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IMPROVED HEALTH AND PRODUCTIVITY OF SWINE WITH TREATMENT OF AMMONIA FROM MANURE

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ABSTRACT
Substantial animal production advantages can be realized by improvements in manure management. In this study, the direct linkage between improved manure management and animal productivity and health was documented in a full-scale on-farm demonstration of an innovative swine manure treatment system operating at full-scale during five pig production cycles. Indicators of better productivity and health were healthier pigs, reduced mortality, increased daily gain, improved feed conversion, and substantial economic benefits to the producer. In North Carolina, USA, construction of new swine farms or expansion of existing swine farms requires new waste management systems that meet multiple environmental standards of reduced ammonia, odor emissions, and pathogens release, and the substantial elimination of soil and groundwater contamination by nutrients and heavy metals. A treatment system that met these multiple standards was implemented at full-scale in a swine farm. It combined high-rate solid-liquid separation with nitrogen and phosphorus removal/disinfection processes that replaced the existing anaerobic lagoon treatment for the waste. Ammonia concentration in the manure effluent was reduced by 96% and pathogens 99.99%. The reuse of cleaner, sanitized water to refill barn pits reduced ammonia concentration in the air and improved the growing environment. Ambient ammonia levels in the barns dropped an average of 75%, from 11.3 to 2.8 ppm. As a result, animal health and productivity were enhanced. Daily weight gain increased 6.1%, and feed conversion improved by 5.1%. Animal mortality decreased 47%, and cull weight was reduced by 80%. The farmer sold an average of 5,265 pigs per growing cycle, which resulted in a 516,300-kg net gain per cycle. During five production cycles, the farmer sold 28,100 kg more hogs (a 5.8% increase) per growing cycle compared to the previous lagoon management at the same farm.

INTRODUCTION
Typically, waste from confined swine production operations in the south-eastern U.S. is stored and treated in large, open anaerobic lagoons prior to application on cropland. Environmental and human health concerns associated with the anaerobic lagoon system included emissions of ammonia, odor, pathogens, and water quality deterioration. Therefore, there was a major interest in developing new swine manure treatment systems in the region to address these issues. Consequently, demonstrations of new treatment systems were conducted on-farm to demonstrate feasibility of environmental superior waste management technologies (EST) that could address five environmental standards: 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 parcel or tract of land on which the swine farm is located; 4. Substantially eliminates the release of disease-transmitting vectors and airborne pathogens; and 5. Substantially eliminates nutrient and heavy metal contamination of soil and groundwater [4]. The swine waste management system described in this work is a manure treatment system [3] developed to meet the environmental standards referenced above. As a result of this process, new legislation in North Carolina was enacted enforcing the environmental performance standards of EST for the construction of new swine farms or expansion of existing swine farms [2]. 2013).

The aim of this study was to evaluate the effects of improved manure management on water quality and air 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.

MATERIAL AND METHODS
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 [3]. 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 (this replaces the use of lagoon water with high ammonia used to flush the barns in previous system). 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. An aerial picture of the system and swine barns is shown in Fig. 1.

RESULTS AND DISCUSSION
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 in the system and the overall efficiency of concentration reduction for these parameters. In cleaning up manure wastewater, the system removed 99.99 percent of pathogens, 99 percent of odor-causing components, and 95 percent of total phosphorus,

97 percent of ammonia, and more than 99 percent of heavy metals copper and zinc. These high removal efficiencies significantly reduced the environmental footprint of the operation. For this reason, the farmer was permitted by State authorities to expand its operation from 5,145 to 11,025 pigs.

Figure 1. Aerial picture of waste treatment system and barns. It treated all the manure flushed from seven barns with 735 pigs each.

Table 1. Manure treatment plant performance by treatment step and overall efficiency.
Data are means of 122 samples during five pig growth cycles (Vanotti et al., 2018).

Water Quality Parameter	Raw Flushed Manure	After Solids Separation Treatment	After Biological N Treatment	After Phosphorus Treatment	System Efficiency (%)
TSS (mg/L)	11,754 ± 6417	1254 ± 1015	227 ± 199	325 ± 215	97.2
BOD (mg/L)	7364 ± 6313	3185 ± 2692	62 ± 88	41 ± 61	99.4
TKN (mg/L)	2054 ± 778	1466 ± 600	138 ± 166	87 ± 130	95.7
NH_4-N (mg/L)	1290 ± 615	1213 ± 451	124 ± 171	45 ± 92	96.5
TP (mg/L)	492 ± 272	151 ± 79	83 ± 30	33 ± 23	93.3
Cu (mg/L)	16.8 ± 11.1	2.0 ± 2.4	0.2 ± 0.1	0.2 ± 0.1	98.8
Zn (mg/L)	25.4 ± 12.6	2.9 ± 2.8	0.4 ± 0.4	0.3 ± 0.3	98.8
Odor Compounds (ppb) [a]	71,269 ± 14,733	63,642 ± 12,366	40 ± 17	44 ± 11	99.9
Fecal Coliforms (log cfu/mL)	4.11 ± 0.19	3.47 ± 0.16	0.84 ± 0.23	0.17 ± 0.18	99.99
Salmonella (log cfu/mL)	1.79 ± 0.11	1.14 ± 0.30	0.00 ± 0.00	0.00 ± 0.00	100.00

[a] Odor compounds = sum of phenol, p-cresol, p-ethylphenol, indole, and skatole concentrations in the liquid.

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. The treated water with low ammonia and pathogens was reused on the farm to flush the pits under the barns. It replaced the dirtier lagoon liquid charged with ammonia (532 ± 189 mg/L) used for the same task under the traditional lagoon management. Since the recycled wastewater was mostly ammonia free, ambient ammonia levels in the air in the barns dropped an average of 75 percent, from 11.3 to 2.8 ppm. As a result, animal health and productivity were enhanced (Table 2). Daily weight gain increased 6.1 percent, and feed conversion improved 5.1 percent. Animal mortality decreased 47 percent, and cull weight was reduced by 80% (Table 2). The farmer sold an average of 5,265 pigs per growing cycle, which resulted in a 1,138,247-pound net gain per cycle. Using the new manure management instead of the lagoon system, the farmer sold 61,996 pounds more hogs—a 5.8 percent increase—per growing cycle (Table 2). Results obtained in this demonstration project are consistent with previous observations [1] 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 on the same farm. Data are means of production records obtained in seven barns during five production cycles before conversion and five production cycles after conversion.

	Five pig growing cycles using the old lagoon system (before new system)	Five pig growing cycles with the new manure treatment system	% Change[a]
Mortality (%)	5.23	2.77	-47%
Daily Gain (lb/pig/day)	1.48	1.57	+6.1%
Feed Conversion (lb feed/lb meat produced)	2.56	2.43	-5.1%
Cull/cycle (lb)[b]	23,575	4,777	-80%
Gain/cycle (lb)	1,076,251	1,138,247	5.8%

[a] % Change compares the performance obtained with the new system with performance obtained using the preceding lagoon system.
[d] Entire hogs that did not pass inspection.

CONCLUSIONS

This full-scale study evaluated the effects of improved manure management on air and water quality in a swine farm, and the effect of the improved environment on 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. Animal health and productivity were enhanced: mortality decreased 47%, daily weight gain increased by 6.1%, and feed conversion improved 5.1% compared to the traditional lagoon management. These results overall showed that cleaner alternative technologies for manure management can have significant positive impacts on livestock production and the environment.

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