DEVELOPMENT OF ENVIRONMENTALLY SUPERIOR TECHNOLOGY TO REPLACE SWINE LAGOONS IN THE USA

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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 hog 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; phosphorus and ammonia removal; piggery.*

INTRODUCTION

Minimizing livestock wastewater manure's impact on the environment is one of U.S. agriculture's major challenges. Once dominated by many small operations as part of traditional crop-hog farms, hog production has become highly concentrated on large operations with production in several different sites. Considerable consolidation occurred in hog production during the 1990s. Since 1994, the percent of the hog and pig inventory on farms with 2,000 head or more increased from 37% to nearly 75%. About half of hogs and pigs were on farms with more than 5,000 head in 2001, compared with about a third in 1996 (USDA, 2003). This development has separated animal production from crop production. Thus, the amount of manure produced in confinement often exceeds local demand for use as fertilizer.

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. Using environmentally safe alternatives to land application of manure and organic by products could be an integral part of comprehensive nutrient management plans (CNMP). These alternatives are needed in areas where nutrient supply exceeds available land and/or where land application

would cause significant environmental risk (USDA, 2001). More efficient and cost effective methods are needed for manure handling, treatment, and storage. Areas in need of targeting include: (1) improved systems for solids removal from liquid manure; (2) improved manure handling, storage, and treatment methods to reduce ammonia volatilization; (3) treatment systems that transform and/or capture nutrients, trace elements, and pharmaceutically active chemicals from manure; (4) improved composting and other manure stabilization techniques; and, (5) treatment systems to remediate or replace anaerobic lagoons. In this paper, we report the process leading to development of a new treatment system to replace lagoons and provide an environmentally-safe alternative to traditional land application.

DEVELOPMENT OF ENVIRONMENTALLY SUPERIOR TECHNOLOGY

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 hog producing companies in the world, to develop and demonstrate environmentally superior waste management technologies for implementation onto farms located in North Carolina that are owned by these companies. In October 2000, the Attorney General reached a similar agreement with Premium Standard Farms, the second largest pork producer in the country. Taken together, Smithfield and Premium Standard represent over 75% of the hog 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.

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. One of the two technologies treated the entire waste stream from a swine farm using solids separation, nitrification/denitrification, and soluble phosphorus removal system, while the second was designed to treat the separated solids using high solids anaerobic digestion system (Williams, 2004).

PERFORMANCE VERIFICATION OF ON-FARM TREATMENT SYSTEM

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.

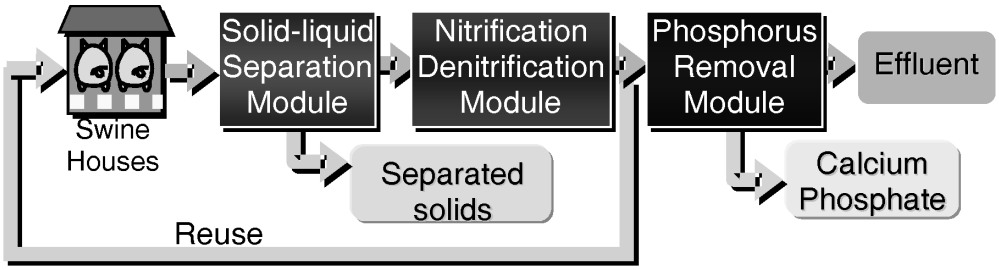

Figure 1. *Diagram of the swine manure treatment system installed at Goshen Ridge farm, North Carolina, USA.*

The system made use of three 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. During the year-long evaluation, this 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. The second step used the Biogreen Nitrogen Removal Module, developed by Hitachi Plant Engineering & Construction Co. in Tokyo, Japan. After biological N treatment, the liquid went to the final step, the Phosphorus Separation Module. Developed by ARS (Vanotti et al., 2001), this final step is where phosphorus is recovered as calcium phosphate with addition of only small quantities of liquid lime and without losses of ammonia. Additionally, pathogens are destroyed by alkaline pH.

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

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. 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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