SOLIDS SEPARATION, NITRIFICATION-DENITRIFICATION, SOLUBLE PHOSPHORUS REMOVAL, SOLIDS PROCESSING SYSTEM

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MANURE TREATMENT SYSTEM DESCRIPTION

Systems of treatment technologies are needed that capture nutrients, reduce emissions of ammonia and nuisance odors, and kill harmful pathogens. A system of swine wastewater treatment technologies was developed to accomplish many of the tasks listed above. The system greatly increases the efficiency of liquid/solid separation by injection of polymer to increase solids flocculation. Nitrogen management to reduce ammonia emissions is accomplished by passing the liquid through a module where immobilized bacteria transform nitrogen. Subsequent alkaline treatment of the wastewater in a phosphorus module precipitates calcium phosphate and kills pathogens. Treated wastewater is recycled to clean hog houses and for crop irrigation. The system has been pilot tested (Vanotti *et al.*, 2001a) and is going through full-scale demonstration and verification as part of the Smithfield Foods/Premium Standard Farms/Frontline Farmers Agreement with the North Carolina Attorney General to identify technologies that can replace current lagoons with Environmentally Superior Technology (Williams, 2001). If the full-scale demonstration proves to be successful, the technology can be used in new systems where the lagoon is omitted.

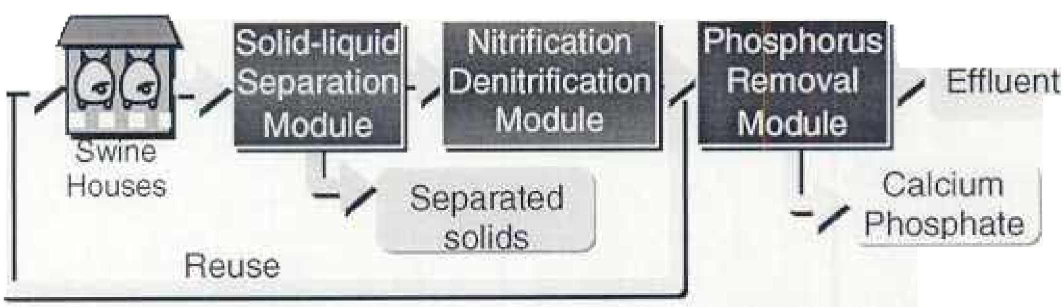

FIGURE 1. Diagram of wastewater treatment system installed at Goshen Ridge farm.

The full-scale demonstration facility was installed at Goshen Ridge, a 4,400-head finishing farm in Duplin County, NC. The on-farm system uses polymer liquid-solid separation, nitrification/denitrification, and soluble P removal modules (Figure 1). The system was constructed by Super Soil Systems USA of Clinton, N.C. The total system is completed with the centralized solid processing facility at Super Soil Systems USA headquarters in Sampson County, N.C, where separated manure solids go through aerobic composting and blending processes to produce value-added products to include organic fertilizer, soil amendments, and proprietary soilless media[1] for use in horticultural markets.

[1] Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the U.S. Dept. of Agriculture and does not imply its approval to the exclusion of other products or vendors that also may be suitable.

The objective of this paper is to describe the main components of the full-scale waste treatment system shown in the Virtual Tour presentation.

SOLID-LIQUID SEPARATION MODULE

In contrast to systems that use slow anaerobic digestion of waste in lagoons, systems that use quick separation of solids and liquids can conserve much of the organic fraction of animal waste. However, to effectively recover the solids, some form of flocculation must be used. Polyacrylamides were found to be effective (Vanotti and Hunt, 1999). The solids in the treatment facility are separated from the liquid with the Ecopurin separation module developed by a Spanish company, Selco MC. The module is contained in a separation building. It is fully automated through the use of a programmable logic controller (PLC) for 24 hr/day operation. Treatment parameters such as polymer rate, wastewater flow, and mixing intensity are set by the operator using a tactile screen in the control panel. In the main module, the liquid manure is reacted with polymer and separated with a self-cleaning rotating screen. Subsequently, a dissolved air flotation unit (DAF) polishes the liquid effluent while a small filter press dewaters the solids. The dewatered solids fall in a 120 ft^3 trailer and are transported daily to the central processing plant. The separated liquid is discharged into a small concrete pit, where it is continuously pumped into the biological N removal module for further treatment. Data in Fig. 2 show the treatment efficiency of solids separation module during the first 4-month evaluation period. Separation efficiency was consistently high with an average of 94% TSS separation.

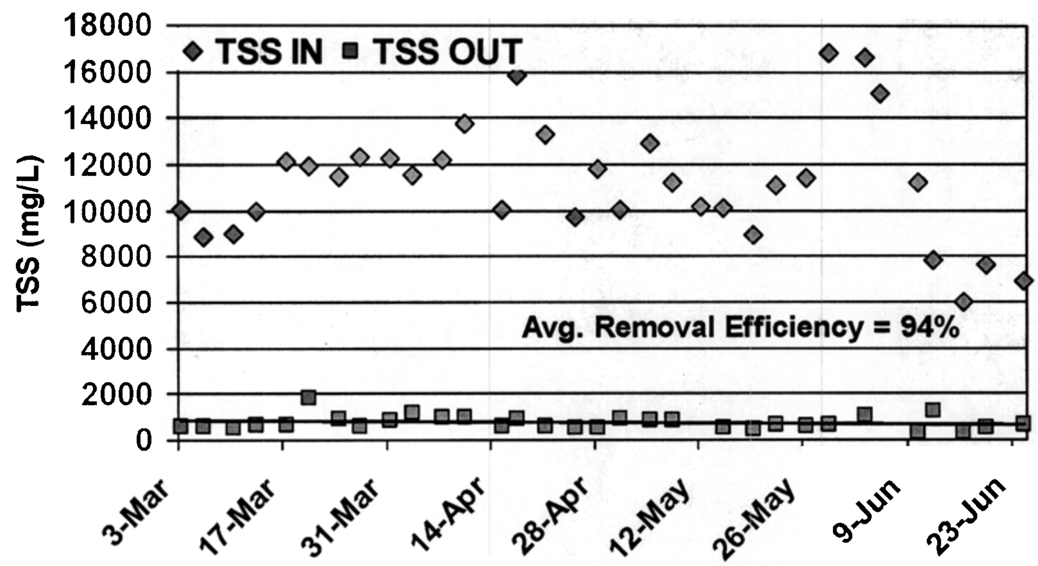

FIGURE 2: Total suspended solids (TSS) concentration in liquid swine manure before and after solid-liquid separation treatment during the first four months of evaluation.

The process separated most of the suspended solids, and oxygen demanding compounds and organic nutrients associated with these solids. Reduction of suspended organic compounds is an important consideration for the efficiency of the nitrification treatment, while capture of carbon and organic nutrients is important for the efficiency of the solids processing operation. The polymer treatment separated 70% of the total P, 35% of total N, 96% of Cu, and 95% of Zn in the liquid manure. Soluble ammonia and phosphate concentration changed little (< 7 and 17% reduction, respectively) with separation treatment. On the other hand, organic N and P were effectively captured in the solids, resulting in concentration reductions of 85 and 90%, respectively.

A total of 85 trailers containing 265 m^3 of separated solids were produced and left Goshen farm during the initial 4-month evaluation period. This amount of manure weighed approximately 204,700 kg (451,300 lb) and contained

18.4% (± 1.1%) of solids (81.6% moisture), 1,605 kg of nitrogen, 1,051 kg of phosphorus, 87 kg of copper, and 83 kg of zinc.

BIOLOGICAL NITROGEN REMOVAL MODULE

Once the solids are removed, a relatively smaller amount of suspended organic waste remains to be treated in the wastewater by the nitrification/denitrification. The liquid contains significant amounts of soluble ammonia and phosphorus. The demonstration project uses a Biogreen process (Hitachi Plant Engineering & Construction Co., Tokyo, Japan) that biologically removes the ammonia-N. The process has a pre-denitrification configuration, where nitrified wastewater is sent through a denitrification cycle to remove most (> 80%) of the nitrate using the soluble carbon (COD) contained in the manure after separation. A unique feature of the process is that the concentration of bacterial biomass in the nitrification tank is increased by using nitrifying bacteria encapsulated in polymer gel pellets (Vanotti and Hunt, 2000; Vanotti *et al.*, 2000). These pellets are permeable to ammonia and oxygen needed by the nitrifiers and are kept inside the tank by means of a screen structure. The reaction tank at Goshen contains 12 m^3 of the nitrifying pellets. There is a second denitrification tank built into the system, where methanol can be injected for reducing the remainder nitrate in the effluent. This feature was not used during the first 3 months of operation summarized in this report in order to evaluate denitrification when effluent is recycled to recharge the pits under the houses. The following diagram illustrates the biological N removal module installed:

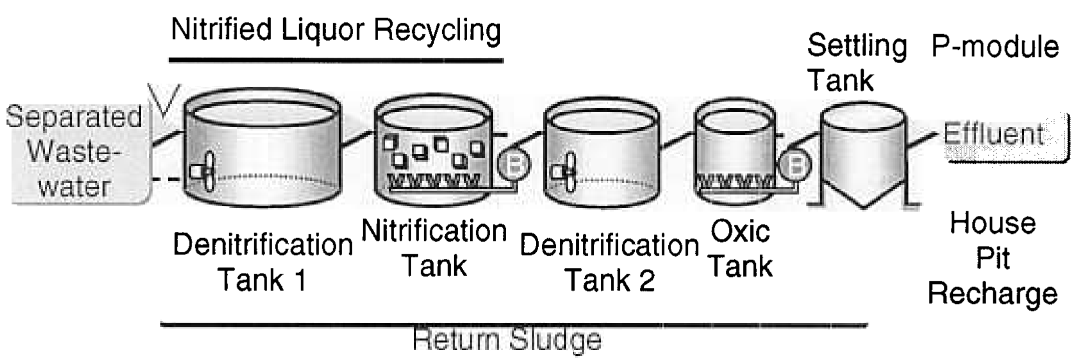

FIGURE 3. Diagram of the biological nitrogen removal module installed at Goshen Ridge farm.

Once the proper mixers and recirculation equipment were in place, it took about 4 weeks for the nitrifying bacteria to be fully acclimated to the high-strength swine wastewater (Fig. 4). Acclimation process was carried out in a stepwise procedure, where flow loads were increased from 25% of the flow being processed by the separation module to 100% (full-scale). Pellets were sampled every week to conduct nitrification and respiration activity tests done in bench reactors also in the laboratory. For design purposes, pellets were considered acclimated with an activity of 6 kg N/m3-pellet/day (Fig. 4) that is equivalent to a nitrification capacity of 72 kg N/day in the treatment module.

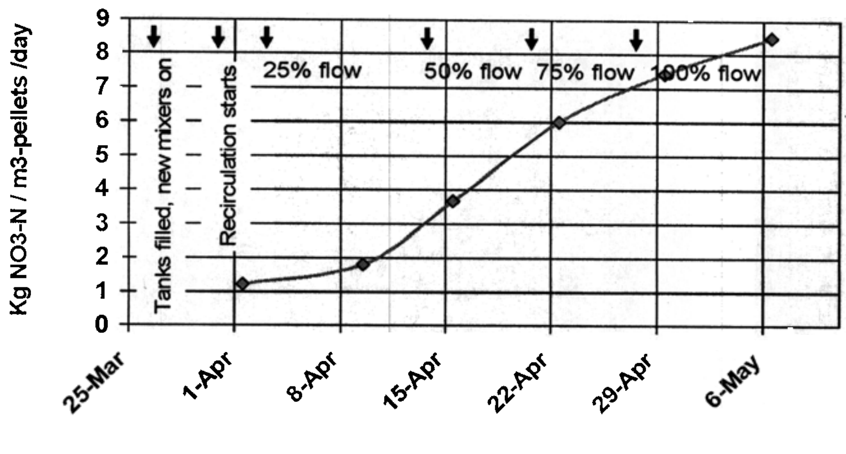

FIGURE 4: Nitrification activity of pellets during acclimation to swine wastewater

Ammonia removal efficiencies of Biogreen process were consistently high (> 99%). This performance was obtained with influent concentration varying from about 500 to 1,500 ppm and effluent concentration < 10 ppm throughout the evaluation period (Fig. 5). The decrease in N concentration observed in late June was due to the changes in pigs in the production houses (50 lb pigs replacing market 250 lb hogs).

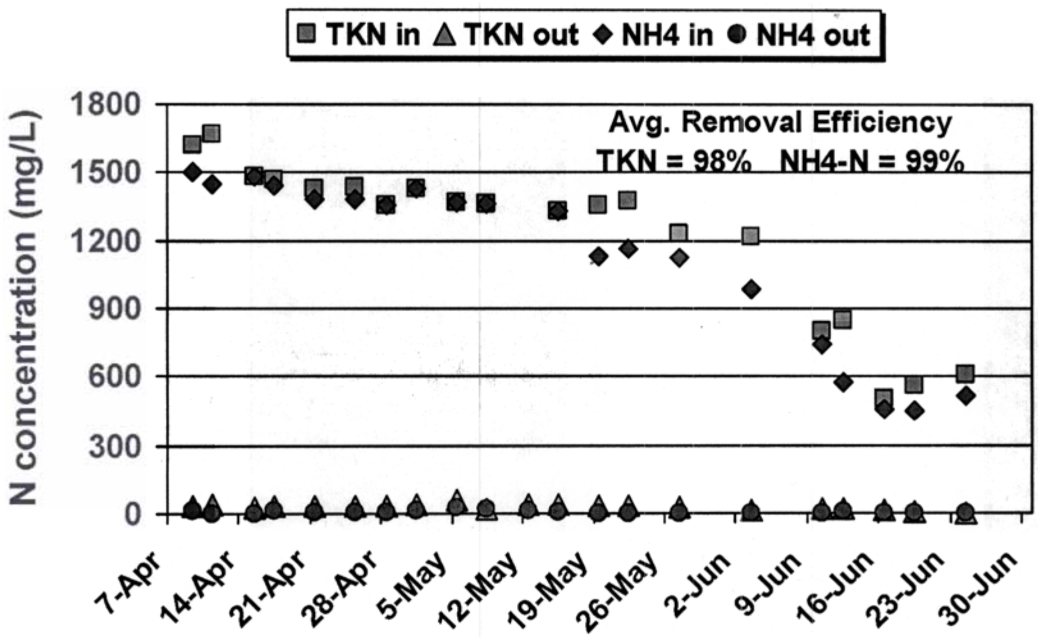

FIGURE 5: Treatment of nitrogen using immobilized bacteria and nitrification-denitrification process.

SOLUBLE PHOSPHORUS REMOVAL MODULE

After biological N treatment, the liquid flows by gravity to the phosphorus separation module developed by USDA-ARS, where P is recovered as calcium phosphate and pathogens are destroyed by alkaline pH (Vanotti *et al.*, 2001b; 2003a and 2003b). Figure 6 shows a schematic diagram of the technology installed at Goshen Ridge farm. Liquid from which ammonia nitrogen and carbonate buffers have already been removed is mixed with hydrated lime in a reaction chamber. A pH controller is linked to the lime injector and keeps the process pH at 10.5-11.0. The liquid and precipitate are separated in a settling tank. The precipitated calcium phosphate sludge is further dewatered in filter bags with a capacity of about 50 lb each. Polymer is added to the precipitate to enhance P separation. Automation to the system is provided by sensors integrated to a programmable logic controller (PLC) for 24 hr/day operation; treatment parameters such as process pH are set by the operator using another tactile screen in the plant control panel. Removal efficiencies of the soluble phosphate averaged 91% for wastewater containing 90 to 185 ppm PO_4-P.

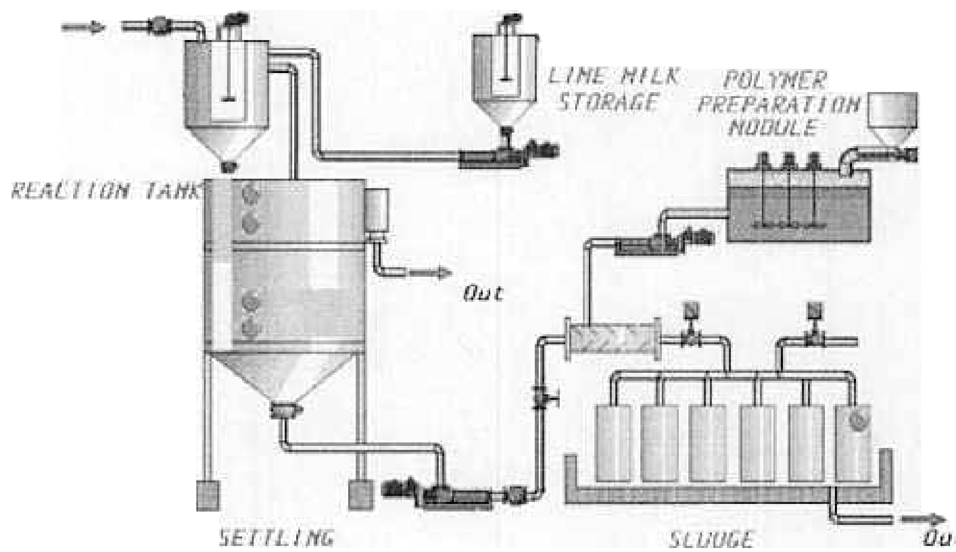

FIGURE 6. Schematic diagram of phosphorus separation module at Goshen Ridge farm, Duplin County, N.C.

SYSTEM PERFORMANCE

Performance data obtained when all three modules were in-line show the unique contributions of each module to the efficiency of the total system (Table 1). Overall, the demonstration system at full-scale performed to design expectations with respect to nutrient and heavy metal elimination Total suspended solid concentration was reduced >97%, mostly in the separation module. By capturing the suspended particles, most of the volatile and oxygen-demanding organic compounds are removed from the liquid stream. Instead of being used to break down organic compounds, the oxygen in the subsequent aeration treatment is used efficiently to convert ammonia to nitrate. The nitrification eliminates natural buffers, which substantially reduces the overall chemical demand needed for optimum phosphorus precipitation and removal.

TABLE 1: Reduction of suspended solids, COD, BOD, and nutrient concentration by total treatment system at Goshen farm. Data are means for the period of April 15-July 1, 2003 when all three modules were in-line (n=21).

Water Quality Parameter	Raw Flushed Manure (mg/L)	After Solids Separation Treatment (mg/L)	After Biological N Treatment (mg/L)	After Phosphorus Treatment (mg/L)	Total System Efficiency (%)
TSS	10,441	679	129	268	97.4
VSS	7,420	516	67	88	98.8
COD	19,554	6,411	867	694	96.5
BOD_5	6,425	3,305	16	7	99.9
TKN	1,975	1,241	32	24	98.8
NH_4-N	1,242	1,166	9	1	99.9
TP	596	192	149	31	94.8
PO_4-P	172	142	138	12	93.0

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