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TREATMENT OF CHEESE PROCESSING WASTE USING SUBSURFACE FLOW WETLANDS

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ABSTRACT

Eichten Cheese is a small, family owned dairy located near Center City, Minnesota. Primary products produced by the dairy include specialty cheeses. The system consisted of a septic tank, subsurface flow constructed wetland and an infiltration bed. Due to the cold climate, the wetland and infiltration bed were insulated with mulch. The wetland has operated since startup without freezing problems.

Quarterly sampling was initiated under the County operating permit. The initial round of sampling showed influent concentrations far higher than expected for $CBOD_5$ (2,820 mg/L vs. 174 mg/L design value). Further investigation revealed that the facility piping resulted in most of the cheese processing waste being diverted to the septic system. Core sampling of the septic tank revealed large accumulations of cheese solids. Organic overloading of the subsurface flow wetland was obvious, with anaerobic protein degradation within the subsurface flow wetland causing a net production of ammonia. This organic loading, if left unabated, would cause rapid biomat plugging and hydraulic failure of the infiltration bed.

In April, 1999, an aeration system (Forced Bed Aeration™) was retrofitted to the wetland cell to increase the oxygen transfer rate. The aeration blower was operated intermittently from April to July 1999 due to startup problems, and full-time thereafter. Since initiation of full-time aeration, $CBOD_5$ removal improved from 17% to 94%, while Total Nitrogen removal improved from 44% to 74%. This performance improvement indicates that the wetland reactor had adequate detention time and surface area for $CBOD_5$ removal, but was initially limited by the oxygen transfer rate. Total Nitrogen removal is still limited by the ability to oxidize ammonia, indicating that there is still not enough oxygen available to completely satisfy both the carbonaceous and nitrogenous oxygen demands.

INTRODUCTION

The author's primary interest has been in developing simple constructed wetland treatment systems as an alternative to more complex mechanical systems with an emphasis on small community wastewater treatment. This is driven in part by the demonstrated need for better wastewater alternatives, even in the United States. On-site septic systems serve approximately 25% of the US population (USEPA 1997), and in 1995 alone, over 2.5 million septic systems malfunctioned (NODP). Contrary to the belief that regional wastewater facilities are solving the nation's problems, more Americans are using septic systems now than in 1990 (NODP).

Prescriptive methods typically used to design onsite wastewater systems focus only on flow (National Small Flows Clearinghouse, 1996). However, non-residential sources such as restaurants and food processing facilities produce wastes that are much stronger than domestic wastewater (NCS). Using a flow-only approach results in organic overloading, causing rapid biomat formation and failure of the infiltration system (Converse & Tyler, 1994).

Constructed wetlands have many unique benefits as a wastewater treatment process, including the ability to operate on ambient solar energy, self-organize and increase treatment capacity over time, create wildlife habitat, produce oxygen and consume carbon dioxide, and achieve high levels of treatment with minimal maintenance (Wallace, 1998). Constructed wetland technology was initially selected for the Eichten Cheese facility to provide wastewater pretreatment and extend the life of the infiltration system.

SYSTEM DESIGN

The wastewater system was designed to handle a flow rate of 1,400 gallons per day (5.3 cubic meters per day). Initial treatment (consisting of primary settling and low-rate anaerobic digestion) occurs in a 3,000-gallon (11.4 cubic meter) precast concrete septic tank. Septic tank effluent then enters a 1,500-gallon (5.7 cubic meter) pump tank equipped with a single 1/3-HP (0.25 kW) effluent pump. This pump is used to pump wastewater into the wetland treatment cell.

Due to the cold climate, a horizontal flow subsurface wetland process was selected. Subsurface flow wetlands have the primary benefit that water is not exposed during the treatment process, minimizing energy losses through evaporation and convection. The wetland treatment cell and infiltration area were insulated with mulch. This is necessary to prevent freezing during snow-free winters (Kadlec, 2000). The insulation design methodology is discussed in detail elsewhere (Wallace et. al., 2000).

The wetland treatment cell was sized based on the design equations in *Treatment Wetlands* (Kadlec & Knight, 1996) using temperature-corrected kinetic parameters. The resulting wetland design called for a 2,040 square foot (189 square meter) treatment cell, resulting in a hydraulic loading of 0.69 gallons per day per square foot (2.8 centimeters per day). The wetland was projected to achieve an effluent $CBOD_5$ of 12.7 mg/L based on an influent concentration of 174 mg/L.

After treatment, effluent flows into a 680 square foot (63 square meter) infiltration bed for disposal.

Design Modifications. Initial sampling of the influent (after the septic tanks) indicated a CBOD concentration of 2,820 mg/L, over 16 times greater than the original design. After the presence of cheese waste in the system was confirmed, the wetland was retrofitted with a Forced Bed Aeration™ system (Wallace, 2001). One thousand linear feet (305 meters) of aeration tubing with turbulent flow emitters spaced every 24 inches (610 mm) was installed. A ¾-HP (0.56 kW) blower is used to pressurize the aeration system. The blower is programmed to run 23 hours per day. A schematic of the aeration system is shown in Figure 1.

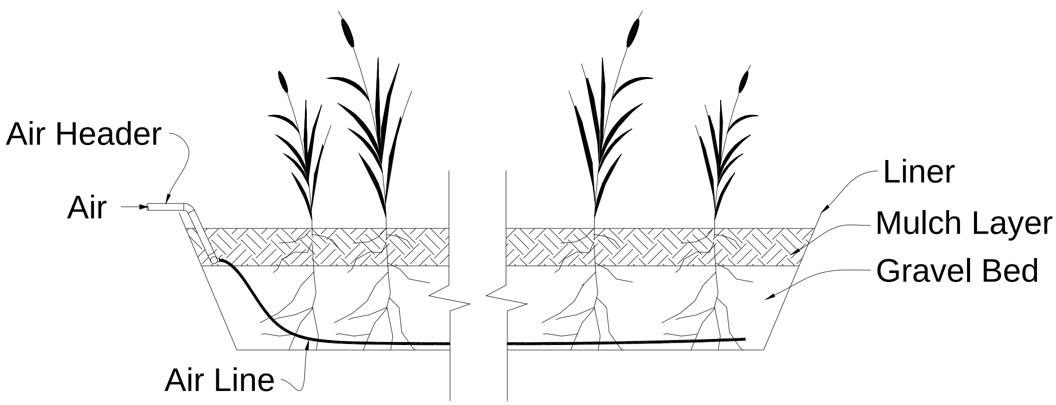

FIGURE 1. Forced Bed Aeration™ process schematic (Wallace, 2001).

SYSTEM PERFORMANCE

Initial monitoring was begun in December, 1997 under a County operating permit that requires quarterly monitoring. A contract operations firm performs analytical monitoring while Eichten Cheese conducts flow monitoring.

Flow. Flow data was reported to Chisago County, Minnesota during 1998 and 1999. Actual system flows are close to the design flow of 1,400 gallons per day (5.3 cubic meters per day). Flow data is summarized in Table 1.

$CBOD_5$ and Total Nitrogen. The wetland system is sampled quarterly for fecal coliform, carbonaceous biochemical oxygen demand, ammonia, nitrate/nitrite, kjeldahl nitrogen, total suspended solids and total phosphorus. Analytical data for $CBOD_5$ and Total Nitrogen is summarized in Table 2 and Figures 2 and 3.

TABLE 1. Flow data for Eichten Cheese.

Date	Average Flow gpd	Average Flow m^3/d
January 20 – 29, 1998	852	3.2
January 30 – February 4, 1998	910	3.4
February 5 – 27, 1998	775	2.9
February 28 – March 4, 1998	504	1.9
March 5 – 13, 1998	783	2.4
March 14 – May 21, 1998	908	3.4
May 22 – August 7, 1998	1,384	5.2
August 8 – November 9, 1998	1,344	5.1
November 10, 1998 – June 8, 1999	1,201	4.5
June 9 – July 21, 1999	1,215	4.6

TABLE 2. $CBOD_5$ and Total Nitrogen removal data for the wetland treatment system.

Date	$CBOD_5$, mg/L Influent	$CBOD_5$, mg/L Effluent	Total Nitrogen, mg/L Influent	Total Nitrogen, mg/L Effluent
December 10, 1997	2,820	1,740	92.5	13.9
March 12, 1998	2,100	444	105	56.8
April 9, 1998	1,050	1,250	51	68.1
March 4, 1999	2,250	1,610	119.3	57.4
April 14, 1999	2,160	1,800	88.1	58.6
Aeration system placed into intermittent operation				
April 28, 1999	3,750	1,130	96.7	65.4
June 3, 1999	1,680	324	78.1	62.3
June 23, 1999	3,000	240	91.2	67.4
Aeration system in full operation				
September 30, 1999	5,130	105	164	48.1
December 15, 1999	7,200	42	194	48.5
March 22, 2000	3,210	197	153	29.1
June 7, 2000	2,700	42.3	149	74.9
September 17, 2000	730	156	97.3	85.5
December 19, 2000	711	41.3	387	27.1
March 27, 2001	2,300	108	157	29.6

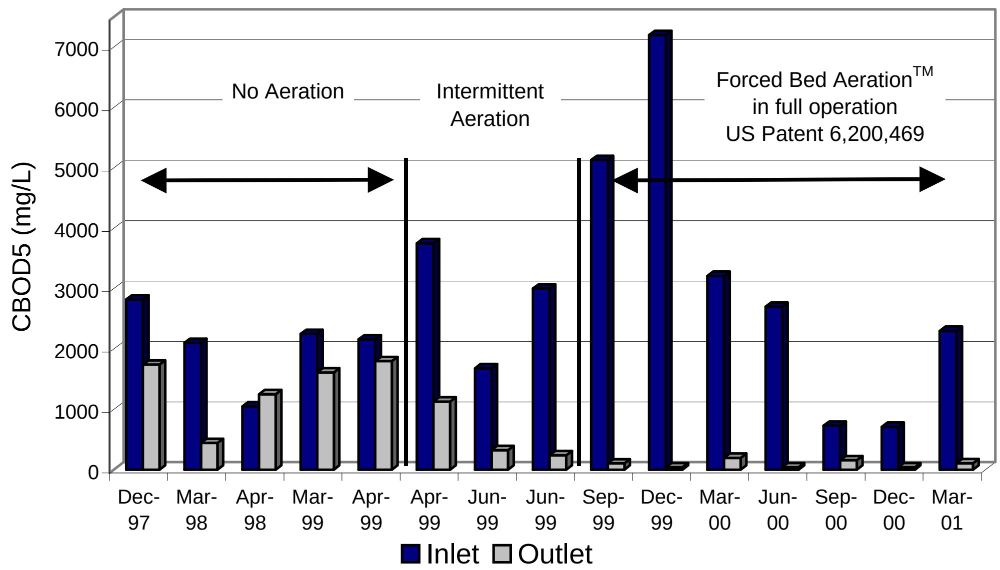

FIGURE 2. Summary of influent and effluent $CBOD_5$ concentrations for the wetland treatment system. $CBOD_5$ removal improved from 17% to 94% after full-time aeration was implemented.

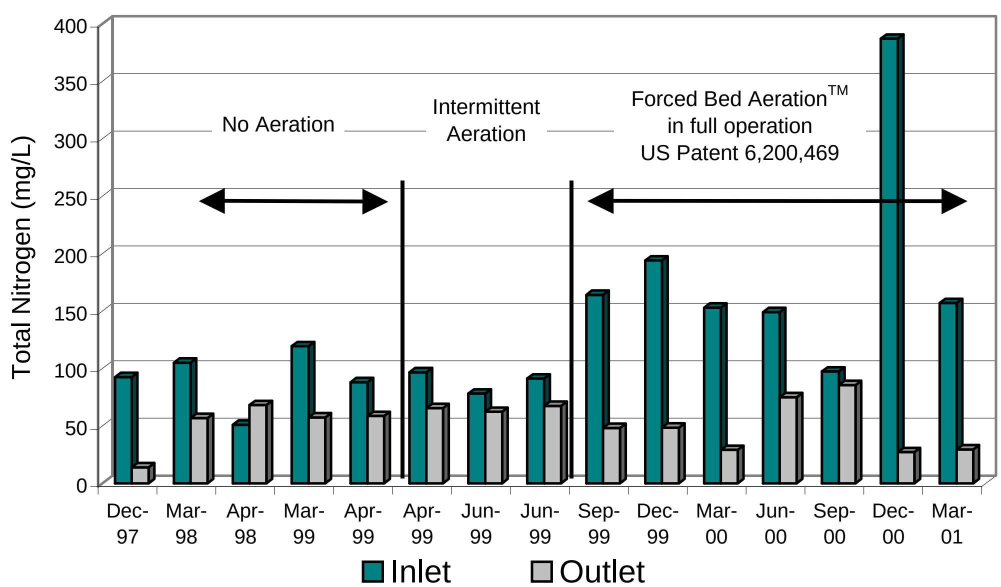

FIGURE 3. Summary of influent and effluent Total Nitrogen concentrations for the wetland treatment system. Total Nitrogen removal improved from 44% to 74% after full-time aeration was implemented.

CONCLUSIONS

Since initiation of full-time aeration, $CBOD_5$ removal has improved from 17% to 94%, while Total Nitrogen removal has improved from 44% to 74%. This performance increase indicates that the wetland reactor had adequate detention time and surface area for $CBOD_5$ removal, but was initially limited by the oxygen transfer rate. Total Nitrogen removal is still limited by the ability to oxidize ammonia, indicating that not enough oxygen is available to satisfy both the carbonaceous and nitrogenous oxygen demands. (Almost all effluent nitrogen is in the form of ammonia). A larger wetland treatment cell would improve performance, although the current system provides adequate pretreatment for subsurface disposal.

The oxygen demand exerted on the wetland system has averaged 0.027 pounds O_2 per square foot (134 grams O_2 per square meter per day) since September 1999. Assuming that in the absence of aeration, atmospheric diffusion and wetland plants could jointly transfer up to 7.2 grams O_2 per square meter per day (Gersberg et. al., 1989), the Forced Bed Aeration™ system is operating at an average oxygen transfer efficiency of 14%.

The Eichten Cheese system demonstrates that constructed wetlands can be used for year-round treatment of high strength wastes, even in cold climates. Neither $CBOD_5$ nor Total Nitrogen removal was affected to any appreciable degree by the cold weather. This is consistent with other wetland studies. Nitrification in aerated wetland systems has been documented at very cold temperatures (Cross, 2001).

There are currently 17 subsurface flow constructed wetlands using Forced Bed Aeration™ for treatment of domestic and industrial wastes. In addition, a number of vertical flow wetlands have also been installed with Forced Bed Aeration™.

In cases where existing constructed wetlands are overloaded or do not meet nitrogen limits, aeration could be retrofitted to improve treatment performance.

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