DEVELOPMENT OF ENVIRONMENTALLY SUPERIOR TECHNOLOGY IN NORTH CAROLINA: THE SUPER SOIL PROJECT

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ABSTRACT. *A treatment system was developed to eliminate animal-waste discharge to surface and groundwaters and contamination of soil and groundwater by nutrients and heavy metals, along with related release of ammonia, odor, and pathogens. The system greatly increased the efficiency of liquid-solid separation by injection of polymer to increase solids flocculation. Nitrogen management to reduce ammonia emissions was accomplished by passing the liquid through a module where bacteria transformed ammonia into harmless nitrogen gas. Subsequent alkaline treatment of the wastewater in a phosphorus module precipitated recoverable phosphorus and killed pathogens. Treated wastewater was recycled to clean swine houses and crop irrigation. The system was tested during one year at full-scale in a 4,400-head finishing farm as part of the Agreement between the Attorney General of North Carolina and Smithfield Foods/Premium Standard Farms to replace current anaerobic lagoons with environmentally superior technology. The system removed 97.6% of the suspended solids, 99.7% of BOD, 98.5% of TKN, 98.7% of ammonia, 95% of total P, 98.7% of copper and 99.0% of zinc. It also removed 97.9% of odor compounds in the liquid and reduced pathogen indicators to non-detectable levels. It was verified that the technology was technically and operationally feasible. Based on performance results obtained, it was determined that the treatment system met the Agreement's technical performance standards that define an environmentally superior technology.*

Keywords. *Manure treatment, confined swine production, alternative technologies , liquid-solid separation, phosphorus and ammonia removal, pathogen destruction, odor control, swine lagoons, CAFO.*

INTRODUCTION

Minimizing livestock wastewater manure's impact on the environment is one of U.S. agriculture's major challenges. When properly managed, manure can be used as nutrient sources for crops and to improve soil properties through accretion of soil organic matter. On the other hand, improperly managed manure can pose a threat to soil, water and air quality, and human and animal health.

Currently, there is a government-industry framework in North Carolina for conversion of anaerobic swine waste lagoons and sprayfields to alternative technologies. In July 2000, the Attorney General of North Carolina reached an agreement with Smithfield Foods, Inc. and its subsidiaries, the largest swine producing companies in the world, to develop and demonstrate environmentally superior waste management technologies for implementation onto farms that are owned by these companies located in North Carolina. In October 2000, the Attorney General reached a similar agreement with Premium Standard Farms, the second largest swine producer in the country. Taken together, Smithfield and Premium Standard represent over 75% of the swine farms in North Carolina. The agreement defines an environmentally superior technology (EST) as any technology, or combination of technologies that (1) is permittable by the appropriate governmental authority; (2) is determined to be technically, operationally, and economically feasible and (3) meets the following environmental performance 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 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 (Williams, 2004). Selection of EST candidates to undergo performance verification involved a request of proposals and competitive review by the Agreements Designee and a Panel representing government, environmental and community interests, the companies, and individuals with expertise in animal waste management, environmental science and public health, economics and business management. This process yielded 18 technologies candidates among about 100 submitted projects. In July 2004, two of the technologies were shown to be capable of meeting the environmental performance criteria necessary for the technologies to be considered environmentally superior (Williams, 2004). One of the two technologies treated the entire waste stream from a swine farm using a wastewater treatment system consisting of solids separation, nitrification/denitrification, and soluble phosphorus removal (Vanotti et al., 2001), while the second treated the separated solids off-farm using high solids anaerobic digestion.

In this paper, we describe the process leading to development of the new on-farm treatment system designed to replace anaerobic swine waste lagoons, and report performance verification results. Performance verification was done in a swine farm at full-scale during one-year period.

MATERIALS AND METHODS

The on-farm project was a collaborative, 3-year effort involving scientists, engineers and personnel from private businesses, university and USDA. Engineering design and permitting of the alternative system was completed during the first year of the project, and construction and startup was completed in the second year. Subsequently, the system was evaluated during one year operation period under steady-state conditions. The full-scale demonstration facility was installed on a 4,400-head finishing farm in Duplin County, North Carolina. The system was constructed and operated by a private firm called Super Soil Systems USA of Clinton, NC.

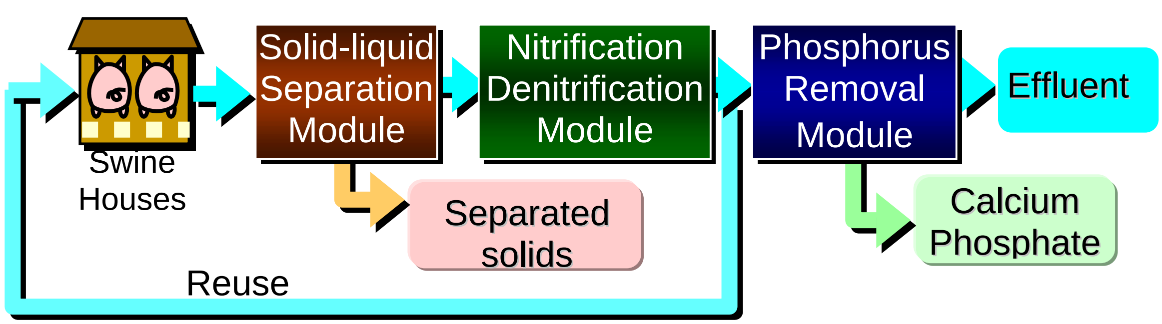

Figure 1. Diagram of the swine manure treatment system installed at Goshen Ridge farm, North Carolina, USA

The system made use of three unit processes or modules (Figure 1). The first – the Ecopurin Solid-Liquid Separation Module, developed by the Spain-based firm Selco MC of Castellon – quickly separated solids and liquids with PAM addition and mechanical dewatering. The second step used the Biogreen Nitrogen Removal Module, developed by Hitachi Plant Engineering & Construction Co. of Tokyo, Japan. This process had a pre-denitrification configuration, and used immobilized bacteria to enhance nitrification. After biological N treatment, the liquid went to the final step, the Phosphorus Separation Module, developed by USDA-ARS (Vanotti et al., 2001). The process recovered phosphorus as calcium phosphate and destroyed pathogens by alkaline pH. It used hydrated lime (Chemical Lime Company, Charlotte, NC) applied after natural pH buffers in the liquid were removed.

RESULTS AND DISCUSSION

During the year-long evaluation, the solids separation module removed 93% of total suspended solids, 94% of zinc and copper, and 70% of phosphorus, from the wastewater (Vanotti, 2004). It also produced 657 tons of separated solid waste that were converted to organic plant fertilizer, soil amendments, or energy. Ammonia removal efficiencies of the Biogreen process were consistently high (> 95%) during both the first month acclimation period and the subsequent 10 months evaluation. These high process efficiencies were obtained with influent ammonia concentrations varying from 400 to 1500 mg/L and with loading rates varying from about 20 to 50 kg N/day. Removal efficiencies of the soluble phosphate using the P-removal module averaged 94% for wastewater containing 77 to 191 mg/L PO_4-P. A total of 285 bags of calcium phosphate product containing 1,160 lb of P were produced and left the farm in a 9-month period. The phosphorus was 90% plant available based on standard citrate P analysis used by the fertilizer industry.

The complete system removed 97.6% of the suspended solids (TSS), 99.7% of BOD, 98.5% of TKN, 98.7% of ammonia, 95% of total P, 98.7% of copper and 99.0% of zinc (Table 1). The treatment system also removed 97.9% of odor compounds in the liquid and reduced pathogen indicators to non-detectable levels (Vanotti, 2004). In less than a year, the anaerobic lagoon that was replaced with the treatment system was converted into an aerobic pond with ammonia concentration in the liquid of < 30 mg/L that substantially reduced ammonia emissions.

Table 1. Elimination of TSS, BOD, nutrients, heavy metals, odors and pathogen indicator by treatment system developed to replace swine lagoons in USA. BDL=Below detection limit.

Water Quality Parameter	Raw Flushed Manure	After Solids Separation Treatment	After Biological N Treatment	After Phosphorus Treatment	System Efficiency (%)
TSS (mg/L)	11,051	823	122	264	97.6
BOD_5 (mg/L)	3,123	1,078	33	10	99.7
TKN (mg/L)	1,584	953	34	23	98.5
NH_4-N (mg/L)	872	835	23	11	98.7
TP (mg/L)	576	174	147	29	95.0
Cu (mg/L)	26.8	1.54	0.53	0.36	98.7
Zn (mg/L)	26.3	1.47	0.40	0.25	99.0
Odor compounds (μ/L)	206.8	181.7	4.6	4.3	97.9
Enterococci (log_{10}/mL)	5.73	4.84	2.67	BDL	99.999

CONCLUSION

Major goals in the demonstration and verification of the new wastewater treatment system for swine manure were achieved including replacement of anaerobic lagoon treatment, and consistent .treatment performance, with varying solid and nutrient loads typical in animal production. The year-long evaluation verified that the technology was technically and operationally feasible. Based on performance results obtained, it was determined that the treatment system met the Agreement's technical performance standards that define an Environmentally Superior Technology. This project was considered an important milestone in the search of alternative treatment technologies, and justified moving ahead with innovation and evaluation of lower cost, next-generation systems (Williams, 2004).

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