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# Sludge Management for Anaerobic Lagoons and Runoff Holding Ponds

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This NebGuide defines critical issues to be addressed by a sludge and sediment management plan for anaerobic lagoons and outdoor lot holding ponds.

Nebraska's permit process for a Livestock Waste Control Facility (LWCF) requires a sludge and sediment management plan. The Nebraska Department of Environmental Quality (NDEQ) must approve this plan prior to issuing an NDEQ operating permit to a livestock operation.

## Current Knowledge

Preparing a sludge management plan should include recognizing our current knowledge of earthen structures. In this publication, an anaerobic lagoon refers to an impoundment with a permanent liquid pool for encouraging biological breakdown of manure and a storage volume. A runoff holding pond refers to an impoundment with a storage volume only for collecting storm water runoff from an outdoor lot such as a cattle feedlot. The following summary lists some critical factors to consider when planning.

Three distinctly different zones are likely to be found within an anaerobic lagoon *(Figure 1)*. First, an accumulation of inert solids, likely high in phosphorus, is found in the vicinity of the inflow pipe(s) from the animal housing. This sediment is solid in nature with an easily identifiable interface between the solids and the slurry. Second, above this zone, a moderately viscous sludge (applesauce or pudding consistency) high in nutrients, bacteria, and organic matter is commonly found. This sludge layer may occur in mounds rather than in an evenly distributed layer on the bottom of the lagoon. This material can be handled by pumps designed for higher solids (e.g., dairy manure slurry) applications. It is biologically active and the likely source of much of the anaerobic degradation occurring in a lagoon. Lastly, above the sludge layer is a liquid layer low in solids, moderately rich in nutrients, and easily pumped with irrigation pumps.

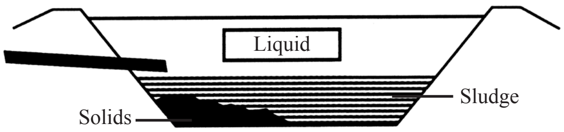


**Figure 1. An anaerobic lagoon will contain solids, sludge, and liquid layers as a result of manure additions.**

Annual sludge accumulation volume in an anaerobic lagoon is estimated by the following equation (Natural Resources Conservation Service, 1992):

**SV = 365 x AU x TS x SAR x T (*Equation 1*)**

where:

| | | |
|---|---|---|
| AU | = | Number of 1,000 pound animal units |
| SV | = | Sludge volume in cubic feet |
| T | = | Sludge accumulation time (years) |
| TS | = | Total solids production per animal unit per day (lb/AU/day) |
| SAR | = | Sludge accumulation ratio ($ft^3$/lb TS). See *Table I.* |

**Table I. Sludge accumulation ratio (anaerobic lagoons only) and total solids production for livestock.**

| | *Total Solids Production (pounds/day/1,000 pounds live weight)* | *SAR* |
|---|---|---|
| Dairy | | 0.0728 |
| Lactating cow | 12.5 | |
| Dry cow | 11.6 | |
| Heifer | 10.7 | |
| Beef (feeder cattle) | 5.9 | No published value. Use dairy cattle value. |
| Swine | | 0.0485 |
| Nursery | 10.6 | |
| Grower/finisher | 6.3 | |
| Lactating sow | 6.0 | |
| Gestating sow | 2.5 | |
| Poultry | | |
| Layer | 15.1 | 0.0295 |
| Broiler | 20.0 | 0.455 |
| Turkey | 10.9 | |

Source: Natural Resources Conservation Service's Agricultural Waste Management Field Handbook, 1992.

Sludge is rich in nutrients, particularly phosphorus. Phosphorus will often be the limiting nutrient for defining land requirements and application rates. An estimate of the phosphorous accumulation over time can be made from *Table II*. Regular removal of some sludge is desirable to avoid an accumulation of phosphorus beyond what can be agronomically applied in available cropland. However, sludge should never be totally removed due to its contribution to the biological treatment processes of a lagoon.

Sludge and solids removal practices that ensure liner integrity are essential. Mechanical damage or liner erosion during sludge removal should be avoided. Earthen manure storage structures with well-designed, constructed, and maintained liners experience less seepage. Manure will also reduce seepage rates in most situations due to physical, chemical, and biological processes that contribute to the clogging of soil pores.

### Principles of Sludge Management

Regular sludge and solids removal should be a part of the management of any anaerobic lagoons and open lot runoff holding ponds. The following principles apply primarily to an anaerobic lagoon. Some are applicable to the management of solids entering a runoff holding pond.

1. *Identify practices minimizing sludge accumulation.* Settling basins and mechanical separators can substantially reduce sludge buildup in a lagoon or runoff holding pond. Efforts to minimize sludge accumulation should be noted in the management plan.

2. *Identify the trigger point when sludge accumulation is to be pumped down.* The lagoon design should include a design depth or volume for the accumulation of sludge. This depth should serve as a trigger point for sludge removal. If this point is not defined for an anaerobic lagoon, the trigger point for pumping of the sludge accumulation should be set at a depth less than the lagoon's permanent liquid pool depth. For a runoff holding pond, the trigger point should allow sufficient pond volume to handle a 25-year, 24-hour storm plus normal runoff storage required between periods of land application plus 1 foot of freeboard.

3. *Monitor the sludge accumulation relative to the trigger point.* This can be done in one of two ways. First, sludge accumulation can be predicted using *Equation 1* and *Table I*. When the predicted accumulation is approaching the trigger point, a direct measure should be made. For an anaerobic lagoon, a horizontal water bottle sampler, commonly used for lake sampling at a single depth, can be used to collect a lagoon sample at the desired trigger depth. A visual inspection of the sample's clarity will define whether or not sludge has reached this trigger point. For a completely empty runoff holding pond, a permanent marking pole indicating the required depth to provide sufficient volume will aid a visual inspection and sludge removal decisions.

   An alternative method for monitoring sludge accumulation is to visually check at the time the lagoon is pumped to its lowest seasonal level. A visual check of the lagoon surface after draw-down or the last lagoon liquid pumped would confirm an accumulation of sludge fully occupying the lagoon's permanent pool. The appearance of sludge at this time should trigger sludge removal.

4. *Do not remove the last 2 feet of accumulated sludge (anaerobic lagoon only).* The sludge represents the biologically active portion of the lagoon with significant bacteria population for anaerobic processes. Removal of significantly more sludge would adversely affect the manure treatment process and odor control benefits of the lagoon.

5. *Protect the integrity of the earthen liner.* Liner integrity can be compromised by both aggressive agitation and use of front end loaders or backhoes for removal of solids. If agitation is used, appropriately located concrete pads for positioning agitation equipment will reduce liner erosion.

   For open lot runoff holding ponds, installation of a properly designed settling basin to trap solids ahead of the pond is preferred. This will limit the need for entering the pond with heavy equipment for solids removal. If a settling basin is not available, a concrete access ramp and pond bottom would be desirable. If neither option is available, completely drain all liquids and allow sufficient time for drying before removing solids. Operating heavy equipment under wet conditions will damage the liner.

6. *Land apply the sludge and solids to cropland at agronomic rates.* Sludge and solids are likely to have significant

**Table II. Estimate of phosphorus accumulation in the sludge and settled solids of an anaerobic lagoon that is not agitated during annual pumpdown. Does not apply to a manure storage or runoff holding pond for an outdoor lot.**

| | *Number of animals (average one-time capacity)* | | *Sludge $P_2O_5$ accumulation factor (pounds $P_2O_5$ per year)* | | *Years between sludge removal* | | *Total $P_2O_5$ in sludge and solids (pounds)* |
|---|---|---|---|---|---|---|---|
| *Example: Finish* | *1,000* | *X* | *7* | *X* | *10* | = | *70,000* |
| **Swine** | | | | | | | |
| Nursery | | X | 2 | X | | = | |
| Grow/finish | | X | 7 | X | | = | |
| Sows and litter | | X | 30 | X | | = | |
| Sows (gestation) and boars | | X | 11 | X | | = | |
| **Dairy** | | | | | | | |
| Lactating cows | | X | 100 | X | | = | |
| Dry cow | | X | 40 | X | | = | |
| **Poultry** | | | | | | | |
| Layer/Broiler | | X | 0.6 | X | | = | |

Source: Natural Resources Conservation Service's Agricultural Waste Management Field Handbook, 1992.
Assumes 65 percent of the phosphorus excreted by the animals settles into the sludge or settled solids.

**Table III. Estimated phosphorus removal by alternative crops.**

| *Crop* | *$P_2O_5$ removal* | | *Estimated yield* | | *Years of $P_2O_5$ supplied (3 years suggested)* | | *$P_2O_5$ application rate (lb $P_2O_5$/ac)* |
|---|---|---|---|---|---|---|---|
| *Example: Grain corn* | *0.4 lb/bu* | *X* | *150* | *X* | *3* | *=* | *180 lb/ac* |
| Corn, sorghum, and small grains | 0.4 lb/bu | X | | X | | = | |
| Corn silage | 2.9 lb/ton | X | | X | | = | |
| Sorghum silage | 2.6 lb/ton | X | | X | | = | |
| Alfalfa | 11.0 lb/ton | X | | X | | = | |
| Most grasses | 13 to 18 lb/ton | X | | X | | = | |

**Table IV. Estimated land requirements for sludge or slurry application at agronomic rates.**

| *Source of nutrients* | *Total $P_2O_5$ in sludge and solids (Table I)* | | *Fraction to be removed (Between 0 and 1)* | | *Desired $P_2O_5$ application rate (Table II)* | | *Land area required $P_2O_5$* |
|---|---|---|---|---|---|---|---|
| *Example: Swine lagoon sludge from 10-year accumulation* | *70,000 pounds* | *X* | *0.5* | ÷ | *180 pounds/acre* | = | *190 acres* |
| | | X | | ÷ | | = | |

quantities of nutrients, especially phosphorus. Procedures should be defined for analyzing nutrients, estimating the desired application rate, and performing field measurement of the actual application rate. Refer to NebGuide G1335, *Determining Crop Available Nutrients in Manure* and Extension Circular EC117, *Fertilizer Suggestions for Corn*.

An estimate of phosphorus accumulation should be made from *Table II* (anaerobic lagoon only). The required land area should also be estimated assuming phosphorus is applied at a rate meeting three to five years of crop phosphorus needs (*Tables III* and *IV*). Sites with soil phosphorus concentrations below 25 ppm are preferred land application sites. Sites with limited runoff potential are also preferred. Sites with high soil phosphorus concentrations (more than 100 to 200 ppm) should be avoided if possible.

The desired land application rate should be checked against the crop nitrogen requirements after appropriate allowances for the crop availability of manure nitrogen (see NebGuide G1335, *Determining Crop Available Nutrients from Manure*). The final selected application rate should not exceed the crop nitrogen needs for a single season (because nitrogen is mobile) and the crop phosphorus needs for three to five seasons (because phosphorus is less mobile).

7. *Limit the odor production from land application of the sludge.* Sludge is likely to release significant odor during land application. Immediate incorporation of sludge into the soil is the preferred land application method. If surface application or irrigation is to be used, carefully consider wind direction and potential effects on neighbors when timing your application. Odors dissipate most quickly at midday on warm, sunny, breezy days. Avoid application in the evening or nighttime, on days with little or no wind, and when the air is heavy with humidity. Notifying neighbors of your application sites and timing is also encouraged to assure that application activities don't coincide with your neighbors' outdoor activities or other special events.

## Solids Removal

Mechanical agitation or biological suspension is necessary to suspend the settled solids that accumulate primarily near the manure inlet to the lagoon or pond. Since the accumulation of inert solids is generally heaviest near the manure inlet, agitation in the inlet area is critical for effective suspension of solids. For best results, agitate while pumping liquids to the appropriate application equipment.

The moderately viscous sludge found throughout the lagoon can be handled by pumps designed for slurries. Although agitation may not be necessary for handling sludge, screening and diluting sludge with fresh water or lagoon liquid may be necessary if it is to be applied through an irrigation system.

Mechanical agitation is the most common method of suspending solids. High volume pumps (3,000 to 5,000 gallons/minute) specifically designed for agitation and loading will provide the best suspension of solids. However, agitation equipment is generally effective only in suspending solids within a limited area (within about 50 feet of the agitator). Because agitation equipment can also erode earthen liners, it should be used cautiously.

Pump-out of lagoon sludge should be designed to encourage easy setup, regular (every few years) sludge removal, and protection of liner integrity. Infrequent sludge removal will result in significant phosphorus accumulation, substantial land base requirements, and significant transportation cost. Two successful sludge removal methods are illustrated *(Figure 2)*.

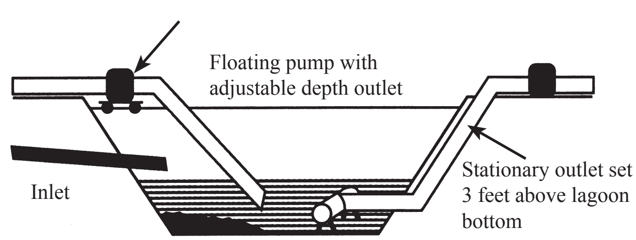


**Figure 2. Two alternative methods for pumping out lagoon sludge or settled solids.**

Numerous commercial products are available for suspension of sludge and solids in the lagoon's liquid. Producer experiences suggest some of these products are effective. Baker's yeast can also be an effective means of solids suspension. In *Removal of Solids from Storage, Manure Matters,* it is suggested that 1 pound of fresh baker's yeast mixed with 1 gallon of lukewarm water (90-100$^{o}$F) should be spread at a rate of 1 gallon per 75 square feet of liquid surface. Wait for two weeks, then agitate and pump. This process produces carbon dioxide and should be used with extreme caution in pits below barn floors due to asphyxiation hazards.

A final option is to hire a custom applicator. Custom applicators should be selected based upon:

- Ability to provide appropriate agitation and pumping equipment for high-solid sludges.
- Ability to immediately incorporate sludge into the soil to minimize odor.
- Ability to transport sludge the required distance.
- Cost. Custom application typically costs between 0.5¢ and 1.0¢ per gallon.

## Conclusion

By following these procedures for sludge management, a plan meeting NDEQ review requirements can be assembled. It will help the producer achieve optimum performance from an anaerobic lagoon or runoff holding pond. It also provides some limit to environmental liability due to its preapproval by the NDEQ.

## Sludge Management Plan Worksheet

Describe anticipated procedures, types of equipment, and any appropriate measurements to be used for each of the following principles of good stewardship when developing a sludge management plan for an NDEQ permit.

| *Sludge management plan principle* | *Individual producer's plan: Describe actual procedures, types of equipment, appropriate measurements, and other procedures specific to individual plan.* |
|---|---|
| 1. *Identify practices minimizing sludge accumulation.* | |
| 2. *Identify the trigger point at which time sludge accumulation is to be pumped down.* | |
| 3. *Describe procedure and frequency for monitoring the sludge accumulation relative to that trigger point.* | |
| 4. *Estimate the approximate quantity of sludge to be removed. Maintaining 2 feet of accumulated sludge is recommended. (anaerobic lagoon only)* | |
| 5. *Describe procedures to be implemented for protection of the integrity of the earthen liner. Include description of equipment and procedures to be used in removing sludge.* | |
| 6. *Estimate quantities of phosphorus that have accumulated, land base required, available land for application, and procedures to be implemented for determining agronomic application rates.* | |
| 7. *Describe procedures for limiting odor production from land application of the sludge.* | |

## Acknowledgment

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## Reference

G.E. Bodman. 1996. Removal of Solids from Storage, *Manure Matters*. Vol. 2, No. 3.

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