Belt System for Swine Waste Management

J.M. Rice, C. Baird, J. Classen, F.J. Humenik, S. Liehr, K. Zering, E. Van Heugten

J. Mark Rice[1], ASAE Member, Extension Specialist, Craig Baird[1], ASAE Member, Research Associate, John Classen[1], Associate Professor, F. J. Humenik[1], ASAE Fellow, Professor, Sarah Liehr, Agricultural Engineer, Associate Professor, North Carolina State University. Kelly Zering, Associate Professor, College of Agriculture and Life Sciences, Department of Agriculture and Resource Economics, North Carolina State University, Raleigh, NC. Eric Van Heugten, Assistant Professor, College of Agriculture and Life Sciences Animal Science Department, North Carolina State University, Raleigh, NC. Corresponding author: Mark Rice, North Carolina State University, Box 7927, Raleigh, NC 27695; phone: 919-515-6794; fax: 919-513-1023; e-mail: mark_rice@ncsu.edu.

[1]Biological and Agricultural Engineering Department, North Carolina State University.

Abstract. An under floor convex belt which provides immediate separation of liquids and solids to reduce odor, ammonia volatilization and facilitate alternative processes for the conservation and processing of value added constituents in the liquid and solid stream has been developed and evaluated.

Key words. Manure, belt systems, waste utilization, air quality protection.

The belt system for swine waste removal and utilization is located at North Carolina State University's Lake Wheeler Road Field Laboratory in Raleigh, North Carolina. This is an alternative manure management system that is designed to maintain separation of the swine manure solids and liquid waste streams. This pilot scale design is based on a swine finishing facility that consists of five pens, which contain a total of fifteen pigs, and provides 7.94 square feet of floor space per pig. Flooring in the pens is slotted which allows the waste to drop through the floor to the belt below. (See Figure 1.) The belt has a convex shape so the liquids flow off into gutters that are positioned along each side of the belt. This waste liquid then flows to an enclosed collection tank for future processing. The solid waste remains on the belt and is carried to a hopper at one end before being conveyed out of the housing facility. (See Figure 2)

Figure 1. Belt system during solids removal

Figure 2. Belt system after solids removal.

By separating the waste streams, bacterial urease, which is present in the feces, has limited opportunity to metabolize the urea in urine to ammonia and carbon dioxide. The reduction in ammonia emissions is one of the performance objectives of an environmentally superior technology.

It must be recognized that the belt is just a single component or unit process for the total swine production/waste management system. It provides an environmentally superior technology for solids separation in a manner that facilitates alternative treatment or utilization strategies for the separated liquid and solids waste streams. The liquid stream volume is reduced resulting in a less expensive liquid treatment system and the solids have lower moisture content than obtained with other solids separation technologies.

While there is great interest in developing a belt system that can be retrofitted into existing houses in North Carolina, there is also international interest in the belt system as a component of the next generation swine production/waste management system that will provide cost effective solids separation for alternative utilization strategies and reduction of odor and ammonia emission within the production unit and total waste management system. Activities have been initiated with an equipment manufacturer and hog producers to further develop prototype belt system designs for retrofitting totally slatted and partially slatted production units in North Carolina. These evaluations will establish the basis for the less difficult assignment of installing a belt system in new buildings.

Project Evaluation

During the evaluation period from January 13, 2003 through January 7, 2004, belt solids and liquids were collected, measured, sampled and characterized during three consecutive rotations of pigs. The belt system is located in a building that is different from the conventional hog houses at this research facility. Because there is not a legitimate control, it was difficult to make animal performance and air quality comparisons.

After startup and optimization of the belt and peripheral system components were performed, solids and liquids were weighed, measured and characterized (Tables 1-4). A benefit of the belt system is the reduced volume of wastewater to be managed on a daily basis since the belt system does not require a waste pit flush system. In addition, liquid storage and treatment costs can be reduced because the solids fraction is managed separately.

Table 1. Average Daily Animal Waste Collected with the Belt System

	Solids lbs/pig/day[3]	Liquid gal/pig/day
2nd Rotation[1]	1.74	0.77
3rd Rotation[2]	1.66	0.69
4th Rotation[1]	2.18	0.96
Average	1.86	0.81

[1] pigs in 2nd and 4th rotations were barrows
[2] pigs in 3rd rotation were gilts.
[3] wet basis (67% moisture)

The belt system provides a platform for alternative waste utilization strategies since the primary nutrients partition differently between the solids and liquid fractions of the waste streams (Table 2). Since most of the phosphorous is contained in the solids stream it can be easily captured for off farm utilization. Most of the nitrogen is retained in the liquid waste fraction and can be managed for alternative utilization and processing, or land applied as a nitrogen source for crop production.

Table 2. Average Waste Partitioning Characteristics, Mass based.[1]

	TKN	TP	Cu	Zn
Solids Fraction	39%	90%	97%	90%
Liquid Fraction	61%	10%	3%	10%

[1] - (2nd, 3rd, and 4th rotations)

Table 3. Average Solids Waste Characterization for Belt System (µg/g)

	TKN [3]	TP [3]	Cu [4]	Zn [4]	%MC
2nd Rotation[1]	14,328	8,515	128	1,657	65.62
3rd Rotation[2]	13,261	6,405	94	1,420	68.55
4th Rotation[1]	12,799	7,729	70	1,038	67.83
Average	13,632	7,637	103	1,441	67.09

[1] - pigs in 2nd and 4th rotations were barrows
[2] - pigs in 3rd rotation were gilts.
[3] - wet basis
[4] - dry basis

Table 4. Average Liquid Waste Characterization for Belt System (mg/l)

	TKN	TP	Cu	Zn	FSS
2nd Rotation[1]	7,455	308	0.28	14.17	3,752
3rd Rotation[2]	5,164	144	0.44	15.52	6,503
4th Rotation[1]	4,981	226	0.25	10.78	2,896
Average	6,141	235	0.33	13.87	4,479

[1] - pigs in 2nd and 4th rotations were barrows
[2] - pigs in 3rd rotation were gilts.

Several alternative waste utilization strategies are being evaluated for the solids. The companion Black Solider Fly biomass conversion project utilizes the belt solids as a food source for the production of Black Soldier Fly larvae for value added processing into animal feed protein meal and oil. A high temperature charring process is being evaluated to produce an agronomic product that provides a stable, pathogen free product with a high cation exchange capacity suited for retention of fertilizer nutrients. In addition, a lime stabilization process of the belt solids is also being evaluated. The research objective is to produce a pathogen free agronomic product and recover the volatilized ammonia during this waste utilization process. Finally, vermicomposting of the waste solids generates a highly desirable soil amendment for use in the lawn care and landscape industry.

The liquid waste is a low-volume stream with a high concentration of ammonia and relatively low amount of solids. These characteristics make this waste stream favorable for ammonia recovery. A pilot scale ammonia stripping process is currently being tested cooperatively by researchers in the Department of Biological and Agricultural Engineering, North Carolina State University, Raleigh, North Carolina and USDA-Agricultural Research Service, Florence, South Carolina. This nitrogen recovery unit will strip the ammonia from the waste liquid and collect it for final product recovery as a concentrated ammonium solution.

A preliminary bench study was conducted to determine the conversion of organic nitrogen to ammonia in the liquid waste collection tank. While better QA/QC procedures must be employed to reduce data variability, it is clear that within 30 hours about 90 percent of the original Total Kjeldahl Nitrogen (TKN) is converted to ammonia. (See Table 5).

A Golden Leaf grant has been obtained by the College of Agriculture and Life Sciences Animal Waste Management Programs and the College of Management at North Carolina State University for "Development of Marketable By-Products from Alternative Swine Waste Treatment Technologies." The major objective is to evaluate the economic benefits of actual and potential value-added by-products from alternative swine waste management technologies. A business feasibility analysis is being conducted to determine the most profitable by-product for typical conditions and thus help direct technology development and optimization. This feasibility analysis, in conjunction with a life cycle contribution analysis will estimate the overall profitability of value-added by-products from the belt system.

Table 5. Conversion of TKN to Ammonia in Collected Belt Waste Liquid

		TKN	NH_3N
5:45 AM	8/26/2003	4,807	261
10:05 AM	8/26/2003	4,567	318
12:05 PM	8/26/2003	4,428	396
2:05 PM	8/26/2003	4,829	537
4:05 PM	8/26/2003	5,144	729
8:15 AM	8/27/2003	5,261	4,487

System Management and Operation

Operation of the belt system required some basic mechanical knowledge, but no specialized training or instruction was needed to operate this system. The belt system offers operational versatility in that it can be configured to operate automatically, or manually. Automated controls may be installed to facilitate automatic operation of the belt system. During this evaluation, the belt system for manure collection was manually operated on a daily schedule, while the liquids were collected continuously. On a daily schedule, an operator turned on the belt to convey belt solids out of the barn. This was typically done early in the morning before the animals were active, in order to collect the driest waste solids. This procedure required approximately fifteen minutes per day. After each rotation of pigs, the building and the belt system were pressure washed and sanitized as part of the clean-up and biosecurity procedure.

During this short evaluation period, daily observation of the belt was sufficient to insure proper system operation. Routine maintenance on the belt system was negligible during this time period. For a full scale, operational system, routine maintenance involves checking the belt system drive components, such as belt tension, alignment and tracking and gearbox fluid levels. This maintenance should be performed at monthly intervals and generally takes about thirty minutes to complete.

Conclusion

There are several benefits of the belt system. It keeps the manure solids and liquids separated so they can be quickly conveyed out of the barn environment, thereby potentially reducing odor and ammonia volatilization and improve animal performance. Nitrogen in the liquid stream, which is primarily organic, can be naturally converted to ammonia and retained in the liquid in an enclosed collection tank. A reduction in overall liquid treatment volume and cost is also realized because liquid and solids are not mixed and flush or pit pre-charge water is not used in the belt system. The belt system provides a platform for alternative waste utilization strategies for converting manure constituents to value-added products for off-farm use and thereby greatly reduces the land acreage required for terminal land application.