6-2009

Daily Cleaning Options for Sloped Manure Pits in Swine Finishing

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Abstract
Two technologies were evaluated for daily manure removal in shallow, sloped pits in swine finishing facilities. The criteria included cleaning ability, initial cost, and water usage. One system selected for the trial was mechanical and one was liquid-based. Preliminary results of the scraper system have shown clean pit floor and side walls. The frequency of scraping has been reduced to several times per day and twice after a weekend. Challenges of the system include cleaning the front 0.45 m (18") along the wall and using water to assist the drainage of manure. Results of the tip tank have shown a 4 gallon per pig recycle water usage per day. Flushability of the solids and development of sufficient head were factors in this 3 design. Both systems were automated to lessen human intervention and designed to allow the recycle pumps to be shut down at night.

Keywords
Ammonia, Air Quality, Odor, Scraper system, Flush tank

Disciplines
Bioresource and Agricultural Engineering

Comments
This is an ASABE Meeting Presentation, Paper No. 096307.

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An ASABE Meeting Presentation

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Written for presentation at the
2009 ASABE Annual International Meeting
Sponsored by ASABE
Grand Sierra Resort and Casino
Reno, Nevada
June 21 – June 24, 2009

Abstract**.** Two technologies were evaluated for daily manure removal in shallow, sloped pits in swine finishing facilities. The criteria included cleaning ability, initial cost, and water usage. One system selected for the trial was mechanical and one was liquid-based. Preliminary results of the scraper system have shown clean pit floor and side walls. The frequency of scraping has been reduced to several times per day and twice after a weekend. Challenges of the system include cleaning the front 0.45 m (18”) along the wall and using water to assist the drainage of manure. Results of the tip tank have shown a 4 gallon per pig recycle water usage per day. Flushability of the solids and development of sufficient head were factors in this

design. Both systems were automated to lessen human intervention and designed to allow the recycle pumps to be shut down at night.

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Introduction

Shallow gutter manure collection systems can incorporate several means of removing manure from under slats. According to Jones (2006), shallow gutters are used because field experience shows that corrosive and odorous gas production increases with storage time, therefore, frequent removal of manure will conserve nitrogen and limit gas production. Multiple options exist for removing manure from under slats. These include mechanical scrapers, gravity draining, flushing with dump tanks and flushing with an automated valve system.

Flushing systems work by creating a surge of water to flush manure from the gutter, Jones and Collins (2006). Procedures for determining the volume of the flush, discharge rate and frequency are well established, MWPS (1985). Underslat flushing generally requires a 3 inch (7.5 cm) initial flow depth and a 1.25% slope. These systems are frequently used with lagoon systems with water recycled from the lagoon to flush. This allows for frequent flushing while conserving water. Flush systems generally work well and tend to be associated with good air quality within the animal space. However, because of the pumping of water in cold weather there may be more opportunities for frozen pipes and more humidity is added to the animal zone during flushing as compared with scraper systems. Recirculation systems sometimes have problems with salt buildup in pipes and pumps, creating maintenance problems.

Many flushing systems use an automated valve system which holds water in a large pipe in the attic until flushing is triggered. These systems use a time clock to trigger flushes. Cold attics or frozen pipes can sometimes cause leaks to develop over time which harms insulation and may be harmful to the building structure. Other systems use a tipping tank located within the room which is triggered by shifting the center of gravity as the tank fills. Frequency of flush is varied using the fill rate. Lim et al (2004) compared daily flushing with static pits drained 7, 14 and 42 day manure accumulation cycles. They found that flushing and static pit recharge resulted in significantly less NH3, H2S and odor emissions ($P<0.05$). They also found that daily flushing reduced odor emissions by 41% and 34% ($P<0.05$) as compared with the 7 and 14 day cycles. A H2S burst occurred during flushing with recycled lagoon effluent.

A scraper system has one or more scraper blades, a cable or chain to pull the scraper, and a power unit with controls. Scrapers generally work in pairs off of one drive unit so that as one gutter is scraped, the other scraper is returned to the starting position. This method mechanically scrapes solids and liquids to a drain pipe leading to manure storage or treatment.

Scraper systems have been used for many years in cattle and swine facilities. MWPS (1985), Vanderholm and Melvin (2006) and Jones (2006) outline proper design for these systems. Gutters are generally recommended to be flat, however Vanderholm and Melvin stated that a slope of 0.5% to 1% toward the discharge end of the scraper will provide drainage of liquids and may clean better. Voermans and van Poppel (1993) examined several systems with the goal of minimizing ammonia emission. They found in a swine nursery a reduction in ammonia emissions of 80% was achieved using a scraper system rather than a deep pit.

Predicala et al (2007) compared a manure scraper system with a pit pull-plug system. They found that daily removal with the scraper system resulted in a measured maximum H_2S concentration that was 90% lower than the pull-plug system but there was no significant difference in NH_3 concentration and emission. They found that the estimated cost of including the scraper system in a new barn is CND$1.89 per pig sold and the estimated cost of retrofitting a barn was CND$2.90 per pig sold.

The objective of this paper is to evaluate the retrofit of a sloped-gutter automated flush valve system with a tipping tank or mechanical scraper system.

Background

An automated flush valve system has been used on the farm being tested for many years. Maintenance problems, indoor air quality concerns and concerns with disease transmission due to recirculation of lagoon effluent prompted the investigation of an alternative system. Pathogens known to be transmitted by manure, among other vectors, are: Clostridium, E. coli, Pasteurella, PRRS, Salmonella, Streptococcus, and Influenza. These pathogens are shown in Table 1. Chimvadagam (2004) noted that E. coli and total bacteria levels rose during two of three tests with a flush system.

Table 1. Organisms present in animal environments and probably transmission mode. Source: Amass (2005).

Organism	People	Semen	Manure	Animals & Birds	Rodents	Insects	Animal Feed	Water	Fomites	Aerosol	Pigs
Bordetella				x	x			x		x	x
Clostridium	x		x		x	x		x	x	x	x
E. Coli	x		x		x	x		x	x	x	x
Mycoplasma								x	x	x	x
Pasteurella			x					x		x	X
Parvovirus		x							x	x	X
PRRS	x	x	x	x		X			x	x	X
Salmonella	x		x	x	x	X	X	x	x	x	X
Streptococcus	x		x	x				x	x	x	X
Influenza	x		x	x						x	X

Selection Criteria

The source of the greatest emissions should be the highest priority for control technologies. That source is the surface of the manure storage area, regardless of whether it is a shallow or deep pit. Slotted floors over shallow gutters were used to move manure to storage or treatment. Several solutions were considered. Selection criteria for a desired system were: 1) limited initial and operating cost, 2) ease of maintenance, 3) low bacterial load in the building, 4) safety, and 5) effective cleaning to keep the shallow pits dry.

Removing manure frequently from the room to reduce the need for pit ventilation plus efficient manure removal was key to selection of a successful system. A long-term solution with minimal maintenance was a key criterion.

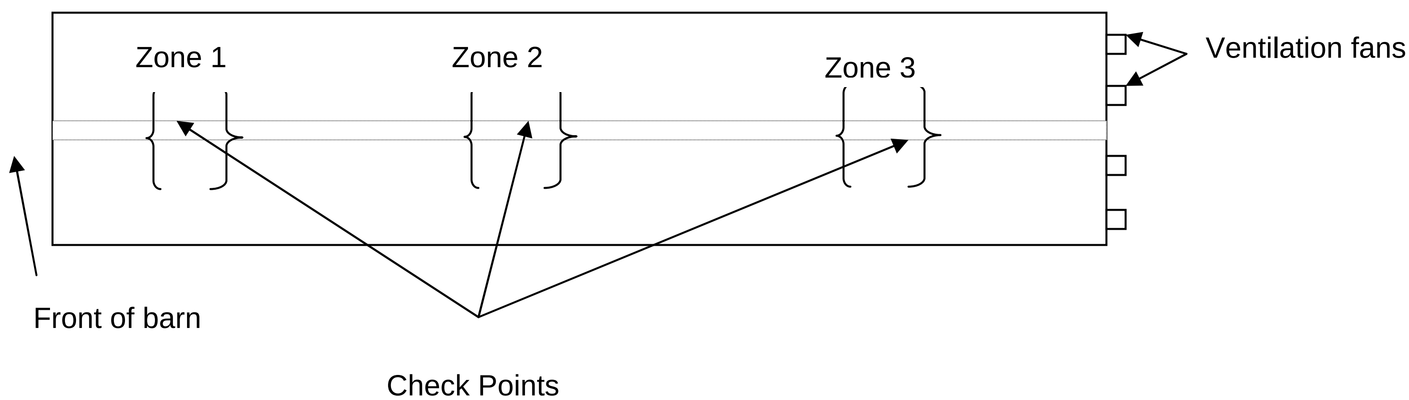
Material and Methods

Description of Facilities

The facilities each were designed as a tunnel ventilated 1100 head finishing barn and measured 14.5 m by 60.6 m. They were previously flushed using automatic flush valves in 4 gutters running the length of the building. These barns were built on a 1.5% slope; therefore the pit was a uniform depth but built on a slope. The alternative manure systems were installed in a series of similar barns at Premium Standard Farms in the fall of 2008. Two 1100 head commercial grower-finisher rooms were used over two production cycles.

The mechanical scrapers were automated to operate every four hours with a time clock. Since the whole building was sloped, one of the scrapers scraped downhill and the other was retracted when going uphill.

The flush tank tipping frequency was based on fill rate. Two tanks were used per pit. Both tanks per pit would fill and discharge simultaneously. These were indoor tanks, and not free-standing exterior tanks.



1 reading point: Zone 2 only

3 reading points:

Zone 1: 15-18 m from front of barn

Zone 2: 30-36 m from front of barn

Zone 3: 42-52 m from front of barn

Figure 1. Layout of sampled finisher barns.

There were two scraper systems per barn. Each system had two 2.6 m (8.5 ft) blades. When going uphill, that blade was in retracted mode, scraping some manure but the amount was minimal. Scraping was done six times per day to ensure the drain system could handle the volume through the 0.2 m (8”) pipe. Each cycle took 6 minutes to go up and 6 min to return to starting position. Newer designed nutrient receiving systems would not require as many cycles in a day. The desired goal is operation three times per day during the week with no weekend cycles. A minimal amount of recycle water was used to assist the effluent going down the drain hole, to help reduce the risk of plugs. This improved nutrient recovery and added minimal liquid to the lagoon.

Photo 1 shows an upright tipping or flush tank at the end of the barn. Each pit had a 900 gallon (1.2 m diameter) and 700 gallon tank (1.0 m diameter) side by side. The tanks were cylindrical and would rotate as they became full due to the change in center of gravity.   The tank rotated towards the exterior of the building and a sloped piece (shown under the tank in Photo 1) ushered the flow in a straight shot into the gutter under the slats.

Photo 1. Tip tank shown in upright position.

Photo 2 shows the tanks as it discharged. The water rushed through the shallow 20 cm (8") pit as a wall of force to remove manure solids in the channel.   Notice the extra room needed at the end of the barn to accommodate the tank. Space immediately in front of the tank was needed also for the wall of water created after tipping.

Photo 2. Flush tank has discharged its contents.

Photos 3 and 4 show the scraper installation at the test barns. Notice the concrete diverters at the end of the pit to lessen the need for fresh water to remove solids at the end of the channel. Electrical rate was $0.08/kWh and cost per gallon of recycled water was $0.01. One 7.5 hp pump was used per tank and one ¾ hp motor per scraper. The size of the drain hole was 0.2 m (8").

Photo 3. Concrete diverters used in the scraper system.

A limit switch is shown in Photo 4 to prevent the length of travel of the scraper to interfere with the pulley guide wheels. Guide wheels were plastic or cast. Notice the cable is stainless steel rather than galvanized to prevent corrosion due to constant exposure to pit gases. There were two drive units per barn. Scrapers were 2.6 m (8.5 ft) wide and barn was 12 m x 67.2 m (40'x220'). Each receiving pit was 5.5 m (18') wide. Each tip tank (4 per barn) was 2.4 m (8') wide. A galvanized tank is projected to last 15 years. The wear part is the cam.

Photo 4. This scraper system showing pulleys with cable leading to the motor.

Photo 5. Safety features of the scraper system above the floor.

Safety Emphasis

With both systems there were concerns about moving parts. These included cables, cams, motors, pulleys, and scraper blades. Previously, the flush tanks were installed in the attic and consisted of long PVC piping and out of reach during daily operations.

With an in-barn tip tank, the cam determines how the tank is emptied into the pit. If not covered, this can be a pinch point for fingers or arms. Since the tank was mounted above the slats on a support structure, it was readily available as a safety concern.

With the scraper system that was installed, there was a shield in-place over the drive unit facing the aisle and mounted on the wall. See Photo 5. A metal sleeve in the pens prevents access to the cable from the floor to the motor. Notice that all wiring was in rubberized cord. The limit switch prevents the scraper blade from passing a certain point under the slats (Photo 4) and the guide wheels were below the slats. The drive wheel was above the slats and parallel to the room wall and protected by the drive motor. No changeable or out-of-route locations of any moving parts were noted above the slats. Only the cable moves above the slats and is parallel to the wall in the end pens.

Results

Cleanability provided by both systems was rated as acceptable. This was determined by daily observation for skips, side misses, and islands of manure left in the pit. Maintenance was aided by having the motor and pulleys easily accessible with the scraper and tanks. All supplemental water used with either system was recycled from a one-stage lagoon. Table 2 shows the annual cost per pig space associated with installation and operation including R&M (repair & maintenance) and electrical costs. R&M includes any repair or replacement, including cables, pulleys, motors, cams, bolts, etc. The scraper system will potentially save $4 per pig space annually.

Table 2. Decision matrix for selecting a technology to replace the auto-flush system. Units are on a per-pig space basis.

	Initial cost ($)	Water usage (gal)	Operational cost ($)	Estimated first year cost ($)	Estimated annual cost over life of equipment ($)	Other considerations
Scrapers	8.54	40	1.36	9.90	1.93	Maintenance
Tip tank	14.54	4,247	5.00	19.54	5.97	Pathogens

Ammonia gas measurements were taken at various times of operation and are listed in Table 3. DrÄeger tubes were used for in-barn sampling. Notice that an average of three readings per date was used in each barn. Both barns had the same dimensions. Notice the increase in ammonia as the turn proceeded.

Table 3. Air quality measurements in sampled barns. The scraper system was in barn 6 and the flush tank barn in 7. From Figure 1, Front = Zone 1, Middle = Zone 2, and End = Zone 3 were averaged.

Date	Barn #	Avg NH_3 (ppm)	Comments
10/31/2008	6	7.75	Scraper was running
	7	7.0	Auto-flush
11/20/2008	6	12.5	Prior to scraper operating
	7	17	In week 7 of Turn
4/8/2009	6	3.7	New group
	7	4.7	

As seen in Table 4, six variables were listed with the preference marked. The tip tanks had its components all above the slats and were easily accessible, therefore making maintenance easier. The scraper had pulleys below the slats and if there was a line break, would need to remove slats. Operating cost was much less for the scraper system, as its electricity cost was less than the pumping cost for the tank. Initial cost was less for the scraper because it didn't have many expensive parts, whereas the tank had a large expense for the tank, cradle, and pump. Users preferred the scraper because it was out-of-sight and they didn't need to plan for the effects of flushing. Both systems seemed to clean effectively. No islands were left and the tank provided the volume and velocity to remove solids consistently. Ammonia readings were similar for both systems.

Table 4. Decision matrix for selecting a replacement manure handling system.

	Tip tank	Scraper

Maintenance	x	
Operating cost		X
Initial cost		X
User preference		X
Cleaning effectiveness	x	X
Perceived air quality		X

Conclusion

Both systems achieved the objective of eliminating the auto-flush manure removal system. Limiting the amount of recycle water became a key driver in the decision process. Other considerations included electrical usage, effectiveness of removing manure, applicability to other stages of production, and expected expenses. For those reasons, we selected the scraper system.

Acknowledgements

Thanks to Dale Houck from Premium Standard Farms for allowing us to install these systems and monitor gas concentrations. A special thanks to Dr. Pablo Moreno for providing the list of organisms present in the animal environment and Mike Daggett for reviewing this paper.

References –

Amass, S.F. 2005. Key Principles of Biosecurity. Pig Journal Vol. 55, 104-114. Department of Veterinary Clinical Sciences, Purdue University School of Veterinary Medicine, West Lafayette, IN.

Chinivasagam, N., and P. Blackall. 2004. Flushing with effluent on the bacterial load in the air of Queensland piggeries. Dept of Employment, Economic Development, and Innovation. Queensland Primary Industries and Fisheries.

Elder, J.D, and R. Petty. 2003. Flush systems and sand. ASAE Publication No. 701P0203. St. Joseph, Mich.: ASABE.

Heber, A.J., P. Tao, J. Ni, T.T. Lim, and A.M. Schmidt. 2005. Air emissions from two swine finishing buildings with flushing: Ammonia characteristics. Proceedings of the Seventh International Symposium. 18-20 May 2005. Beijing, China. ASAE Paper No. 701P0205. St. Joseph, Mich.: ASABE.

Huang, H., G.Y. Miller, M. Ellis, T. Funk, G. Hollis, Y.Zhang, and A.J. Heber. 2003. Odor management and swine finishing building characteristics: costs and effectiveness. ASAE Paper No. 701P1403. St. Joseph, Mich.: ASABE.

Jacobson, L.D., B.P. Hetchler, V.J. Johnson, C.J. Clanton, and D.R. Schmidt. 2006. Minimizing pit emissions from pig barns to optimize "catch and treat" mitigation technologies like biofilters. ASABE Paper No. 06xxxx. St. Joseph, Mich.: ASABE.Jones, D.D. 2006. Shallow Gutter Manure Collection Systems. Pork Information Gateway Factsheet. PIG 09-07-02. USPCE, Ames, IA.

Jones, D.D, and E.R. Collins, Jr. 2006. Recirculation Systems for Manure Removal. Pork Information Gateway Factsheet. PIG 09-07-01. USPCE, Ames, IA.

Karmakar, S., C. Lague, J. Agnew, and H. Landry. 2006. Management practices for swine manure in the Canadian prairies region. Paper No. 06223. St. Joseph, Mich., ASABE.

Karmakar, S., C. Lague, J. Agnew, and H. Landry. 2006. Decision-making process for the design, selection, and operation of manure management systems: a review. Canadian Society for Bioengineering Paper No. 06-115.Lachance, I., S. Godbout, S.P. Lemay, J.P. Larouche, and F. Pouliot. 2005. Separation of pig manure under slats: to reduce releases in the environment. ASAE Paper 054159. St. Joseph, MI.

Lim, T.T., A.J. Heber, J.Q. Ni, D.C. Kendall, and B.T. Richert. 2004. Effects of manure removal strategies on odor and gas emissions from swine finishing. TRANS of the ASABE 47(6):2041-2050.

Midwest Plan Service. 1985. Livestock Waste Facilities Handbook. MWPS-18. Midwest Plan Service. Iowa State University, Ames, IA.

Midwest Plan Service. MWPS-1. Eleventh Ed. 1983. S702.1. Iowa State University, Ames, IA.

Predicala, B.A., E.L. Cortus, S.P.Lemay, and C. Lague. 2007. Effectiveness of a manure scraper system for reducing concentrations of hydrogen sulfide and ammonia in a swine grower-finisher room. Transactions of the ASABE Vol. 50(3): 999-10006

Schmidt, D.R., L.D. Jacobson, and M.A. Schmitt. 1996. A manure management survey of Minnesota swine producers: Summary of responses. Applied Engineering in Agriculture. Vol. 12(5):591-594.

Vanderholm, D. and S. Melvin. 2006. Scraper systems for removing manure from swine facilities. Pork Information Gateway Factsheet. PIG 09-07-03. USPCE, Ames, IA.

Voermans, J.A.M., and F. van Poppel. 1993. Scraper systems in pig houses. In *Proc. 4th Intl Symposium on Livestock Environment, 650*-656. St. Joseph, MI. ASAE.