This is not a peer-reviewed article.

Paper Number: 034156
An ASAE Meeting Presentation

Sludge Accumulation Rate Determination and Comparison for Nursery, Sow and Finisher Lagoons

Anissa D. Morton, Engineer in Training

Enviro-Ag Engineering, Inc., Engineering Consultants, Amarillo, Texas 79124.

Gary M. Chapman, P.E., Senior Engineer

Enviro-Ag Engineering, Inc., Engineering Consultants, Amarillo, Texas 79124.

Norman H. Mullin, P.E., President

Enviro-Ag Engineering, Inc., Engineering Consultants, Amarillo, Texas 79124.

Brent W. Auvermann, Ph.D., Associate Professor and Extension Specialist

Texas Cooperative Extension, Texas A&M Research & Extension Center, Amarillo, Texas.

Written for presentation at the
2003 ASAE Annual International Meeting
Sponsored by ASAE
Riviera Hotel and Convention Center
Las Vegas, Nevada, USA
27- 30 July 2003

Abstract. *Sludge was measured in the treatment lagoon at 15 swine finisher sites, seven sow sites and 15 nursery sites using a commercially available sludge level detector. Lagoon design dimensions or as-built survey data and the resulting sludge levels were used to calculate sludge volume in each lagoon using three-dimensional CAD analysis. Accumulation rates for each lagoon were calculated using the sludge volume, lagoon age, average headcount and total solids calculated using the composition of swine diets. Data indicates the average sludge accumulation rate (SAR) for swine lagoons is not statistically different than the current ASAE recommendation; however, the SAR for sow lagoons is significantly higher than for finisher and nursery lagoons. It is recommended that a revision of ASAE EP403.3 should include SAR values nearer 0.002 m^3/kg TS (0.032 ft^3/lb TS) for nursery and finisher lagoons and 0.0034 m^3/kg TS (0.054 ft^3/lb TS) for sow lagoons.*

Keywords. Sludge accumulation, swine lagoons

Introduction

Sludge was measured in the treatment lagoon at 15 swine finisher sites, seven sow sites and 15 nursery sites using a commercially available sludge level detector. The commercial sow sites ranged in size from 1,400 to 2,300 sows, on average. The units contributing to the sow lagoons consist of breeding, gestating, farrowing units. The commercial finisher sites ranged in size from 2,000 to 20,000 head, on average. The commercial nursery sites ranged in size from 3,400 to 14,000 head, on average.

A review of the design criteria for each lagoon was provided by the producers. Design loading rates for each lagoon were based on either published data (ASAE, NRCS or MWPS) or dietary analysis. Based on information provided by the producers, all of the lagoons studied were pre-charged with freshwater prior to startup. All facilities in this study were constructed between 1994 and 1998 and have under-slat pits with pull-plug systems. The sites consist of both freshwater and recycle wastewater pit pre-charge. Lagoon design dimensions or as-built survey data and the resulting sludge levels were used to calculate sludge volume in each lagoon using three-dimensional CAD analysis. Accumulation rates for each lagoon were calculated using the sludge volume, lagoon age, average headcount and total solids production based on the composition of swine diets obtained from each producer.

Objectives

The objectives of this study were to:

1. Compare sludge accumulation rates (SARs) for finisher, sow and nursery sites.
2. Compare calculated SAR to the current recommendation in ASAE EP403.3.
3. To recommend a SAR to be accepted in a future revision to ASAE EP403.3.

Background

The current ASAE EP403.3 recommendation for sludge accumulation rate for swine lagoons is based on work done by Barth (1985) on six grower/finisher swine lagoons ranging in size from 2,467 m^3 (2 ac-ft) to 12,335 m^3 (10 ac-ft). Since that time, changes in modern commercial swine production have resulted in larger, more efficient facilities, better swine genetics and better feed. The sludge accumulation rate determined by Barth (1985) is likely no longer indicative of current swine waste management practices. Work done by Tyson (2002), demonstrated that sludge accumulation rates in swine lagoons are much lower than the current ASAE recommendation.

Procedures

Sludge Measurement

Lagoon design dimensions or actual as-built dimensions were obtained from the cooperating producers. Rectangular grids were set up for each lagoon with at least 12 sludge measurement points per lagoon. In the field, the grid pattern was staked using a measuring tape extended along the inside top of berm. Two people standing on the lagoon berm, using ropes, navigated the boat to each measurement point using the stakes as a guide. Two readings were taken at each measurement point. The person in the boat obtained the depth from the water level to the sludge level using a Markland Model 10 Portable Sludge Level Detector to 3-cm (0.1-ft) increments. The sensitivity of the gun was held constant for each lagoon. A second measurement was taken using a PVC pipe with 3-cm (0.1-foot) graduated marks to record the depth from the water level to the bottom of the lagoon. This process was repeated for each measurement point in each lagoon.

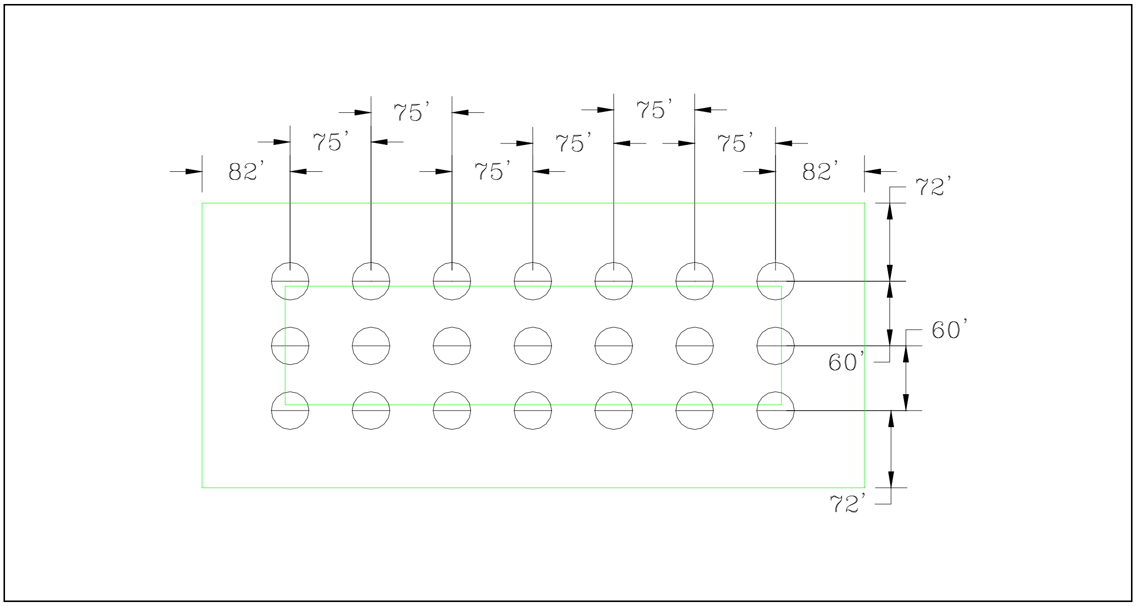

Figure 1: Example of grid used to measure each lagoon.

Sludge Volume Determination

The lagoon bottom measurements were entered into AutoCAD/EaglePoint® drawing files along with either design dimensions or as-built survey data to generate a three-dimensional base model of each lagoon.

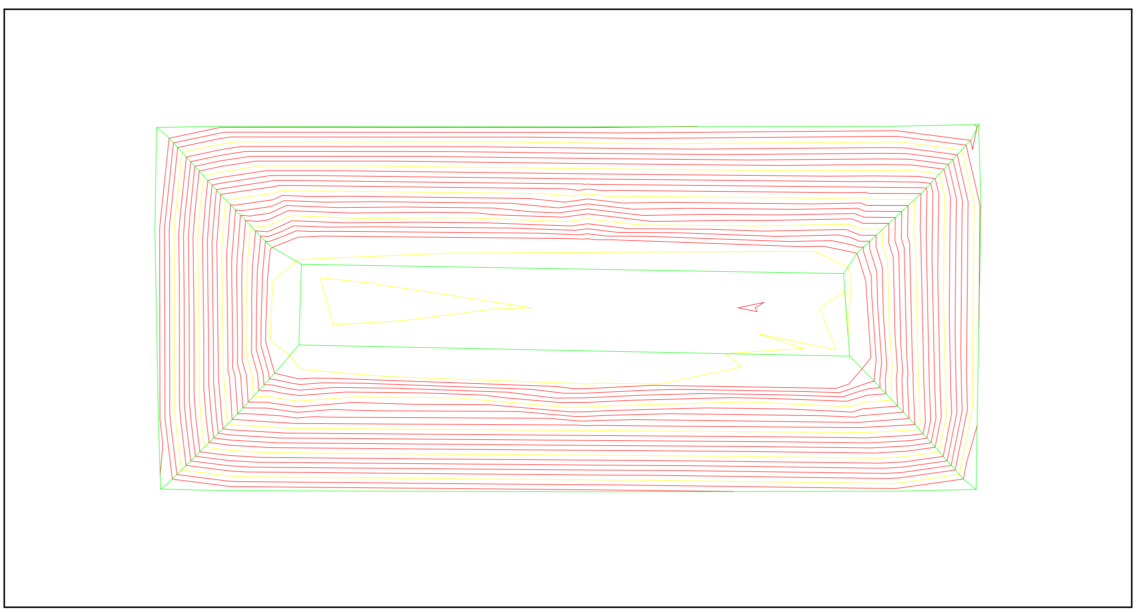

Figure 2: Example lagoon base model with contours.

Most of the sludge volumes in this study were calculated using lagoon design dimensions rather than actual as-built survey data. The use of as-built survey data to develop lagoon base models would increase the accuracy of the sludge volume calculation.

The sludge levels were entered in a separate drawing layer. Based on field observations, sludge is generally distributed evenly across the pond, except for areas surrounding the inlet pipe in the lagoons. Based on this observation, sludge data was projected from the measured points to the lagoon based model. A separate three-dimensional sludge model was then generated using both the measured and the projected sludge data. The sludge volume was calculated as the difference between the sludge model and the lagoon base model using the prismoidal method contained in the Site Design module of EaglePoint® CAD software.

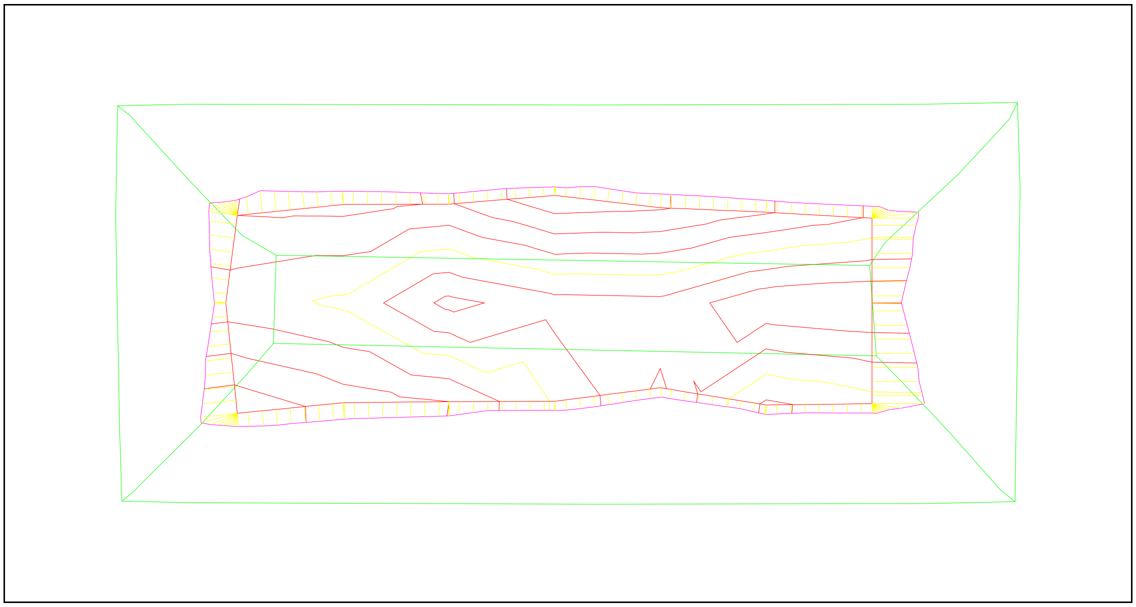

Figure 3: Example sludge model with contours.

Sludge Accumulation Calculation

The cooperating producers provided the original population date, average headcounts and typical swine diet information for each facility. The sludge accumulation rate for each lagoon was calculated using the following equations:

$$SAR = SV / (T * TSrate) \quad (1)$$

Or:

$$SAR = (SV * 365) / (LAW * T) \quad (2)$$

Where:

SAR = Sludge accumulation rate in volume per mass TS added (m^3/kg TS or ft^3/lb TS), as reported in Table 1, ASAE EP403.3 (Equation 1), or in volume per mass LAW per year (m^3/kg LAW-yr or ft^3/lb LAW-yr) (Equation 2)

SV = Measured sludge volume (m^3 or ft^3)

T = Sludge accumulation time in days

LAW = Total Live Animal Weight = average headcount * average LAW (kg or lb)

TSrate = Total solids production rate in mass per day (kg/day or lb/day)

The sludge accumulation time was determined using the original date the facility was populated up to the date the sludge measurement was collected. Average live animal weights were obtained from each producer.

Total solids production was calculated using the composition of the swine diets for each animal type as provided by the producers. Swine diet information included amount of feed delivered per animal per day, feed moisture content, feed dry matter digestibility and percent feed waste. Total solids production is taken as the sum of total solids excreted plus feed waste.

Results and Analysis

Sludge accumulation rates for each lagoon type are presented in Table 1. A statistical analysis was performed to determine if a significant difference exists between the SAR for finisher, nursery and sow sites. At a 95% confidence level using the Student's T test, the SAR for sow site is significantly higher than the SARs for finisher and nursery sites reported in sludge volume per mass total solids added. The opposite result occurs when reporting the SAR in terms of sludge volume per pound Live Animal Weight (LAW) per year. This can be attributed to the much higher LAW for gestating and lactating sows than for finisher and nursery pigs. There is no statistical difference between the SARs for finisher and nursery sites.

Table 1: Summary of Calculated Sludge Accumulation Rates

Type	**m^3/kgTS**	**ft^3/#TS**	**m^3/kgLAWyr**	**ft^3/#LAWyr**
Finish	0.0020	0.032	0.0041	0.066
Sow	*0.0034*	*0.054*	*0.0020*	*0.032*
Nursery	0.0018	0.028	0.0049	0.078
Overall Average:	**0.0024**	**0.038**	**0.0036**	**0.058**
Std. Dev.:	0.0009	0.014	0.0015	0.024
Barth (1985):	**0.00303**	**0.0485**	**0.00784**	**0.1256**

The SAR recommendation for swine lagoons in ASAE EP403.3 is based on Barth's (1985) work. The statistical test above was applied to determine if a significant difference exists between the average SAR and the value reported by Barth. As shown in Table 1, the SARs calculated in this study are not statistically different than Barth's when reported in terms of total solids added, but in terms of LAW, the average SAR is 1/2 of Barth's value. The LAWs used in this study and in Barth's study are shown in Table 2. Barth used 45.4 kg (100 lb) LAW, which is small by today's production standards. Today, grower/finisher swine are fed to a market weight of 113.4 kg to 120.2 kg (250 lb to 265 lb), resulting in a higher average LAW.

Table 2: Summary of Live Animal Weights

Source	Animal Type	LAW	
		(kg)	(lb)
Producer A	Finisher	68.0	150
	Nursery	15.9	35
	Gestating Sow	170.1	375
	Lactating Sow	181.4	400
Producer B	Finisher	70.3	155
	Nursery	15.0	33
	Gestating Sow	192.8	425
	Lactating Sow	192.8	425
	Boar	215.5	475
Barth (1985)	Grower/Finisher	45.4	100

Preliminary data from finisher sites, shown in Table 3, indicates that freshwater pit pre-charge sites have slightly higher SARs than sites using recycled wastewater from the lagoon for pit pre-charge. This may indicate that solids have less time to settle out in a recycle lagoon because pumping occurs on a more regular basis than in a freshwater lagoon, where pumping might only occur during irrigation events.

Table 3: Sludge accumulation rates for recycle versus freshwater pit pre-charge.

Lagoon system	m^3/kgTS	ft^3/#TS	m^3/kgLAW-yr	ft^3/#LAW-yr
Recycle average:	0.0014	0.023	0.0036	0.057
Freshwater average:	0.0030	0.049	0.0054	0.087

Conclusions

The calculated average sludge accumulation rate (SAR) in this study was found to be statistically similar to the rate reported by Barth (1985). However, the SAR for sow lagoons was significantly higher than for finisher and nursery lagoons in terms of total solids added. There was no significant difference between SARs for nursery and finisher lagoons. Today, many commercial producers are combining nursery and finisher operations to reduce labor costs and minimize animal stress. This study did not specifically address lagoons designed for a wean-to-finish system, but the results indicate that since the nursery and finisher SARs are similar, the same SAR would be valid for use in designing a wean-to-finish lagoon.

Total solids production in this study was calculated using the composition of the swine diet. The reporting of sludge accumulation rates in terms of total solids and the use of this SAR in design work is valid when feed composition and digestibility data is available to calculate the total solids production on a site-specific or producer-specific basis. The use of published total solids production values may overestimate the actual total solids production for some stages of growth and underestimate it for others. The SAR reported in terms of Live Animal Weight (LAW) may be used when site-specific total solids production data is not available.

Preliminary data for finisher lagoons indicates that freshwater pit pre-charge sites have higher SARs than sites using recycled wastewater from the lagoon for pit pre-charge. This may indicate that solids have less time to settle out in a recycle lagoon because pumping occurs on a more regular basis than in a freshwater lagoon, where pumping might only occur during irrigation events. More work is needed to determine the effect of recycle pit pre-charge on sludge accumulation.

Based on the results of this study, it is recommended that a revision of ASAE EP403.3 should include SAR values nearer 0.002 m^3/kg TS (0.032 ft^3/lb TS) for nursery and finisher lagoons and 0.0034 m^3/kg TS (0.054 ft^3/lb TS) for sow lagoons.

Acknowledgements

Thanks to the producers who participated in this study.

References

ASAE Standards, 48th ed. 2001. EP403.3. Design of Anaerobic Lagoons for Animal Waste Management. St. Joseph, Mich.: ASAE.

ASAE Standards, 48th ed. 2001. D384.1. Manure Production and Characteristics. St. Joseph, Mich.: ASAE.

Barth, C.L., and J. Kroes. 1985. Livestock Waste Lagoon Sludge Characterization. *Proceedings of the Fifth International Symposium on Agricultural Wastes,* 660-671. St. Joseph, Mich.: ASAE.

Tyson, T. 2002. Sludge accumulation in Alabama swine lagoons less than 5 years old. ASAE Meeting Paper No. 024132. St. Joseph, Mich.: ASAE.