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Closure of Earthen Manure Structures*

Don Jones and Alan Sutton, Purdue University and Ryan Westerfeld, IDEM

Earthen livestock manure structures, properly designed, installed and operated according to accepted engineering standards, should pose little risk to water quality. However, when a production unit ceases operation, proper procedures need to be taken to properly close any earthen manure structures present in order to protect nearby surface and ground water. This includes lagoons, manure storage basins and runoff holding ponds.

The Indiana Department of Environmental Management's (IDEM) CAFO/CFO requires all state-permitted animal confinement production operations that are abandoning an earthen manure storage to close it properly. In general, IDEM takes the position that, as long as the environment is protected, the specific closure procedure used does not matter - but there are a few things to remember:

- Once all of the manure has been removed from the storage, producers must notify IDEM so that they can send an inspector to the farm to verify that the storage is empty. After a successful inspection, the producer can finish closing the structure.
- There could be a penalty if they do not notify IDEM that they have closed the structure.
- If the structure has a plastic or other type of artificial liner, it should be taken to a landfill.
- No additional sampling is required after the closure process has been completed.

This paper provides general recommendations and guidance for closure of manure storages.

GENERAL RECOMMENDATIONS

Several principles should be applied to the abandonment of earthen manure structures that are reasonably well designed and constructed, and operated properly during their useful life. The preparation of an earthen manure structure for closure involves three critical principles:

1) Protection of the soil/organic matter interface layer that forms a relatively impermeable natural liner around the structure contents until after all liquid and sludge have been removed.
2) Removal of all manure liquids and pumpable slurry.
3) Land application of removed liquids and sludge at agronomic rates.

Options for the emptied earthen manure storage include:

A. Permanently eliminate the earthen manure structure.

*Adapted in part from a White Paper with a similar title prepared for the National Center for Animal Waste. 2001.

- Divert surface water away from storage site;
- Fill storage structure with soil to a mounded surface that sheds rainwater;
- Establish a growing crop or sod. It may be necessary to remove a foot or so of the original storage liner after all manure has been removed in order to obtain soil that will support vegetation.;

B. Convert the structure to a fresh water pond.

- Rinse the storage structure several times, with irrigation of the contents onto cropland;
- Any discolored soil at the bottom of the storage structure (usually 6-12 inches) should be removed and land applied. The removed soil should be replaced with an equivalent amount of compacted subsoil if needed to minimize leakage. The removed soil is likely to have a high concentration of nitrogen, phosphorous and other chemicals and should be field applied at the recommended agronomic rate;
- Establish a maximum water level;
- Refill storage with fresh water.

C. Breach the berm so that the structure will not hold rainwater.

- Divert surface water away from the storage site;
- Breach the berm;
- If a plastic liner was used, it should be removed. If there is no artificial liner, any discolored soil at the bottom of the storage (usually 6-12 inches) should be removed and land applied. The removed soil should be replaced with an equivalent amount of top soil that can support vegetation. The removed soil is likely to have a high concentration of nitrogen, phosphorous and other chemicals and should be field applied at the recommended agronomic rate;
- The portion of the original storage depression that is below grade will either need to be filled with soil or converted into a fresh water pond. See above.
- Establish a growing crop or sod on the bottom and sides of the structure.

Regardless of the intended end use or closure method used, all conveyances (pipes and ditches) used to convey manure to the basin should be removed and replaced with properly compacted soil.

CHARACTERISTICS OF EARTHEN STORAGES AND LAGOONS

In a manure storage, the contents are likely to be relatively uniform throughout, with solids content ranging from 3 to 10%. With thorough agitation, manure nutrients can be removed and land applied as a fertilizer resource. In an anaerobic lagoon, however, three different zones shown in Figure 1 are likely to be found. These zones seldom have distinct boundaries and are difficult to determine.

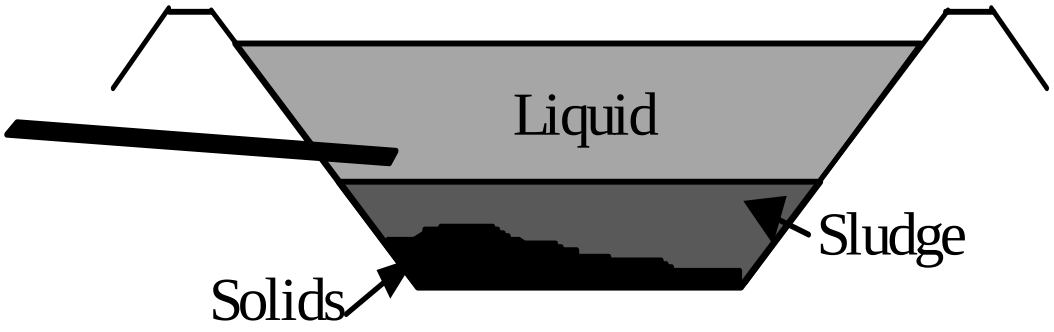

Figure 1. Cross-section of an anaerobic lagoon

1. Relatively inert solids accumulate near the manure inflow points (Figure 1). These solids are typically high in phosphorus, with a discernible interface between the solids and the sludge above it. Complete removal of these solids is difficult without damaging the liner. Maintaining liner integrity until all manure has been removed should be of greater concern than removal of all solids. Typically, more solids buildup in lagoons receiving manure from dairy operations than from swine.
2. A thick sludge, high in nutrients, bacteria, and organic matter, is normally located just above the solids zone. Pumps designed to handle high solids content is typically needed to remove this material. While most of the readily degradable organic matter in the sludge should be broken down, it is still biologically very active and is responsible for the microbial or biological degradation of much of the incoming manure.
3. At the top of the lagoon is a liquid layer that is low in solids and moderately rich in nutrients. It is easily pumpable with conventional chopper-agitators or large irrigation pumps. The liquid and most of the sludge can generally be removed by pumping while still maintaining the integrity of the liner. The liquid can be irrigated onto cropland or injected with a hose-pull drag line system, but it may be necessary to move sludge with a higher solids content using tanker wagons or other solids handling equipment.

The settled solids and sludge layers of an anaerobic lagoon can contain a significant amount of phosphorus that has settled out over the years (Table 1). Before land application, a laboratory analysis is needed to determine an appropriate land application rate. The amount of nutrients present in lagoons tends to be highly variable. Table 1 provides typical lagoon nutrient levels reported by several studies.

Table 1. Typical Livestock Anaerobic Lagoon Sludge Characteristics (mg/L (lbs/1,000 gal))

Species	Units	Total Nitrogen		Total Phosphorus (P_2O_5)		Potassium (K_2O)		Copper		Zinc	
		Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
Swine - active[a]	mg/l (lbs/1,000 gal)	2,930 (24.4)	1,620 (13.5)	6,310 (52.6)	4,120 (34.3)	780 (6.5)	470 (3.9)	36 (0.3)	36 (0.3)	96 (0.8)	72 (0.6)
Swine - inactive[b]	mg/l (lbs/1,000 gal)	2,690 (22.4)	1,320 (11)	1,550 (12.9)	940 (7.8)	170 (1.4)	170 (1.4)	144 (1.2)	160 (1.3)	140 (1.2)	72 (0.6)
Dairy[a]	mg/l (lbs/1,000 gal)	2,290 (19.1)	1,040 (8.7)	5,020 (41.8)	3,940 (32.8)	1,100 (9.2)	860 (7.2)	60 (0.5)	48 (0.4)	84 (0.7)	48 (0.4)
Dairy[c] - complete mix, sludge and supernatant	mg/l (lbs/1,000 gal)	1,990 (16.6)	830 (6.9)	1,070 (8.9)	540 (4.5)	1,750 (14.6)	600 (5)	13 (0.11)	15 (0.12)	19 (0.16)	11 (0.1)
Poultry - layer[a]	mg/l (lbs/1,000 gal)	2,500 (20.8)	1,420 (11.8)	9,260 (77.2)	4,790 (39.9)	1,180 (9.8)	920 (7.7)	12 (0.1)	12 (0.1)	130 (1.1)	120 (1)

[a] = Barker, J.C., J.P. Zublena, and C.R. Campbell. 1994. Livestock manure production and characterization in North Carolina. Agri-Waste Management Bulleting. Department of Biological and Agricultural Engineering, North Carolina State University, Raleigh, NC.

[b] = Sheffield, R. E. 2000. Sludge and Nutrient Assessment of Inactive Lagoons in North Carolina. Presented at the 2000 ASAE Annual International Meeting. ASAE Paper No. 004121. ASAE, 2950 Niles Rd., St. Joseph, MI 49085-9659 USA.

[c] = Mukhtar, S. 2000. Assessment of Nutrients and Sludge from Dairy lagoons in Texas. (Unpublished data)

Published sludge accumulation rates are highly variable, but estimates can be made using Table 2 if field measurements are not available.

LAGOON SLUDGE SAMPLING

To estimate the volume of sludge in a lagoon. samples should be collected from several points around the interior of the lagoon. Such samples tend to be highly variable and may differ widely from point to point. To obtain a sample of the sludge, insert a 0.5 to 0.75 inch PVC pipe into the lagoon sludge until the pipe reaches the bottom. Wearing plastic or latex gloves, cap the end of the pipe to create a vacuum and slowly withdraw it from the lagoon. This will collect a core or profile of lagoon effluent and sludge. Once the pipe outlet is over a clean container, carefully break the vacuum and allow it to drain. Place several samples in the container and stir thoroughly. Use a plastic, wide-mouth bottle, fill to about ¾ full, and follow laboratory instructions when shipping samples for analysis. The periodic manure storage analysis taken previously (as required by IDEM permits) will not be adequate here unless those samples have included the sludge at the bottom of the storage as well as the liquid.

PROTECTING THE INTEGRITY OF THE EXISTING EARTHEN LINER DURING CLOSURE

No matter which closure method is chosen, maintaining an intact liner while manure is present in the storage will reduce the potential impact of manure nutrients on the environment than attempting to remove the liner. Remove as much sludge and solids as possible from the storage without endangering the integrity of the liner.

REMOVAL OF LIQUIDS AND PUMPABLE MATERIAL

Removing sludge and solids from earthen manure structures can be accomplished by several methods:

- Thoroughly agitate with a lagoon or pit agitator pump and remove the combined contents of the structure and land-apply to cropland.
- Remove and land-apply liquids; then, remove sludge using a drag line and land-apply.
- Use a sludge dredge and land-apply sludge; then agitate and remove the remaining liquid and sludge and land-apply the combined mixture.

Agitate the Combined Contents of the Structure and Land-Apply

In this method, liquid and sludge are mixed with an agitator or a chopper-agitator impeller pump. High-volume pumps (3,000 to 5,000 gallons per minute), specifically designed for agitation and loading, provide for suspension of solids. However, agitation equipment is generally only effective in suspending solids within about 50 feet of the agitator. Because high-capacity agitation equipment can scour and erode earthen liners near the agitator, it should be used with caution. Direct the agitation flow away from the liner and keep the agitation unit at least three feet away from the soil surface. The mixed contents can be pumped through a large-bore (at least 1 ¼ in diameter) sprinkler irrigation system onto nearby cropland at the recommended agronomic rate. If possible,-incorporate it into the soil to minimize odor, nitrogen volatilization, and runoff potential. After the liquid and most of the sludge has been removed, it should be possible to remove any remaining solids with a small track-type dozer after the soil liner material has dried.

Remove and Land-Apply Liquids; Agitate, Remove and Land-Apply Sludge

The liquid portion of the earthen structure is typically irrigated onto nearby cropland or forage. The remaining sludge can be agitated and pumped into a sludge applicator. The sludge can be spread onto cropland or forage land or soil-incorporated at agronomic rates. Note that this material can have much higher salt and nutrient concentration than is found in the liquid portion of the contents, and may need to be applied to cropland at a much lower application rate to avoid damage to the crop.This method may not work as well with dairy manure due to the more fibrous nature of the sludge , larger particle sizes and higher solids contents compared to swine and poultry manure. After the liquid and most of the sludge have been

Figure 2. Pumping dredge operating in a lagoon in North Carolina.

removed, it should be possible to remove any remaining solids with a small track-type dozer after the soil liner material has dried.

Dredge and Land-Apply Sludge, Remove and Land-Apply Liquids

Sludge is removed with a dragline or sludge dredge (Figure 2). Note that the dragline must be used very cautiously to avoid damage to the organic liner. With more fibrous manure, it may be practical to establish a gently sloping bermed area beside the structure to receive the dredged sludge and allow liquids to drain back into the earthen structure to provide additional dewatering. This may not be feasible with swine or other non-fibrous sludge that does not stack well. After air-drying to produce a semisolid or solid material, the sludge is hauled and spread with solid manure equipment onto cropland or forage-land at agronomic rates. See the comment above about dealing with a high level of salt and nutrients that can be found at or in the soil liner material. It is important to obtain an accurate analysis of the solids and soil liner material before it is land applied. Soil-incorporation should be used where feasible to better retain and utilize the nutrients in the sludge. The earthen structure can them be dewatered by irrigation onto nearby cropland or forage.

SUMMARY

Land must be available to properly utilize the nutrients removed from a manure storage, without damage to ground or surface water. If land is not available to properly apply the storage contents, other means of utilization must be used. If an accurate nutrient analysis of the storage contents has been obtained, it may be possible to reach an agreement with neighboring crop farmers to land apply the storage contents on their field. In some cases, it may even be possible to sell the nutrient value of the manure applied to help offset the cost of removal and application.