NITRIFICATION OF SWINE WASTEWATER USING OVERLAND FLOW AND MEDIA FILTRATION TREATMENTS

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INTRODUCTION

Livestock waste treatment and disposal has become a major environmental concern not only in North Carolina but nationwide. The areas of concern include ammonia volatilization, surface and ground water contamination, and odor control. These concerns have been fueled by the rapid growth of large scale, confined animal production facilities. This shift in animal production methods has brought about a need for alternative waste treatment systems.

Nitrification is a limiting process in the treatment of wastewater for the removal of nitrogen. The oxidation of the nitrogen is a necessary step in the biological conversion of ammonia nitrogen (NH_3-N) to di-nitrogen gas (N_2), which composes nearly eighty percent of the atmosphere of the earth.

Nitrification can be an option to enhance nitrogen (N) removal in constructed wetlands. Constructed wetlands have been shown to have the potential to remove large amounts of N from swine lagoon liquid (Szogi et al., 1999). However, in a related study, Hunt et al. (1999) showed that the N removal potential of the constructed wetlands is limited by nitrate nitrogen (NO_3-N) availability in the system. The objective of this project was to evaluate nitrification components to be used in conjunction with constructed wetlands in a waste treatment system.

OVERLAND FLOW

Nitrification of wastewater in an overland flow system occurs when a thin film of waste is in close contact with a population on nitrifying bacteria on the soil surface. Overland flow systems also offer some degree of denitrification in the underlying saturated soil layer (Hunt and Lee, 1976).

The study unit consisted of a 4 x 20-meter (m) plot with a 2% slope. The sides and bottom of the unit were lined with a polyethylene membrane after excavation to a depth of 20-cm and then the excavated topsoil replaced. A mixed vegetation stand consisting of fescue, coastal bermuda, and reed canary grass was established. Lagoon liquid was applied five consecutive days each week at a hydraulic rate of approximately 2.5 cm/day. Initial applications were made during an 8-hour period but due to the permeability of the sandy soil, surface runoff was not achieved. Therefore, to ensure a surface flow system, the application period was reduced to only four hours each day during the evaluation period (1996 and 1997). Automated samplers were used to collect samples of the inflow, the surface outflow, and the subsurface outflow. In addition, spatial sampling of the surface flow along the plot was conducted. Wastewater flows were measured with positive displacement flow meters and the total flows recorded manually on a daily basis. A hydraulic balance indicated losses similar to the expected evapotranspiration (0.5 to 0.8 cm per day).

Performance data for the overland flow treatment during 1996 (August-December) and 1997 (March-August) indicates that this treatment can remove relatively large amounts of nitrogen per unit area (Table 1). The application rate was higher in 1997 due to changes in the lagoon N concentrations. The average total nitrogen (TN) removal efficiency was 35% in 1996 and 42% in 1997. This translates to nitrogen removal rates of 22.4 and 41.6 kg/ha/day respectively. These efficiencies are in agreement with previous work of Humenik *et al.* (1975) showing TN removal rates of 35% for swine lagoon liquid treated on a 17 m overland flow system with a hydraulic load of 1.8 cm/day.

TABLE 1. Overland Flow Treatment of Swine Lagoon Liquid.

Year	TN Application Rate[1]	TN Removal Efficiency[2]	N Mass Removal Rate	NO_3-N Recovery	Sampling period
	kg/ha/day	%	kg/ha/day	%	Days
1996	64	35	22.4	7	85
1997	99	42	41.6	7	60

[1]Total nitrogen = TKN+ NO3-N. (Inflow nitrate concentration = 0)
[2] Total Nitrogen removal efficiency = ((TN mass inflow - TN mass outflow)/TN mass inflow) x 100.
[3] Nitrate-N Recovery = (NO^3-N mass outflow/TKN mass inflow) x 100.

Spatial sampling of the surface flow revealed that no nitrification activity occurs in the first 5 m of the plot but beyond this point, the nitrate concentration gradually increased to a maximum at 17 m down slope. The nitrogen balance showed a small (<13%) loss, indicating that the potential ammonia volatilization losses are relatively small. The low recovery of NO3-N observed in the drainage flows after treatment suggests that denitrification occurred in the saturated soil layer of the system, which is a typical feature of overland flow systems (Hunt and Lee, 1976).

MEDIA FILTRATION

Nitrification of wastewater during media filtration treatment occurs as the wastewater passes over the nitrifying bacteria population present in the bio-film supported by the gravel substrate. The hydraulic flow rate of wastewater must be maintained at a rate to ensure unsaturated flow through the media, which allows for oxygen diffusion.

The media filtration unit consisted of a 1.5 m diameter x 0.6 m height tank filled with the marl gravel (Szogi *et al.*, 1997). The distribution of the gravel particles was 85% in the 4.7 to 12.7-mm size class and 14% in the 12.8 to 19-mm size class; this provided a 57% pore space within the substrate. The filtration unit was placed within a slightly larger diameter tank to collect the effluent for recirculation. An additional tank was used for storage of the liquid to be recycled during treatment. Liquid samples were collected manually once per day during system operation.

Lagoon liquid was applied to the media surface at a hydraulic rate of 684 L/m^3 reactor volume/day. This corresponds to a TN loading rate of 249 g N/m^3/day. The unit was operated five days per week from March to July 1997 during the 12-hour period between 6 a.m. and 6 p.m. The flow was applied intermittently in 12-minute intervals to enhance aeration within the media. During application intervals, the liquid was pumped from the storage tank at a rate of 9.5 L/min. A ball valve was used to split this flow with 7.6 L/min going to the surface of the filter and the remaining 1.9 L/min being discharged from the system to a collection sump. At the same time, lagoon liquid was supplied by gravity to the storage tank with the volume maintained by a float valve at 757 L. During the second half of the evaluation period, 100 g of dolomitic lime was applied on the surface of the filter to assess nitrification enhancement potential.

The system required an acclimation period of six weeks for the nitrifying biofilm to reach equilibrium condition, as indicated by stabilization of the nitrification activity. The evaluation was conducted for 90 days after the system had come to equilibrium (Table 2). The natural alkalinity of the lagoon liquid (1950 mg/L) was enough to neutralize the H^+ generated by nitrification of approximately 270 mg/L of NH_3-N. The nitrification performance of the system was significantly increased by the lime supplement (Table 2). This positive effect of the lime addition was most likely due to increased CO_2 availability, rather than supplemental alkalinity (Vanotti *et al.*, 1998). The TN balance indicates that the potential loss of nitrogen due to ammonia volatilization was small. Although gaseous emissions of N were not measured, denitrification occurring in the storage tank could contribute to the N losses during treatment.

TABLE 2. Media Filter Treatment of Lagoon Liquid.

Nitrogen Form (mg/L)	No Lime		With Lime Addition	
	Inflow	Outflow	Inflow	Outflow
TKN	366	221	363	114
NH_3-N	340	193	334	106
NO_3-N	0	133	2	208
TN[1]	366	354	365	321
Nitrification efficiency[2]	26%		57%	

[1]TN = TKN + NO_3-N.

[2]Nitrification efficiency = (NO^3-N conc. in outflow/TN conc. in inflow) x 100.

SUMMARY

Both the overland flow and media filtration systems have the potential for partial treatment of high strength wastewater and were not judged to contribute to odor concerns. The overland flow system is a low-intensity system requiring relatively little technical knowledge or equipment to remove large amounts of N per unit area (up to 42 kg N/ha/day) through nitrification and partial denitrification. The media filtration system is a medium-intensity system which can nitrify up to 57% of the incoming NH_3-N at a TN loading rate of 249 g /m^3/day but requires additional equipment and operational oversight. The incorporation of these unit processes into an overall waste treatment system and their long-term performance must still be evaluated.

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