing conditions, all risers must be protected (stabilized) if left in the field with animals.

The minimum recommended nozzle size for wastewater is 1/4 inch. Typical operating pressure at the sprinkler is 50 to 60 PSI. Sprinklers can operate full or partial circle. The system should be zoned (any sprinklers operated at one time constitutes one zone) so that all sprinklers are operating on about the same amount of rotation to achieve uniform application. Gun sprinklers typically have higher application rates; therefore, adjacent guns should not be operated at the same time (referred to as “head to head”).

Traveling Sprinklers

Traveling sprinkler systems are either cable-tow traveler, hard-hose traveler, center pivot, or linear-move systems.

The cable-tow traveler consists of a single-gun sprinkler mounted on a trailer with water being supplied through a flexible, synthetic fabric, rubber- or PVC-coated hose. Pressure rating on the hose is normally 160 PSI. A steel cable is used to guide the gun cart.
The hose-drag traveler consists of a hose drum, a medium-density polyethylene (PE) hose, and a gun-type sprinkler. The hose drum is mounted on a multiwheel trailer or wagon. The gun sprinkler is mounted on a wheel or sled type cart referred to as the gun cart. Normally, only one gun is mounted on the gun cart. The hose supplies wastewater to the gun sprinkler and also pulls the gun cart toward the drum. The distance between adjacent pulls is referred to as the lane spacing. To provide proper overlap, the lane spacing is normally 70 to 80 percent of the gun wetted diameter. A typical layout for a hard-hose traveler irrigation system is shown in Figure 2-3.

The hose drum is rotated by a water turbine, water piston, water bellows, or by an internal combustion engine. Regardless of the drive mechanism, the system should be equipped with speed compensation so that the sprinkler cart travels at a uniform speed from the beginning of the pull until the hose is fully wound onto the hose reel. If the solids content of the wastewater exceeds 1 percent, an engine drive should be used.

Nozzle sizes on gun-type travelers are 1/2 to 2 inches in diameter and require operating pressures of 75 to 100 PSI at the gun for uniform distribution. The gun sprinkler has either a taper bore nozzle or a ring nozzle. The ring nozzle provides better breakup of the wastewater stream which results in smaller droplets with less impact energy (less soil compaction) and also provides better application uniformity throughout.
the wetted radius. But, for the same operating pressure and flow rate, the taper bore nozzle throws water about 5 percent further than the ring nozzle, i.e. the wetted diameter of a taper bore nozzle is 5 percent wider than the wetted diameter of a ring nozzle. This results in about a 10 percent larger wetted area such that the precipitation rate of a taper bore nozzle is approximately 10 percent less than that of a ring nozzle.

A gun sprinkler with a taper bore nozzle is normally sold with only one size nozzle whereas a ring nozzle is often provided with a set of rings ranging in size from 1/2 to 2 inches in diameter. This allows the operator flexibility to adjust flow rate and diameter of throw without sacrificing application uniformity. However, there is confusion that using a smaller ring with a lower flow rate will reduce the precipitation rate. This is not normally the case. Rather, the precipitation rate remains about the same because while a smaller nozzle results in a lower flow, it also results in a smaller wetted radius or diameter. The net effect is little or no change in the precipitation rate. Furthermore, on water drive systems, the speed compensation mechanism is affected by flow rate. There is a minimum threshold flow required for proper operation of the speed compensation mechanism. If the flow drops below the threshold, the travel speed becomes disproportionately slower, resulting in excessive application even though a smaller nozzle is being used. System operators should be knowledgeable of the relationships between ring nozzle size, flow rate, wetted diameter, and travel speed before interchanging different nozzle sizes. As a general rule, operators should consult with a technical specialist before changing nozzle size to a size different than that specified in the certified waste management plan.

Center Pivots and Linear Move Systems

The use of center-pivot systems for wastewater irrigation is increasing. Center pivots are available in both fixed-pivot point and towable machines. They are available in size from single tower machines that cover around 10 acres to multitower machines that can cover several hundred acres. Center pivots use either rotary sprinklers, small guns, or spray nozzles. Drop-type spray nozzles offer the advantage of applying wastewater close to the ground at low pressure, which results in little wastewater drift due to wind. Linear-move systems are similar to center pivot systems, except that travel is in a straight line. Depending on the type of sprinkler used, operating pressure ranges from 10 to 50 PSI. Low
pressure systems reduce drift at the expense of higher application rates and greater potential for runoff.

These system types can only be used where large fields without drainage ditches exist. As the use of these systems is limited for animal waste application, the calibration of these systems will not be covered.

In summary, below are several advantages and disadvantages for stationary and traveling irrigation systems:

<table>
<thead>
<tr>
<th>STATIONARY SYSTEMS</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>good for small or irregular fields</td>
<td>higher initial costs</td>
</tr>
<tr>
<td></td>
<td>do not have to move equipment</td>
<td>must protect from animals in fields</td>
</tr>
<tr>
<td></td>
<td></td>
<td>small bore sprinklers more likely to get plugged or broken</td>
</tr>
<tr>
<td></td>
<td></td>
<td>no flexibility to move to other (new) fields</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TRAVELING SYSTEMS</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>system is transportable</td>
<td>more difficult to calibrate</td>
<td></td>
</tr>
<tr>
<td>application rate can be adjusted (speed and nozzle settings)</td>
<td>does not maximize the use of area for irregularly shaped fields</td>
<td></td>
</tr>
<tr>
<td>easily used for new fields</td>
<td>impractical for small areas</td>
<td></td>
</tr>
</tbody>
</table>

Describe the advantages and disadvantages of stationary and traveling sprinkler systems.
PUMPS

Pumps used for land application of wastewater are generally straight centrifugal pumps when solids content is less than 4 percent. A centrifugal pump consists of an impeller rotating in a casing. Open impeller-type pumps are normally used for wastewater applications. A gate valve, discharge check valve, and totalizing propeller-type flow meter should be installed on the discharge side of the pump. The suction line and strainer should be floated in the lagoon so that the intake is about 18 inches below the water level and able to draw the most solids-free liquid. The pump should be located as far from the inlet pipe to the lagoon as possible. If the lagoon is located in an area where a prevailing wind direction exists, the pump should be located on the upwind side of the lagoon because solids tend to migrate to the downwind side.

Pumps are rated to deliver a set number of gallons at a given operating head (pressure) at a specified efficiency. Pump manufacturers provide pump curves for each of their pumps. These curves show the relationship between head, horsepower, capacity, and efficiency. Pump curves can be used in case you need to modify your operating conditions from the original irrigation design. As pump models are discontinued it becomes more difficult to obtain this information for older pumps. Keep equipment specification information in a safe place, such as with your other operational records.

OPERATION

A thorough knowledge of the irrigation system is needed to apply wastewater in accordance with the waste utilization plan. The operator must be familiar with correct pressure settings, sprinkler spacing, and time of operation needed to ensure the appropriate amount is uniformly applied. Irrigation equipment calibration will be discussed in detail in Chapter 5.
**Pump and Haul Waste Management Systems**

Describe the advantages and disadvantages of a pump and haul waste management system.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• provides more transport mobility</td>
<td>• requires more time and labor</td>
</tr>
<tr>
<td>• allows direct soil injection</td>
<td>• higher operating costs</td>
</tr>
<tr>
<td></td>
<td>• requires improved travel roads and proper soil trafficability</td>
</tr>
</tbody>
</table>

Proper location and design of pumping and loading areas are necessary to protect equipment and operators and to avoid damaging the lagoon dike or embankment. Care should be taken to minimize spills during loading and transport.

Liquid tank spreaders must be accurately calibrated to apply wastes at proper rates. Calibration is the combination of settings and travel speed needed to apply wastes at a desired rate and to ensure uniform application. To calibrate you must know the spreader capacity, which is normally rated by the manufacturer in gallons. Calibration procedures for pump and haul systems are found at the end of Chapter 5.

**Review Questions**

1. Name the six design volumes for an anaerobic lagoon. ............................................................see page 2A-2

2. Describe some common types of lagoon liners. ........see page 2A-4

3. Explain when and why you should pump lagoon wastewater to cropland. ........................................ see page 2A-6

4. What should you do if your lagoon is generating a significant amount of foul odors? .............................................see page 2A-11
5. Name some maintenance procedures that should be performed periodically to ensure the lagoon does not leak or develop a dam break. ................................................. see pages 2A-11 to 2A-12

6. Name several causes of lagoon failures. ..................see page 2A-16

7. List several ways in which you may be able to reduce the amount of solids entering an anaerobic lagoon. ..see pages 2A-17 to 2A-18

8. Name some advantages and disadvantages of the following types of waste application equipment:
   
   • stationary big guns .......................................see page 2A-26
   
   • traveling guns ...............................................see page 2A-26
   
   • pump and haul (honey wagon) .........................see page 2A-28