Removal of pathogenic and indicator bacteria from dairy wastewater using an ecological treatment system

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Abstract

In the quest to improve the sustainability of water treatment options, plant-based systems, such as wetlands and ecological treatment systems, are a promising alternative. Traditionally, agricultural wastewater has been stored in lagoons, which can overflow or fail with drastic consequences to water quality (Innes 2000). As a result of lagoon failures and application of manure to crop fields, nutrients from animal waste are the second most common cause of water pollution leading to reductions in dissolved oxygen and contributing bacteria that are harmful to humans and fish populations (USEPA 1993). Alternatively, ecological treatment systems, which rely on renewable resources, and combine anaerobic reactors, vegetated reactors, and wetlands, could be used to treat agricultural wastewater. Ecological treatment systems have successfully treated municipal and industrial effluents with reduced costs compared to conventional methods (Austin 2000). Nutrients, solids and BOD also have been effectively removed from liquid manure wastewater using ecological treatment systems (Lansing and Martin, in press). To date, most of the research on ecological treatment systems has focused on the ability of these systems to remove excess nutrients, turbidity and biochemical oxygen demand from wastewater. However, another key factor to making these systems successful is ensuring their ability to remove pathogens present in wastewater.

Introduction

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Specific Objective

- The specific objectives of this study were to determine the bacterial pathogen removal efficiency of an ecological treatment system for dairy wastewater and to identify the potential environmental consequences to water quality.
- We hypothesized that total coliforms and E. coli in the wastewater would be significantly reduced between the influent and effluent of the ecological treatment system, with the majority of the removal occurring as result of sedimentation in the first clarifier

Ecological Treatment System Description

The ecological treatment system is located at Waterman Farm (WETS) (40°N, 83°W), a working dairy farm, on The Ohio State University campus in Columbus, Ohio. The WETS is housed in a 0.1 m x 10.36 m polyhouse and consists of two identical treatment lines, each receiving waste from a 7.57 m³ dosing tank. Dairy wastewater is collected from two feeding barns and the milking parlor and stored in a 46.1 m³ wastewater reservoir. Wastewater is pumped from the reservoir to the WETS dosing tank, from which it is pumped into the polyhouse and distributed to two identical treatment lines. After exiting the WETS, a third pump returns the treated water to the wastewater reservoir.

Each treatment line is designed in the following manner: one 0.357 m³ anaerobic reactor, one anaerobic reactor (0.416 m³), one closed aerobic reactor (0.416 m³), one open aerobic reactor (0.416 m³), one clarifier (0.586 m³), one subsurface flow gravel wetland (1.2 m x 0.6 m x 1.3 m) length x width x depth), two aerobic reactors (0.34 m³), one clarifier (0.34 m³), and two subsurface flow gravel wetlands (1.2 m x 0.6 m x 0.3 m) length x width x depth) (Fig. 1). Two feedback lines return wastewater from the first clarifier to the anaerobic reactor and from the second clarifier to the second aerobic reactor for further treatment. Wastewater is pumped into the system at a rate of 0.35 m³ day⁻¹.

Methods

- A field experiment was conducted over the 2005 summer to assess the capacity of the WETS to remove pathogens from wastewater at three increasing concentrations.
  - July 1: part wastewater to 3 parts well water
  - August 1: 1:1
  - September 2:1
- Samples were serially diluted down to 10⁻⁴ and then spread-plated on MacConkey agar for total coliform identification.
- Plates were incubated for 18-24 hrs at 37 °C.
- Total coliforms were identified as pink colonies (Fig. 3)
- E. coli colonies on MUG plates were identified by fluorescence under a UV lamp (Fig. 4)
- Water quality monitoring:
  - Dissolved oxygen (DO) and temperature were monitored weekly using a handheld YSI probe.
  - Samples were collected from influent and effluent twice a week and from internal reactors once per dosing regime.
- Pathogen concentration was determined by plate counts and enzymatic methods. Water Research 36: 2607-2617.

Results and Discussion

- Over 65% of the pathogen reduction occurred in the first two reactors (Fig. 5 and 6).
- Total coliform and E. coli did not significantly differ at a particular location, from one dosing regime to the next, implying that the system treated wastewater at a constant rate and was able to handle the increased wastewater concentration.
- Although reductions were substantial, USEPA discharge requirements for E. coli of 126 cfu 100 ml⁻¹ were not met.
- Pathogen concentration was significantly positively correlated with TSS during the 1:1 and 2:1 WWV concentrations (Fig. 7).
- About 35% of pathogens in wastewater treatment system effluent are hypothesized to be attached to suspended matter > 3.5 µm (George et al. 2002.
- Therefore, sedimentation in anaerobic and clarifier reactors is an important pathogen removal mechanism.

Conclusions

- The WETS achieved substantial reductions in pathogen concentration regardless of dairy wastewater concentration.
- Majority of the reduction occurred in the first two reactors, anaerobic and anoxic, respectively.
- While reductions were substantial, discharge requirements of 126 cfu 100 ml⁻¹ were not met.
- Improvements in TSS removal may increase pathogen removal rates sufficient to meet discharge requirements.

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References

Lansing, S.L., Martin, J.F. Use of an ecological treatment system (ETS) for removal of nutrients and solids from dairy wastewater. (accepted by Ecological Engineering 12/2005).