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Effect of intermittent drainage on swine wastewater treatment by marsh–pond–marsh constructed wetlands

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ABSTRACT

The research objective was to investigate the effect of intermittent wetland drainage on swine wastewater treatment by marsh–pond–marsh (m–p–m) constructed wetlands. For 16 weeks beginning in June 2002, each of four m–p–m wetlands in Greensboro, NC, USA, received a different application of swine wastewater. The four application schemes were as follows: (1) continuous application; (2) 1 week of no application for every 4 weeks of application; (3) 1 week of no application for every 3 weeks of application; and (4) 1 week of no application for every 2 weeks of application. The effect of intermittent wetland drainage was determined by comparing each system's soil oxidation, wastewater constituent removal, and ammonia volatilization. Soil oxidation was increased during drainage periods of the systems with four and five drainage periods. While the removal of total suspended solids, chemical oxygen demand, and total phosphorus were not affected by the incorporation of drainage periods, the efficiency of total nitrogen removal significantly increased with increased number of drainage periods. For treatment wetlands that incorporated zero, three, four, and five drainage periods, the total nitrogen removal efficiencies were 57, 64, 70, and 67%, respectively. An increase in the number of drainage periods did not reduce ammonia volatilization from either marsh or pond sections.

1. Introduction

Even though constructed wetlands have been used for decades to treat municipal and industrial wastewater, the ability of this technology to treat animal wastewater has only recently been examined by significant research efforts (Hunt and Poach, 2001; Knight et al., 2000; Cronk, 1996). This research verified that constructed wetlands used in conjunction with land application were effective for treating animal wastewater, especially the removal of nitrogen and oxygen-demanding substances. Despite this effective treatment, the capacity of the constructed wetlands to remove wastewater nitrogen and oxygen-demanding substances was limited by the oxygen availability in the wastewater and wetland soil (Hunt et al., 2003).

Modifications of wetland operation can enhance the oxygen content of the wastewater and wetland soil; thereby, improving the removal of wastewater nitrogen and oxygen-demanding substances. Oxygen-enhancing modifications include intermittent wetland drainage (alternating fill and drain cycle). Intermittent drainage of wetland mesocosms treating dairy wastewater enhanced the removal of chemical

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oxygen demand (COD) and nitrogen as compared to continuous application (Tanner et al., 1999). Although intermittent wetland drainage did not increase wetland removal of dairy wastewater phosphorus (Tanner et al., 1999), it did increase the removal of phosphorus in simulated wastewater (Busnardo et al., 1992). Therefore, phosphorus removal by constructed wetlands under intermittent drainage needs further study.

While oxygen input to wetland soil can be enhanced by the modification of wetland operation, oxygen input to the wastewater can be enhanced by the modification of wetland design. One of these design modifications, referred to as a marsh–pond–marsh (m–p–m) design, consists of a traditional continuous-marsh design bisected by a deeper, open-water or pond section. The pond section has been shown to increase the dissolved oxygen concentration and oxidation status of animal wastewater (Cathcart et al., 1994; Reddy et al., 2001). Although increased oxygen concentration was expected to promote nitrification in the pond section, m–p–m systems did not exhibit increased wastewater nitrogen removal when compared to continuous marsh systems (Poach et al., 2004b; Moore et al., 1995). This discrepancy suggests that the increased oxygen concentration did not support an increased rate of nitrification. The restriction on nitrification likely resulted from the application of wastewater biochemical oxygen demand (BOD) in excess of the first marsh's removal capacity (Poach et al., 2004b).

While the BOD treatment capacity of the first marsh in a m–p–m system can be increased by increasing the size of the first marsh, this modification may not be feasible for pre-existing systems. This modification is also not desirable for areas where animal wastewater treatment is land limited, especially when a goal of maximum nitrogen removal also maximizes BOD loading. One possible alternative for enhancing the treatment capacity of m–p–m systems is to apply wastewater on an alternating fill and drain cycle. If intermittent wetland drainage improves the BOD treatment capacity of the first marsh then the pond section should promote nitrification. Enhanced nitrification in the pond section should reduce ammonia (NH_3) volatilization generated by the pond (Poach et al., 2004a). Partial nitrification of swine wastewater before wetland application reduced NH_3 volatilization from continuous marsh wetlands (Poach et al., 2003).

The objective of this research was to evaluate how intermittent wetland drainage affects the ability of m–p–m constructed wetlands to treat wastewater from a confined swine operation. To meet this objective, different wastewater application schemes were used to load swine wastewater to four m–p–m wetland systems.

2. Materials and methods

2.1. Site description

The experiment was conducted at the swine research facility of the North Carolina A&T State University farm in Greensboro, NC, USA, using four surface-flow wetlands in a m–p–m design. The wetlands (11 m × 40 m) were constructed in 1995 (Reddy et al., 2001). Each wetland system (WS) consisted of an 11 m × 10 m marsh at both the influent and effluent ends and an 11 m × 20 m pond section separating the marshes (Fig. 1). The marsh sections were planted with *Typha latifolia* L. (broadleaf cattail) and *Schoenoplectus americanus* (Pers.) Volkart ex Schinz & R. Keller (American bulrush) in March 1996. The wetlands have been treating swine wastewater every year since the first application in 1997.

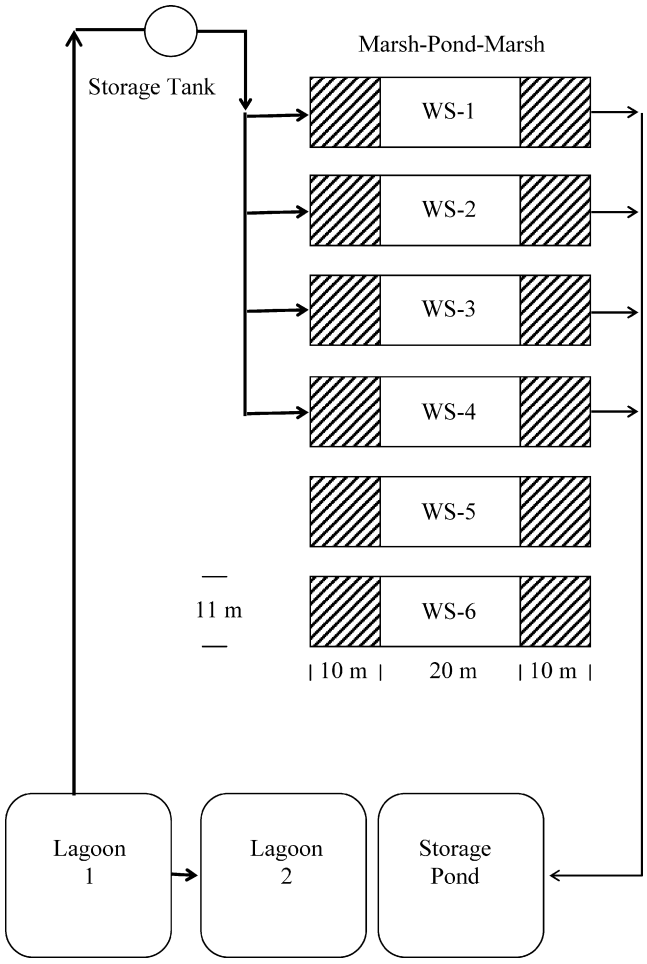

Fig. 1 – Schematic of the marsh–pond–marsh constructed wetland design showing the sources and flow paths for swine wastewater. Only wetland systems (WS) 1–4 were used in this experiment.

2.2. Experimental design

The study was conducted for 16 weeks from June to October 2002. During the study, each WS received a different swine wastewater application scheme. The four application schemes were as follows: (1) continuous application (no drain periods); (2) 1 week of no application for every 4 weeks of application (three drain periods); (3) 1 week of no application for every 3 weeks of application (four drain periods); and (4) 1 week of no application for every 2 weeks of application (five drain periods). These application schemes resulted in drainage frequencies that were 0, 19, 25, and 31% of the total study period, respectively.