Constructed Wetland to Treat Swine Wastewater
Duplin County, North Carolina

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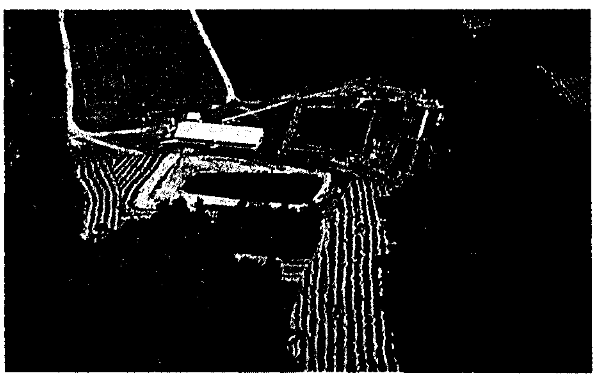
Introduction

This project was located at a swine facility housing 2600 nursery pigs having an average weight of 11.8 kg. The swine are housed in a single building which is flushed six times per day into a 0.24 ha anaerobic lagoon. Wastewater from the lagoon is irrigated directly onto nearby pasture and crop land. The constructed wetland is operated as an independent, no-discharge system with all effluent being returned to the lagoon for land application.



Aerial view of lagoons and wetland

The project was undertaken to address concerns and to answer questions about the ability of wetland systems to (1) produce an effluent that met discharge limits for nitrogen and phosphorus and (2) remove high percentages of nitrogen from wastewater. As this description shows, these goals were sometimes met individually but could not be met at the same time. The performance of the system depended on the loading rate at which the effluent was discharged to the wetland.

Regulatory Context

To discharge the treated effluent to a local stream, the wetland system had to produce effluent concentrations with nomore than 4 mg/L total nitrogen in the summer and 8 mg/L in the winter, as well as 2 mg/L total phosphorus year-round.

Wetland Design

The wetland was designed according to guidance on nitrogen loading rates. For municipal wastewater wetlands, the recommended loading rate was total Kjeldahl nitrogen (TKN) or ammonia nitrogen (NH_3-N) at 18 kilograms per hectare per day (kg/ha/day). For livestock wastewater wetlands, recent guidelines varied from 10 to 15 kg/ha/day. While this system was being designed, the Tennessee Valley Authority (TVA) issued new criteria of less than 3 kg/ha/day for wetlands designed to meet advanced discharge standards. As a result the system was designed for a low TKN loading rate of 3 kg/ha/day.

Six 3.6 x 33.5-meter wetland cells were constructed in 1992 (Figure 1). They were

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divided into three parallel systems of two cells in series. Wetland system 1 contained rushes and bulrushes; wetland system 2 contained bur-reed and cattails; and wetland system 3 contained soybeans in saturated soil culture and rice. Due to different operational parameters for wetland system 3, a summary of results was not available.

The cell bottoms and sidewalls were lined with clay and then covered with 20 to 30 cm of loamy sand soil. Lengthwise slopes were 0.2 percent or less. Water depth at the end of the slope was maintained below 15 cm.

Monitoring

V-notch weirs and PDS-350 ultrasonic open-channel flow meters were installed at the inlet and outlet of each of the three wetland systems. Five ISCO 3700 samplers were installed; one sampler collected samples of the wastewater influent and the other four sampled the water at the end of each single cell. The water sampler combined hourly samples into composites. A CR7X data logger with two multiplexers were installed for hourly acquisition of flow, weather, and soil redox potential data.

Operation and Performance

From May 1993 to June 1994, wastewater was applied to the constructed wetland at a rate of 3 kg/ha/day of TKN. Lagoon wastewater was diluted about tenfold with fresh water to meet the low TKN application rate and to make up for evapotranspiration during summer. As a result of the increased dilution, TKN concentrations in the influent wastewater were lower in the summer. Wastewater input to the wetland was continuous, and flow control valves in a mixing tank were set to provide the desired proportion of lagoon liquid and diluted water. Effluent TKN ranged from about 30 to 50 mg/L total nitrogen for winter.

At the 30 mg/L loading rate, effluent TKN was generally less than 8 mg/L. At the 50 mg/L loading rate, effluent TKN was generally more than 10 mg/L. TKN removals on a mass basis for the 3 kg/ha/day loading rate were 96 and 91 percent for wetland systems 1 and 2, respectively (see Table 1). The effluent sometimes met local stream discharge requirements of 4 mg/L total nitrogen for summer and 8 mg/L total nitrogen for winter.

Table 1. Effluent TKN and TP Concentrations in Response to Different Mass Loading Rates.

TKN Loading (kg/ha/d)	Effluent TKN		Effluent TP	
	mg/L	% Removal	mg/L	% Removal
3	<8	91-96	7	73
10	10-20	73	10-20	10-17

Effluent total phosphorus averaged about 7 mg/L for the TKN loading rate of 3 kg/ha/day. In general, effluent total phosphorus concentrations exceeded the discharge allowance of 2 mg/L year-round. Total phosphorus removal on a mass basis was about 73 percent.

From June 1994 to January 1996, the TKN loading rate was increased to 10 kg/ha/day with the new goal being maximum nitrogen removal rather than meeting stream discharge requirements. After increasing the TKN loading rate, effluent TKN concentrations generally exceeded local stream discharge requirements. However, at the higher loading rate, both wetland systems still removed more than 73 percent of TKN on a mass basis.

At the higher TKN loading rate, effluent total phosphorus ranged from 10 to 20 mg/L Only 10 percent and 17 percent of the total phosphorus was removed by wetland systems 1 and 2, respectively. Total phosphorus removals on a mass basis decreased significantly with time and higher TKN loading rates.

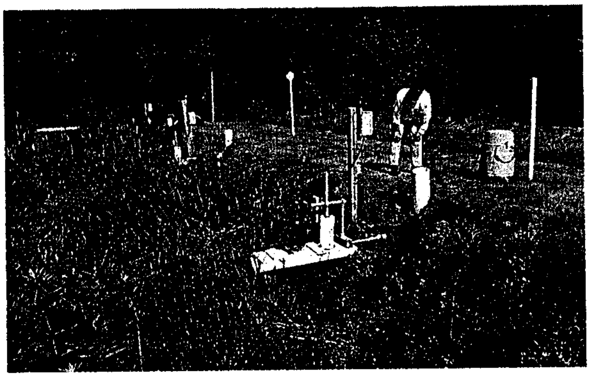
Effluent total organic carbon concentrations varied widely for both TKN loading rates. The wetland systems did not appear to affect total organic carbon concentrations (TOC) and, in some cases, TOC increased.

Conclusions

At the loading rate of 3 kg/ha/day of TKN, the wetland discharge met nitrogen criteria during some time periods. The discharge did not meet phosphorus criteria, except temporarily in wetland system 2 before TKN loading was increased.

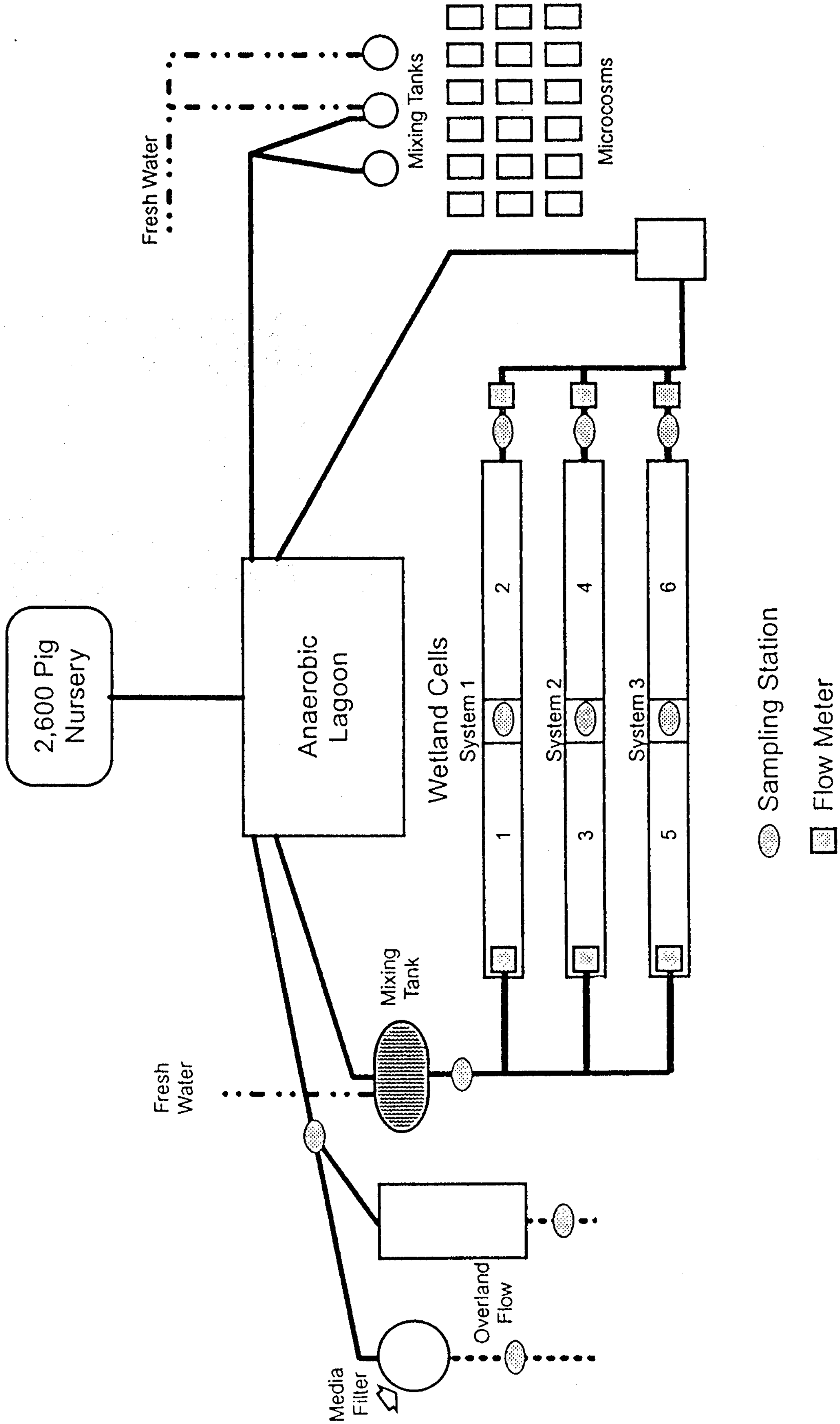
At the loading rate of 10 kg/ha/day of TKN, the wetland discharge often exceeded the nitrogen criteria and consistently exceeded the phosphorus criteria. However, the wetland did meet the secondary goal of high nitrogen removal with removal efficiencies of about 73 percent.

While wetlands can significantly reduce nitrogen mass loading, they do not appear to be a viable treatment method to achieve stream discharge since the procedure of diluting livestock wastewater to obtain constructed wetland loading rates for advanced discharge standards is not consistent with basic principles of wastewater volume reduction and pollution prevention.



The wetland system is very well monitored.

To further evaluate the potential for nitrogen removal at higher loading rates, the TKN loading rate has been increased to 15 kg/ha/day. In addition, researchers are evaluating model unit processes that could improve treatment, such as overland flow, media filter, aerated lagoon, and unaerated lagoon. The goal of the current evaluation is to identify a treatment train of aerobic and anaerobic unit processes that provide maximum removal of phosphorus and nitrogen. The ultimate objective is to incorporate wetland systems into livestock wastewater management programs that reduce costs and land requirements to swine producers.



Fresh Water
Mixing Tanks
Microcosms
2,600 Pig Nursery
Anaerobic Lagoon
Wetland Cells
System 1
System 2
System 3
1
2
3
4
5
6
Mixing Tank
Fresh Water
Overland Flow
Media Filter
Sampling Station
Flow Meter