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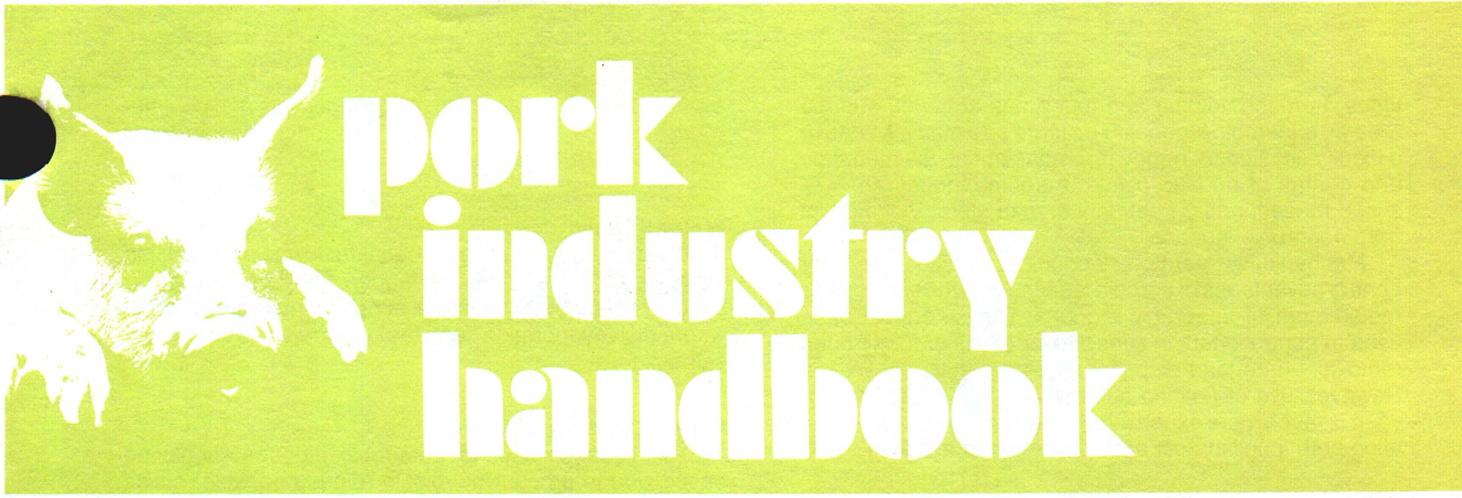

COOPERATIVE EXTENSION SERVICE ● MICHIGAN STATE UNIVERSITY

Lagoon Systems For Swine Waste Treatment

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Lagoon systems provide treatment of livestock manure and storage of treated products prior to final utilization or disposal on land. Lagoons designed and operated for destructive treatment (breakdown) of manure can reduce organic matter and nitrogen by more than 50%. In addition, lagoons can be designed and operated to provide ample storage of manure and wastewater to meet no-discharge requirements of state and federal water pollution control agencies and to fit cropping and labor cycles of the livestock feeding operation. Lagoons are also used to supply water for flushing in many swine operations.

Advantages and Disadvantages

Properly designed and operated lagoon systems for treatment and storage of livestock waste have many advantages. These include:

- Compatibility with modern hydraulic cleaning and/or pit overflow systems
- Low cost construction
- Maximum convenience in manure handling and land spreading
- Minimum operating costs
- Low labor requirement
- Reduction or elimination of fly problems

However, there are also disadvantages in using lagoon systems. Some disadvantages are:

- Appreciable loss of manure fertilizer value, especially nitrogen
- Need for terminal disposal of effluent by irrigation
- Need for periodic sludge removal
- Possible formation of mosquito habitat
- Cost of equipment and electrical energy where aerators are used

Also, odors, flies and groundwater pollution may result if the system is under-designed or poorly managed.

Lagoon systems are preferable to storage pit/tank wagon systems when insufficient cropland is available for full utilization of manure as fertilizer, when large volumes of water are used for manure removal, and/or when labor is limited. Lagoons are not recommended for a site that has a porous subsoil or a high water table unless an impervious lining is installed. Lagoons are recommended only where adequate distances to property lines and residences can be established.

Types and Characteristics of Lagoons

Livestock waste lagoons act as digestion facilities in which three categories of bacteria—aerobic, anaerobic and facultative—decompose the manure organic matter. Aerobic bacteria require dissolved oxygen to survive. Anaerobic bacteria cannot survive in free oxygen. Facultative bacteria can grow with or without free oxygen in the liquid waste material.

Anaerobic lagoons are commonly used for livestock waste treatment. This type of lagoon can handle relatively high loading rates of organic wastes. However, anaerobic decomposition of livestock waste can result in the production and release of odorous compounds. Proper design and operation will lessen odor emissions. Lagoon volume and dimensions should be carefully selected. Relatively constant operating conditions for anaerobic decomposition should be provided by maintaining the proper water level and by discharging manure into the lagoon daily or as frequently as possible.

In aerobic lagoons, algae generate oxygen through photosynthesis, which takes place where sunlight penetrates the water (upper 4-5 ft.). Oxygen diffusion also occurs by wind action across the surface of the water. Thus, a maximum water depth of 5 ft. is recommended. Aerobic bacteria produce little or no odor but much more sludge than anaerobic bacteria. A naturally aerobic livestock waste lagoon is generally impractical as the sole means of treatment because a very large surface area is required for oxygen transfer. Aerobic lagoons must have about two times as much volume and four times as much surface area as anaerobic lagoons. The large size may also cause difficulty in sludge removal, embankment maintenance and control of aquatic plants. Aerobic lagoons are well suited for secondary treatment and/or storage of effluent from anaerobic lagoons.

Mechanically aerated lagoons combine the odor control advantages of aerobic lagoons with the smaller size requirement of anaerobic lagoons. They are most often used to control odors in sensitive locations or for nitrogen removal where land disposal areas are severely limited. However, use of floating surface aerators to provide oxygen is much more expensive than anaerobic lagoon operation both in initial cost and maintenance expense.

Primary Lagoon Design

Location

Locate anaerobic lagoons near the source of livestock waste, yet as far from inhabited dwellings as practical. Recommended minimum distances range from 500 ft. in some states to as much as 3750 ft. in other states. Lagoons should be at least 100 ft. from wells used for human water supply. Prevailing summer winds should carry odors away from nearby residences. Natural or constructed visual barriers such as trees or fences around the lagoon can minimize possible complaints from neighbors.

In general, runoff from outside drainage areas should be diverted around the lagoon(s) to minimize storage capacity requirements and to avoid upsetting the biochemical balance needed for proper digestion. However, outside runoff can be helpful in maintaining the design water level in water-short areas. In some cases, a combination anaerobic lagoon/runoff holding pond is a practical solution for swine operations consisting of both open lots and confinement buildings. This problem requires special design and is not addressed in this fact sheet.

Water Supply

Water supply must be adequate to maintain design water depth in the anaerobic lagoon. Farm ponds may be used as a temporary source of supplemental dilution water where high evaporation depletes lagoon water and leads to salt buildup.

Liquid Capacity

The liquid volume of anaerobic lagoons should be based on the amount of volatile (biodegradeable) solids produced from the swine facility. This is the minimum space needed for proper bacterial decomposition. Volatile solids production is directly related to swine liveweight and ration. Smaller liquid volumes (higher loading rates) generally can be used in climates where higher temperatures enhance digestion of solids. For purposes of lagoon design, climatic zones are defined in Figure 1. The liquid volume chosen also depends upon the relative need for controlling odors.

Recommended minimum liquid volumes of anaerobic lagoons are given in Table 1. Where it is necessary to maintain low odor levels the liquid volumes shown in Table 1 should be doubled or tripled.

Providing the proper lagoon loading rate can help avoid odors associated with production of volatile acids and promote the growth of desirable bacteria, such as purple sulfur bacteria (PSB), which store sulfur in their cells and reduce hydrogen sulfide emissions.

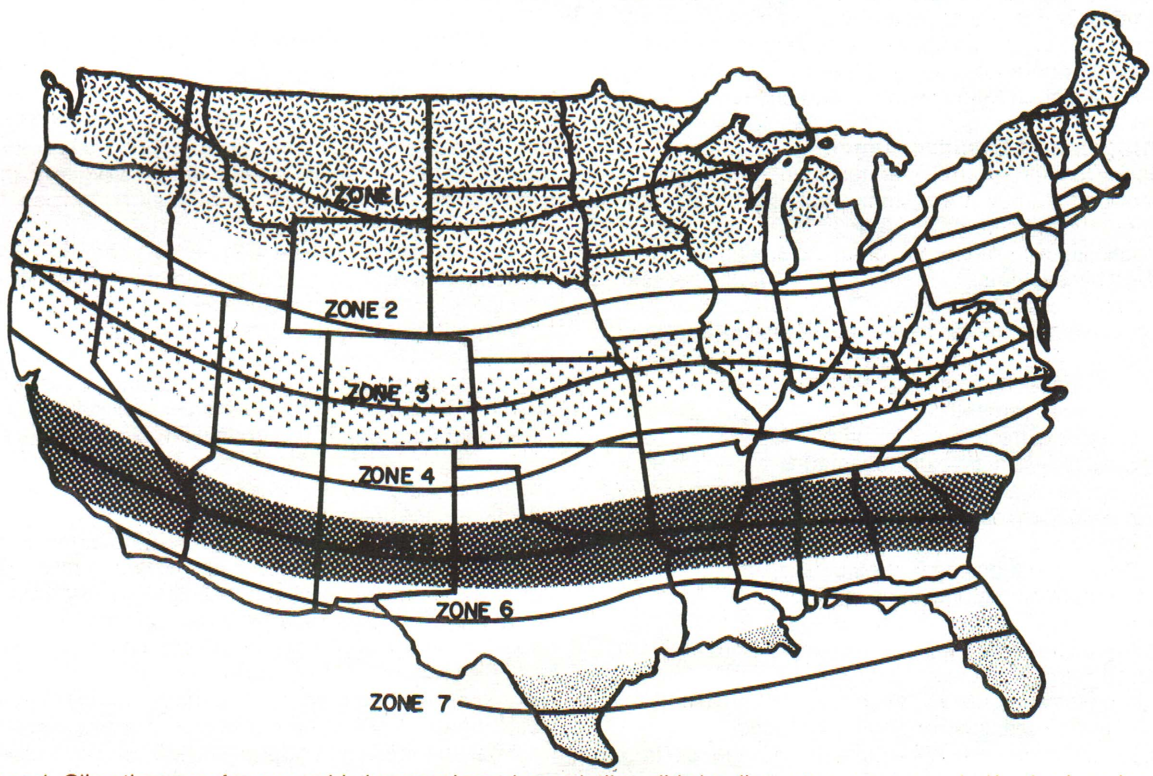

Figure 1. Climatic zones for anaerobic lagoons based on volatile solids loading rates recommended by the American Society of Agricultural Engineers.

The treatment volume of lagoons can be reduced by 25% if all coarse solids are removed from the liquid manure stream before entering the lagoon. The two principal methods of solids separation are settling pit with settled solids taken to land disposal and mechanical screen (stationary or vibrating).

In addition to the treatment volume listed in Table 1, producers may want to provide room for sludge storage, irrigation storage and/or dilution water. Sludge accumulation rates are discussed later in this fact sheet. For a two-stage lagoon system, storage and dilution volume should be provided in the secondary lagoon. Where a single-stage anaerobic lagoon is pumped down periodically for irrigation, additional storage volume should be provided to accommodate the net waste inflow during the period of storage.

In high rainfall areas, the waste storage volume will be essentially equal to the total waste produced by the livestock facility for a specific period of time. Under typical Midwestern conditions, total waste flow to the lagoon has been found to average 0.4 cu. ft. per yr. per lb. swine liveweight. But it will be less in areas with higher evaporation rates.

If the lagoon is maintained at or above the design water level determined from Table 1, ample dilution water will be present for solids digestion *unless* salts inhibit bacterial action. The primary reason for allowing additional lagoon capacity for dilution is to keep salt content, as measured by electrical conductivity meter or commercial laboratory, at or below 8 mmhos/cm (5000 ppm salt). Above 10 mmhos/cm (6400 ppm salt), bacterial action is markedly inhibited and land disposal of saline effluent will also be a problem.

Dimensions

Once the liquid volume of the primary anaerobic lagoon has been calculated, the actual dimensions of the lagoon can be computed. Various combinations of lengths, widths and depths are given in Table 2. Select the volume in the left-hand column of Table 2 and then read the dimensions (lengths and widths) at the top of the excavation, at the water line and at the bottom needed to provide the lagoon volume determined from Table 1. The dimensions and volumes shown in the tables were derived using side slopes of approximately 2:1 (horizontal: vertical). For other sizes, volume is roughly equal to depth times length at mid-depth times width at mid-depth.

Primary anaerobic lagoons should have a liquid depth of at least 5 ft. Depths of up to 20 ft. are encouraged to minimize the odorous surface area, encourage mixing owing to rising gases of decomposition, reduce land requirement, enhance sludge removal operations and minimize temperature variations in winter months.

A freeboard of 2 feet above the operating water surface is recommended to allow for large and unexpected amounts of rainfall. Where surface runoff can enter the lagoon, a protective spillway (open channel or pipe) should be provided at an elevation of approximately 1 ft. above the maximum water surface.

Side slopes should be 2:1, 2.5:1, or 3:1 to allow use of scrapers, loaders and dozers for excavation and partial compaction. Using draglines is not recommended except in stable, heavy clay soils where compaction for seepage control is not necessary. The top width of embankments should be at least 8 ft. Slopes on the outside of the lagoon embankment should be less steep to allow for mowing.

Lagoons may be square, rectangular, circular or eliptical to allow good mixing of lagoon contents. The periphery should be reasonably uniform and free of pockets or bays.

Table 1. Minimum recommended volume of anaerobic lagoons (cu. ft. per animal).

Type animal	Avg. animal size (lb.)	Climatic zone (Fig. 1)						
		1	2	3	4	5	6	7
Nursery pig	35	48	42	37	34	31	28	26
Growing pig	65	90	78	69	62	57	52	48
Finishing hog	150	210	180	160	140	130	120	110
Gestating sow	275	190	170	150	130	120	110	100
Sow and litter	375	690	600	530	480	440	400	370
Boar	350	240	210	190	170	150	140	130

Derived from: Proposed Engineering Practice Standard, American Society of Agricultural Engineers, January, 1977; "Manure Production and Characteristics," ASAE Data D384, 1978-79 Agricultural Engineers Yearbook; and "Livestock Waste Facilities Handbook," MWPS-18, Midwest Plan Service, 1975.

Table 2. Water volume of anaerobic lagoons of various sizes (Total depth 14 ft. - water depth 12 ft.).[1]

Volume to waterline (cu.ft.)	Top		Waterline		Bottom	
	Length (ft.)	Width (ft.)	Length (ft.)	Width (ft.)	Length (ft.)	Width (ft.)
18,000	70	70	61	61	10	10
27,000	80	80	71	71	20	20
40,000	90	90	81	81	30	30
54,000	100	100	91	91	40	40
93,000	150	100	141	91	90	40
133,000	200	100	191	91	140	40
163,000	150	150	141	141	90	90
172,000	250	100	241	91	190	40
211,000	300	100	291	91	240	40
257,000	180	180	171	171	120	120
331,000	200	200	191	191	140	140
416,000	220	220	211	211	160	160
560,000	250	250	241	241	190	190
697,000	275	275	266	266	215	215
848,000	300	300	291	291	240	240
1,490,000	540	280	531	271	480	220

[1] Side slopes are 2.13:1.

Table 3. Surface area for aerobic second-stage lagoons (sq. ft. per head).

Type animal	Avg. animal size (lb.)	Climatic zones (See fig. 1)						
		1	2	3	4	5	6	7
Nursery pig	35	25	20	15	13	11	10	10
Growing pig	65	45	35	30	25	20	20	20
Finishing hog	150	110	80	65	55	50	45	40
Gestating sow	275	100	75	60	50	40	40	35
Sow and litter	375	360	270	220	180	160	145	135
Boar	350	125	95	75	65	55	50	45

Design of Secondary Lagoons

Second-stage lagoons are desirable (required in some states) as a means of improving lagoon treatment efficiency and providing flexibility in managing lagoon liquid. The main function of second-stage lagoons is usually storage, rather than treatment. Second-stage lagoon liquid is still not of acceptable quality for discharge, but it is of suitable quality for recirculation and reuse as hydraulic flush water. Effluent application on land is periodically necessary to avoid discharge and/or to control salt accumulation which leads to lagoon failure.

The size and capacity of second-stage lagoons usually are not as critical as first-stage lagoons because the entering waste is less concentrated. If the second stage lagoon is to be aerobic, it should be designed on the basis of surface area needed to achieve oxygen transfer. Water depth should be approximately 5 ft.

The recommended surface area for a second-stage aerobic lagoon can be calculated from Table 3 by multiplying by the equivalent number of hogs. Dimensions of this lagoon can be obtained from Table 4. Note that land requirements are appreciable.

Second-stage lagoons may also be designed as lightly-loaded anaerobic cells. Overflow from the primary lagoon ordinarily contains less than one-fourth of the initial volatile solids load. Where treatment is the main objective, it is suggested that a second-stage anaerobic lagoon have 50% of the liquid volume of the first stage anaerobic lagoon (Table 1). Where temporary storage is the main goal, the second-stage anaerobic lagoon should be able to store all wastewater produced during the storage period plus any rainfall or runoff that would enter the lagoon system.

A lightly-loaded, anaerobic second-stage lagoon also serves as a storage for purple sulfur bacteria during cold months. If the first stage is pumped to remove some of the load in the spring, reinoculation of the primary lagoon with second-stage lagoon liquid may help reduce odors in the spring and summer.

Mechanical Aerators

For floating aerators, the minimum aeration requirement for odor control at the lagoon surface is 1 h.p. per 750-1,000 sq. ft. of surface area. Designing the aeration system for complete mixing of lagoon liquid is normally considered uneconomical and unnecessary except when a very high level of odor control or treatment is required. In this situation, an engineer should design the aeration system based on knowledge of the chemical oxygen demand and the fraction of total nitrogen that can be converted to nitrate by aeration.

Inlet/Outlet Devices

Lagoon inlets should be constructed of smooth steel or plastic pipe at least 6 in. in diameter and laid on a minimum slope of 1% (⅛ in. per ft.). A larger pipe diameter is needed to convey wastewater from flushing systems. Cleanout ports should be placed every 75-100 ft. Cantilevered pipe sections should not exceed 5 ft. without a supporting member. The discharge end of lagoon inlets can be either below or above the water line of the primary lagoon. Lagoon inlets below the water line are more susceptible to stoppage. Inlet and outlet devices should be on opposite sides of the lagoon. Outlets or inlets that trickle above the water level are subject to freezing in cold climates.

Outlets connecting the primary lagoon with a secondary lagoon should be located across the lagoon from the inlet pipe. They should be T-shaped and designed to remove lagoon liquid from 1-2 ft. below the lagoon surface. Alternately, an underwater outlet pipe can empty to a manhole set in the embankment, with a vertical riser pipe used to control primary lagoon elevation. Discharge from the manhole flows by gravity to the second stage lagoon. For each acre of primary lagoon surface, one outlet pipe with a diameter of 6 in. will be sufficient to convey heavy rainfall into the second lagoon. A concrete channel or spillway is suitable only in warm climates. Excess liquid in the second-stage lagoon should be applied to land by irrigation.

Seepage Control

Lagoons should be located in soils of low permeability or in soils that can be adequately sealed to prevent groundwater contamination. While bacteria and solids on the lagoon bottom clog soil pores and reduce seepage by 90-99%, self-sealing action alone may not be adequate to protect groundwater. A 6- to 12-inch layer of compacted clay may be required for seepage control in some instances. Swine producers should check requirements of local and state water pollution control agencies before beginning construction.

Lagoon Operation and Maintenance

Loading Procedure

A new anaerobic lagoon should be filled with relatively clean water to at least 50% of the design depth before loading begins. Start-up should take place during spring or

Table 4. Water volume of aerobic lagoons (Total depth 7 ft. - water depths 5 ft.).[1]

Water surface area (sq. ft.)	acre	Volume to waterline (cu. ft.)	Top Length (ft.)	Top Width (ft.)	Waterline Length (ft.)	Waterline Width (ft.)	Bottom Length (ft.)	Bottom Width (ft.)
10,000	0.2	40,000	109	109	100	100	78	78
25,000	0.6	108,000	167	167	158	158	136	136
40,000	0.9	179,000	209	209	200	200	178	178
50,000	1.1	227,000	233	233	224	224	202	202
75,000	1.7	346,000	283	283	274	274	252	252
100,000	2.3	465,000	325	325	316	316	294	294
150,000	3.4	707,000	396	396	387	387	365	365
200,000	4.6	950,000	456	456	447	447	425	425
300,000	6.9	1,440,000	557	557	548	548	526	526
400,000	9.2	1,930,000	641	641	632	632	610	610

[1] Side slopes are 2.2:1

summer so that maximum bacterial reproduction, digestion and stabilization can be achieved before cold weather begins. If feasible, manure loading should be increased gradually to reach the full loading rate after several weeks or months. It may take 2 yrs. for the lagoon to fully stabilize.

An anaerobic lagoon in proper balance will have a pH of approximately 7.5 (slightly basic). The pH in new lagoons (or in overloaded lagoons) can fall to 6.5 or less (slightly acidic), thereby creating odor problems. This can be corrected by applying hydrated lime (initial rate of 1 lb. per 1000 sq. ft.).

Anaerobic lagoons should be loaded with manure at least once daily. Less frequent loading can cause as much odor production as lagoon underdesign. Lagoons loaded several times a day exhibit the best performance. Excess bedding material, straw, oil, plastic sheeting and other foreign material should be kept out of lagoons.

Special precautions apply to areas of high to moderate evaporation. Producers should strive to keep the lagoon relatively full (except after pump down for land application) to avoid concentrating salts and organic matter. The inflow should contain dilution water in the ratio of 3-5 parts water to 1 part wet manure. Where lagoon supernatant is recirculated as fresh water, solids and salts will accumulate in the system, necessitating periodic pump down and replenishment with dilution water. Hydraulic flush systems with a fresh water source normally add ample dilution water.

Supernatant Disposal

When the concentration of soluble salts in lagoon liquids exceeds 5,000 ppm (8 mmhos/cm), bacterial action is inhibited. Salt buildup is especially likely in high evaporation areas, where the water supply has a high salt content, and/or where recirculation for flushing is practiced. Up to one-half of the lagoon contents should be disposed of by irrigation whenever the total salt concentration exceeds 5,000 ppm. In dry climates, lagoons should be partly refilled with fresh water after pump down.

Lagoon liquid can provide a substantial amount of nutrients to pasture and cropland. Many swine producers prefer to irrigate with lagoon liquids annually or more often to reclaim fertilizer value for crops. At least ½ of the minimum liquid volume (from Table 1) should be retained to provide bacterial innoculum.

The concentration of nutrients and salts in supernatant from primary and secondary lagoons varies widely, depending upon many factors. Nutrient concentrations appear to be closely related to the solids content. Typical nutrient concentrations of primary swine lagoon effluent are listed in Table 5.

Soil application rates usually are based on the nitrogen concentration in the lagoon liquid and on soil test results. The salt content may also be a limiting factor in some soils, requiring dilution water for leaching. Salt tolerant crops should be used. In some circumstances, water intake rates or water holding capacities may be the limiting factor. Contact local Extension or Soil Conservation Service-USDA offices for guidance on land disposal. Other guidance on land application is available in Pork Industry Handbook fact sheet PIH-25.

Liquid from second-stage lagoons can be applied using conventional sprinkler irrigation equipment with ¼- to ⅜-inch nozzles. Effluent from primary swine lagoons can normally be disposed of through ⅜- to ⅝-inch nozzles.

Coarse protective screening of the intake pipe should be provided. The intake pipe should be placed near the bottom across from the lagoon inlet. Pump power requirements for disposal of lagoon liquid are the same as for irrigation water at equivalent pressure-discharge combinations, provided the solids content is less than 2%.

Lagoon liquid may contain live salmonella and other disease organisms; therefore, direct contact with humans or animals should be avoided. However, it is safe to use lagoon liquid on non-food crops and pastures because these organisms are rapidly destroyed in the soil and on plant surfaces.

There may be some advantage to pumping from the primary lagoon in the spring because higher nutrient and undigested solids loads usually prevail at that time. Reinnoculation of the primary lagoon with second-stage lagoon liquid may help reduce odors.

Table 5. Typical nutrient content of anaerobic swine lagoon liquid.

Parameter	Concentration, %*
Solids content	0.5-1.1
Nitrogen (N)	0.06-0.2
Phosphorus (P)	0.006-0.01
Potassium (K)	0.04

* Conversion factors—multiply values shown by 2265 to get lb. per acre-inch or by 83.4 to get lb. per 1000 lb.

Sludge Removal

Approximately 20% of swine manure solids are non-biodegradeable. These fixed solids (ash), plus slowly-biodegradeable organic compounds such as lignin and cellulose, will accumulate as sludge on the bottom of the lagoon, eventually requiring cleanout. Even with good bacterial digestion, as much as 1/3-1/2 of the total solids inflow may remain as sludge. The rate of sludge buildup depends upon many variables—type of animal, ration, temperature, loading rate and chemical balance—and it appears to average 10-12 cu. ft. per finishing hog per year. Maintaining the design water level will result in maximum sludge digestion and compaction.

In general, it is recommended that sludge be removed when the buildup occupies 1/3 of the lagoon volume. Disposal on land will generally be controlled by the high phosphorus content in lagoon sludge. Advice from professional agronomists should be sought.

Types of equipment available for lagoon sludge removal include:

- Sludge pumps
  Centrifugal; long hitch trailer mounted; PTO drive
  Chopper-agitator; 3-point hitch mounted; PTO drive
  Diaphragm suction; electric or gasoline engine drive
  Helical rotor; electric or PTO drive
- Agitation
  Long shaft propeller; 3-point hitch mounted
  By-pass valve for recirculation from centrifugal or chopper-agitator pumps
- Tank wagons; vacuum loaded
- Hydraulic dredge
- Dragline

Sludge can be disposed of with surface or large bore sprinkler irrigation systems if ample dilution water is used. For small lagoons, liquid manure spreading with a tank wagon will suffice.

Maintenance

Lagoons should be inspected periodically to ensure that inlet devices are operational and that floating debris, odors and flies are at a minimum. Grass and weeds around the embankment should be closely mowed, as they make inspection difficult, increase the likelihood of accidental slippage into the lagoon, add to the organic loading rate and increase attractiveness to flies and mosquitoes.

Operators should plan adequate roads to provide access to the lagoons and appurtenances. If the fill is also used as a road, adequate access ramps should be provided. Where lagoons represent a safety hazard, they should be fenced, and warning signs should be posted.

Determining Lagoon Sizes
Examples

Part 1—Anaerobic Lagoon Volume
A Northern Missouri hog producer wants to construct an anaerobic lagoon for 2,000 finishing hogs with an average weight of 150 lb. From Figure 1, he determines that he lives in climatic Zone 3. From Table 1, he determines that the anaerobic lagoon volume should be 160 cu. ft. per 150-lb. hog. Thus, the overall liquid volume should be:

Lagoon Volume = 2,000 hogs x 160 cu. ft./hog
= 320,000 cu. ft.

Note that where it is necessary to maintain low odor levels, the liquid volumes shown in Table 1 should be doubled or tripled.

Part 2—Anaerobic Lagoon Dimensions
Dimensions for the anaerobic lagoon for the 2,000 hog finishing operation in Northern Missouri are determined from Table 2. A lagoon with a liquid depth of 12 ft. (14 ft. total depth), waterline dimensions of 188 ft. x 188 ft., and bottom dimensions of 140 ft. x 140 ft. will be adequate because the lagoon has a liquid capacity of 325,000 cu. ft.

Part 3—Second-Stage Lagoon
The size of an aerobic second-stage lagoon to store and treat liquids from the primary anaerobic lagoon designed in Parts 1 and 2 can be determined from Table 3. The recommended surface area is 65 sq. ft. per hd. Thus, the lagoon surface area should be:

Surface area, sq. ft. = 65 sq. ft./hd x 2,000 hogs
= 130,000 sq. ft., or 3.0 acres

Waterline dimensions of 370 ft. x 370 ft. would provide this area. With a water depth of 5 ft. and 2:1 side slopes, the bottom dimensions would be 350 ft. x 350 ft., and top dimensions would be 378 ft. x 378 ft., assuming 2 ft. freeboard.

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