Improvements in animal productivity and health with a total aerobic manure management system

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Abstract

The aim of this study was to evaluate the effects of improved manure management using second generation technology on air and water quality and the beneficial effect of a cleaner environment on animal productivity and health. The technology is a lower cost, second generation treatment system developed as an alternative to the lagoon/spray field system typically used to treat the wastewater generated by swine farms in the USA. The aerobic system combines solid-liquid separation, biological ammonia treatment, phosphorus recovery and compost of manure with cotton gin residue. This combination of processes substantially eliminates release into the environment of odors, pathogens, ammonia, greenhouse gases and heavy metals. It also produces a deodorized and disinfected liquid effluent used for flushing the barns and for crop irrigation, and value-added organic products for use in horticultural markets. The system was demonstrated full-scale in 2007 in a 5,150-head finishing swine operation in North Carolina under steady-state conditions. It removed 97.7% of the total suspended solids, 99.6% of BOD, 96.1% of TKN, 97.3% of ammonia, 94.0% of total phosphorus, 99.3% of copper, 99.2% of zinc, 99.9% of the odor compounds, and 99.99% of pathogens. Compared to the traditional lagoon system, ammonia concentration in the exhaust air from the barns was reduced 75% with the use of the new treatment system. In turn, the improved housing environment enhanced animal health and productivity: mortality decreased 57%, daily weight gain increased 11%, and feed conversion improved 5.4% compared to the traditional lagoon management. As a result of this research, new legislation was enacted in North Carolina to promote the conversion of farms to cleaner technologies. These results overall show that cleaner alternative technologies can have significant positive impacts on livestock production and the environment.

Introduction

Substantial animal production advantages can be realized by improvements in manure management. Barker (1996) documented with many examples the direct linkage between improved manure management and improved air quality in the barn - especially lower ammonia concentrations - and their combined effect on animal productivity and health. Indicators of better productivity and health were healthier pigs, reduced mortality, increased daily gain, improved feed conversion, and substantial economic benefits to the producer.

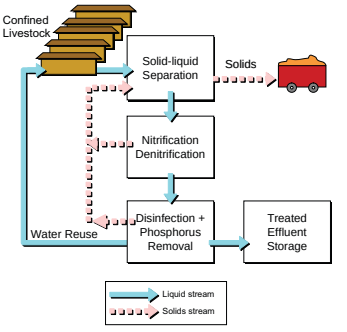
A new wastewater treatment system was developed to replace the anaerobic swine lagoon technology commonly used in the USA to treat swine waste (Vanotti et al., 2007a). The system met the criteria of an environmentally superior technology (EST) as determined by an agreement between government and swine industry to find technologies that could replace the lagoon system (Williams, 2006). The environmental performance standards of an EST are the following: (1) eliminate the discharge of animal waste to surface waters and groundwater through direct discharge, seepage, or runoff; (2) substantially eliminate atmospheric emissions of ammonia; (3) substantially eliminate the emission of odor that is detectable beyond the boundaries of the swine farm; (4) substantially eliminate the release of disease-transmitting vectors and airborne pathogens; and (5) substantially eliminate nutrient and heavy metal contamination of soil and groundwater.

The aim of this study was to evaluate the effects of improved manure management on air and water quality and the beneficial effect of a cleaner environment on animal productivity and health. The study was done at full-scale on a 5,600-swine finishing farm where the manure management system was converted from anaerobic lagoon to a new EST wastewater treatment system.

New wastewater treatment system

The on-farm system uses solid-liquid separation, biological nitrogen removal, and disinfection and phosphorus removal unit processes linked together into a practical system for livestock operations (Figure 1). The system greatly increases the efficiency of solid-liquid separation with flocculation of the suspended solids using polymer. Nitrogen management to eliminate ammonia emissions is accomplished by passing the liquid through a biological module containing nitrification and denitrification bacteria adapted to high-ammonia wastewater. Subsequent alkaline treatment of the liquid in a phosphorus removal module precipitates phosphate and kills pathogens. The phosphorus precipitate is simultaneously separated with the manure. The system recycles clean water to flush the barns. The treated water is stored in the former lagoon and used for crop irrigation. The solids are removed from the farm and used for the manufacture of value-added products and energy production.

Figure 1. Schematic of the second generation treatment technology



The first generation technology was demonstrated full-scale in Goshen Ridge farm, a 4,400-head finishing farm in Duplin County, NC. The on-farm technology met the environmental performance criteria of an EST (Williams, 2006). It was determined as an unconditional EST for new farms which are permitted and constructed for the first time after March 2005 and for expansion of existing swine farms (Williams, 2006). Recommendations were also made to evaluate an improved, redesigned second generation version of the wastewater treatment system. The new system design is based on experiences gained during first generation demonstration and incorporates new science (Vanotti et al., 2007b). It is intended to significantly lower capital, maintenance and operating cost of the system without lagoon and also improve system reliability and simplicity. Detailed description of the new system is provided in Vanotti and Szogi (2007).

Swine farm characteristics

The full-scale demonstration facility was installed on B&B Tyndall farm near Clinton, Sampson Co., NC, and evaluated intensively under steady-state conditions. The farm contained seven swine barns and two traditional anaerobic lagoons of equal area (0.58 ha each) for treatment and storage of the manure. Manure was collected under the barns using slotted floors and a pit-recharge system typical of many swine farms in North Carolina and

treated and stored in the anaerobic lagoons. Under this traditional management, lagoon liquid was recycled into the barns to recharge the pits under the slotted floor and facilitate flushing of the newly accumulated manure. Farm records for the previous three growing cycles (2005-2006) showed the farm produced 1,287,613 lb of total live weight (1,073,719 lbs gain) in each growing cycle. The growing cycles started with an average of 5,697 pigs. The average weight of a pig was 147.7 lb (range 0 to 253 lb).

System performance – water quality improvement

The wastewater treatment performance data obtained during full-scale operation are summarized in Table 1 showing the values of various water quality indicators as the liquid passed through each treatment module and the overall efficiency of concentration reduction for these parameters. The on-farm system lowered concentration of constituents in wastewater as follow: 97.1% of TSS, 99.4% of BOD_5, 95.5% of TKN, 96.9% of NH_4-N, 92.2% of TP, 99.0% of Cu and 98.8% of Zn. On a mass basis, the treatment system removed 97.7% of the TSS, 99.6% of BOD_5, 96.1% of TKN, 97.3% of NH_4-N, 94.0% of TP, 99.3% of Cu and 99.2% of Zn. It also eliminated 99.9% of the odor compounds and 99.99% of the pathogens. These high treatment concentration reduction efficiencies were obtained during a 6.5-month period with average daily air temperatures ranging from -1.5 to 28.2°C and large variations in the strength of the manure due to typical livestock growth cycles. Therefore the second generation treatment system met the standards for ammonia, nitrogen, phosphorus, copper, zinc, odor and pathogen removal that define an Environmentally Superior Technology.

Table 1. Elimination of TSS, BOD, nutrients, heavy metals, odors and pathogen indicator from wastewater by second generation treatment system developed to replace swine lagoons in USA. Data are means of samples collected during the period of Dec. 9, 2006 – July 2, 2007 (n=60)

Water Quality Parameter	Raw Flushed Manure	After Solids Separation	After Biological TreatmentN	After Phospho-rus Treatment	System Efficiency (%)
TSS (mg/L)	11,230	1,320	270	325	97.1
BOD5 (mg/L)	7,725	3,548	67	43	99.4
TKN (mg/L)	1,910	1,428	101	85	95.5
NH_4-N (mg/L)	1,180	1,182	59	37	96.9
TP (mg/L)	461	184	73	36	92.2
Cu (mg/L)	14.0	2.57	0.16	0.14	99.0
Zn (mg/L)	20.5	3.33	0.36	0.25	98.8
Odor Compounds (ppb) [a]	0.17	99.99	51	39	99.9
Fecal Coliforms (log10 cfu/mL)	4.11	3.47	0.84		

[a] Odor compounds = phenol, p-cresol, p-ethylphenol, indole, and skatole.

Reduction of ammonia in the barns

Ammonia concentration in the air inside the barns was measured during traditional lagoon treatment in 2006 and again with the new treatment system in 2007. Measurements were done in the same barns (barns # 2 and 6) during the same time of the year (May-September) at the following points inside the barn: 1) at 5 ft height (operator nose), 2) at 1 ft height (pig nose), and 3) at 6 in. below the slotted floor (inside the manure pit atmosphere). We also measured the ammonia in the air blown out by the large exhaust fans that provide ventilation to the buildings. Each of the four-month measurement periods included pig sizes representative of a full production cycle; the average pig weight per barn was 113,134 lb during 2006 measurements and 112,943 lb during 2007 measurements. Results of the air measurements showed a vertical gradient of ammonia inside the barns

with higher concentrations close to the liquid manure in the pit. However, the new system had significantly lower ammonia concentrations in the air than the lagoon management system at all depths, and the differences between management systems were more pronounced at the lower depths. Compared to the lagoon system, the new system lowered ammonia concentrations in the air inside the barns by an average of 40.3% at the operator nose level (from 3.05 to 1.82 ppm), 44.5% at the pig nose level (from 3.73 to 2.07 ppm), and 58.1% in the manure pit atmosphere below the slotted floor (from 12.09 to 5.06 ppm). We also found pronounced differences in the quality of the air blown to the outside by the barn's ventilation fans; the average ammonia concentration reduction in the exhaust air was 75.1% with the use of the new treatment system (from 11.3 to 2.81 ppm) (Figure 2).

Animal productivity and health improvement

The reuse of cleaner, sanitized water to refill barn pits reduced ammonia concentration in the air and improved the growing environment. As shown in Figure 1, part of the treated water was reused on the farm to flush the pits under the barns. It replaced the dirtier lagoon liquid charged with ammonia used for the same task under the traditional lagoon management. As a result, animal health and productivity were enhanced (Table 2). These data show that, compared to lagoon management, significantly fewer pigs died as a result of the cleaner environment (mortality decreased 57%). In addition, the rate of feed conversion into meat improved 5.4%. The pigs also grew faster with the cleaner environment. The average daily weight gain (lb/pig/day) increased 11%. Results obtained in this demonstration project are consistent with the observations of Barker (1996) on the substantial animal production advantages that can be realized by improvements in manure management in swine production buildings.

Table 2. Improvement of animal productivity and health indicators obtained with the new waste treatment system compared with the previous lagoon system. Data are means ± s.e. of production records in seven barns (n=7)

	Previous growing cycles using the old lagoon system			Pig growing cycle with new system	
	Oct. 2005 - Feb 2006	Feb. 2006 - July 2006	July 2006 - Dec.2006	Dec. 2006 - May 2007	% Change [a]
Mortality(%)	10.01 ± 0.98	7.60 ± 0.84	3.58 ± 1.05	3.06 ± 0.80	- 56.7%
Daily Gain [b] (lb/pig/day)	1.529 ± 0.02	1.485 ± 0.02	1.644 ± 0.02	1.718 ± 0.02	+ 10.5%
Feed Conversion [c] (lb feed/lb meat)	2.78 ± 0.05	2.48 ± 0.03	2.59 ± 0.05	2.47 ± 0.03	-5.4%
Condemnation [d] (%)	0.26 ± 0.19	0.17 ± 0.05	0.21 ± 0.15	0.13 ± 0.07	-38.1%

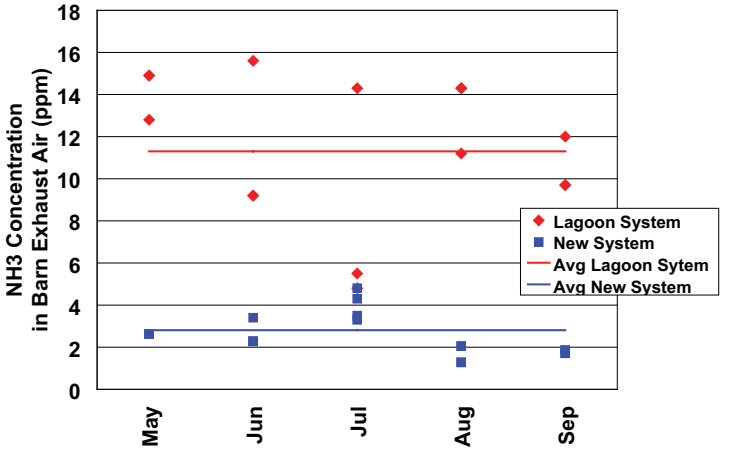
[a] % Change compares performance obtained with the new system with average performance obtained in the three previous cycles using the lagoon system. [b] Daily gain = Finished weight minus start weight divided by number of days on feed.
[c] Actual feed conversion after condemnation. [d] Entire hogs that did not pass inspection.

Conclusions

We evaluated the effects of improved manure management on air and water quality and animal productivity and health. The treatment system substantially removed N, P, copper, zinc, odor and pathogens. Ammonia concentration in air of the barns was reduced, and animal health and productivity were enhanced: mortality decreased 57%, daily weight gain increased 11%, and feed conversion improved 5.4% compared to the traditional lagoon management. These results overall showed that cleaner alternative technologies can

have significant positive impacts on livestock production and the environment. For this reason, the State of North Carolina has established a lagoon conversion program (LCP, 2007) that provides financial incentives to assist producers in the conversion of anaerobic swine lagoons to cleaner environmentally superior technology.

Figure 2. Ammonia concentrations in fan exhaust air with the traditional lagoon system (2006 measurements) and the new treatment system (2007 measurements)



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