USING COMPACT, LOW-ENERGY ONSITE SYSTEMS TO TREAT BREWERY WASTEWATER WITH HIGH LEVELS OF BOD AND TSS

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1. INTRODUCTION

Organic matter in wastewater contributes to the Biological and Chemical Oxygen Demands (BOD/COD) responsible for eutrophication and deteriorating water quality in untreated discharge streams. Reduction of BOD is one of the most crucial steps in wastewater treatment, and is typically the target contaminant during the aeration/biological treatment process of municipal treatment facilities. Typical medium-strength municipal wastewaters contain raw BOD and COD concentrations of around 200 and 500 mg/L, respectively (Metcalf and Eddy, 2014). However, higher influent BOD concentrations in the range of 500 -1000 mg/L can often be seen as a result of industrial discharge, including sewer contributions from breweries, meat processing facilities, and textile facilities. These discharges can contribute to significantly higher influent BOD and COD loads which have the potential to disrupt plant processes, reduce effluent quality, and increase energy consumption and associated energy costs. As a result, municipalities are cracking down on these industrial users by imposing surcharges on users who fail to comply with sewer discharge limits.

In Canada, one growing industry that has become the focus of new enforcement strategies is the beer and brewing industry. According to Beer Canada, from 2015 to 2020, the number of breweries in Ontario doubled to 360, which also led to a significant increase in the volume of wastewater discharged to municipal sewers. The quality and quantity of brewery effluent can fluctuate significantly as it depends on various processes within the brewery (raw material handling, wort preparation, fermentation, filtration, cleaning, packaging.) (Driessen and Vereijken, 2003). The beer production steps and the different types of wastes generated are shown in Figure 1. Previous studies reported that approximately 3 to 10 liters of waste effluent is generated per liter of beer produced in breweries (Kanagachandran and Jayaratne, 2006). It should be noted that wastewater from brewing and cleaning processes is very high in organic materials, with total suspended solids (TSS) and BOD concentrations averaging 10,000 mg/L, potentially reaching as high as 50,000 mg/L. The pH values can often be outside of the required discharge range (6-9) due to the chemicals utilized in the cleaning processes. Therefore, breweries can face significant challenges in implementing onsite treatment systems that can meet sewer discharge limits and avoid surcharges from the municipality. Additionally, most of Canada's breweries are smaller craft/local operations, meaning they are frequently limited by capital and footprint availability.

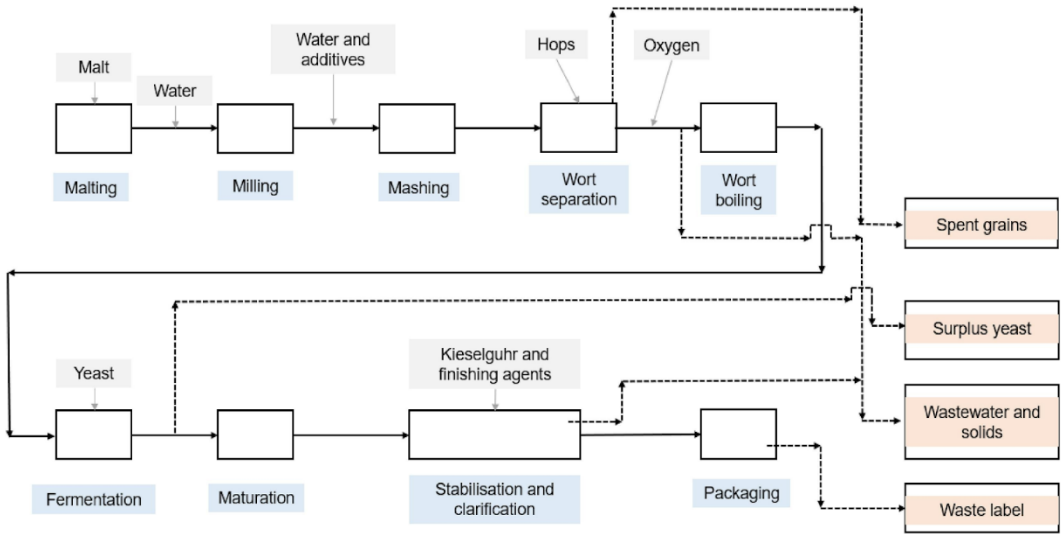

Figure 1. Beer production process and the different types of wastes generated (Ashraf et al., 2022)

In an effort to develop a compact, cost-effective solution for both breweries and municipalities looking to reduce organic loading from brewery wastewater discharges, a pilot study was conducted in partnership with a local Southern Ontario brewery. The intent of this project was to demonstrate the ability of a combined dewatering/pH adjustment and fixed-film treatment system to significantly reduce TSS and organics concentrations from brewery wastewater.

2. METHODOLOGY

2.1 Treatment system and operation

The schematic of the treatment system is shown in Figure 2. The treatment process involved pH adjustment using 25% Sodium hydroxide (Kencro Chemicals Ltd, Oakville, ON). Coagulation and flocculation were conducted to remove TSS and particulate matter from the brewery wastewater. The flocculated material was run through a geotextile dewatering bag (Figure 3) to remove the solids. The chemicals used for coagulation and flocculation are Solve 80 (Polyaluminium chloride solution) and Solve 9330 (proprietary chemical), both procured from WaterSolve LLC, Caledonia, MI. The woven geotextile material (Figure 3) produces a porous, yet robust container, that allows for the passive retainment and consolidation of solid material while allowing filtrate to pass through the microscopic openings (420 um). The clear filtrate was released and was collected in a feed tank for further downstream biological treatment (Figure 2). Lastly, the filtrate was pumped to an aerated fixed-film biological treatment system, a BioCord™ Reactor, for the energy-efficient reduction of soluble BOD, COD, and ammonia before final discharge.

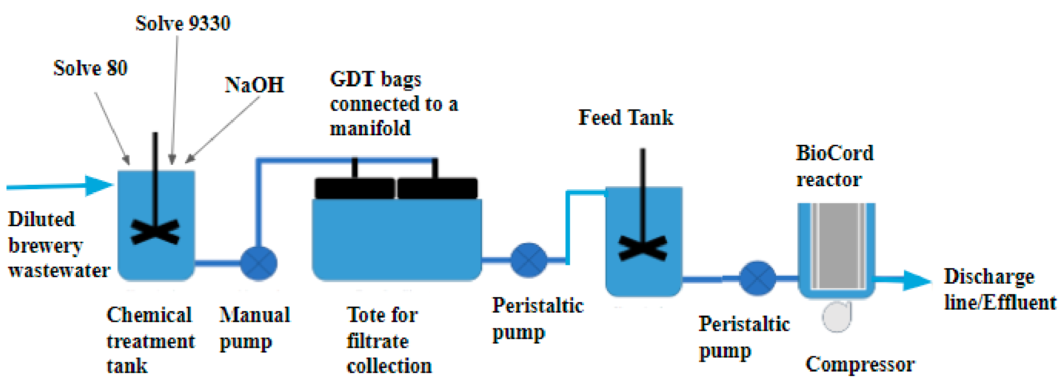

Figure 2. Schematic of the pilot brewery wastewater treatment system

Figure 2. Geotextile dewatering bag for dewatering

The working volume of the BioCord^{TM} Reactor is 120L and operated at a flow rate of 2 L/hr. The BioCord^{TM} Reactor was seeded with waste-activated sludge (WAS) from the Renfrew Wastewater Treatment plant (Renfrew, ON). The specific surface area of the BioCord media in the reactor is 70 m^2/m^3. Details about BioCord Reactors were previously described by Gan et al (2018)and Shewa et al. (2022).

The BioCord reactor was continuously fed with the filtrate (stored on the feeding tank) using FLEX-PRO® A2 peristaltic pump (Huntington Beach, CA) and aerated with a rocking piston compressor (Model: KM-60C, CanadianPond, Knowlton, QC).

2.2 Influent characteristics

The raw brewery wastewater has a pH of 4.6±0.03 and an average tCOD and NH_3-N concentrations of 42,822 and 116 mg/L, respectively. A significant variation in the raw brewery wastewater NH_3-N and COD concentration was observed during the duration of this study. The COD/NH_3-N ratio observed in the influent to the BioCord Reactor ranges from 80 to 190. The average wastewater characteristics of the influent to the BioCord reactor are given in Table 1.

Table 1 Characteristics of BioCord Reactor influent.

Parameter	**Average** ± SD
Wastewater Temperature (ºC)	17.3 ± 1.5
pH	7.4 ± 0.4
Alkalinity as (CaCO3), mg/L	126.8 ± 26.5
tCOD (mg/L)	1582 ± 775
TSS (mg/L)	112.8 ± 59.3
NO_2-N (mg/L)	15.1 ±11.1
NO_3-N (mg/L)	3.1 ±2.1
NH_3-N (mg/L)	27.2 ± 17.6

2.3 Analytical schedule and methods

Influent and effluent samples were collected twice per week for total COD, NH_3-N, NO_2 -N, NO_3 -N, alkalinity and TSS analysis. Bioreactor temperature, dissolved oxygen (DO), and pH were monitored daily. The DO concentration and pH were measured using Hanna Portable Dissolved Oxygen Meter (Model: HI9142) and Oakton™ handheld pH meter. COD, NH_3-N, NO_2 -N, NO_3 -N and alkalinity were measured using HACH kits and HACH DR/3900 photometer (HACH, Loveland, CO). % solid was determined using a moisture analyzer (Ohaus MB35, Nänikon, Switzerland).

3. RESULTS AND DISCUSSION

3.1 Overall performance of the treatment system

The optimal dosages of Solve 80 and Solve 9330 used in the coagulation-flocculation step are 8,800 and 145 ppm, respectively. The process demonstrated an ability to reduce a raw TSS value of 24,400 mg/L (2.44% solids) down to 151 mg/L (99% reduction). The chemical treatment system prior to the BioCord reactor reduced an average raw tCOD value of 21,411mg/L (brewery wastewater after 1:1 dilution) to an average tCOD of 1582 mg/L. The BioCord reactors reduced the tCOD further down to 368 mg/L mg/L. Therefore, the pilot system (Figure 2) is a compact, low-energy solution for breweries to achieve sewer discharge limits and avoid surcharges. It is a treatment system that can also address the challenges associated with treating high organic concentrations via biological oxidation methods.

3.2 BioCord reactor performance

3.2.1. COD removal

The treatment system was operated for about 12 months. The data shown in this paper is for the steady-state operation period (November 25, 2021, to March 13, 2022). Figure 3 shows concentrations in the influent and effluent of the BioCord Reactor and respective removal efficiencies. The tCOD loadings and removal rates are shown in Table 2. Despite significant influent tCOD fluctuation, the removal efficiency is consistently higher than 50%. The average tCOD removal efficiency is 72.59 %.

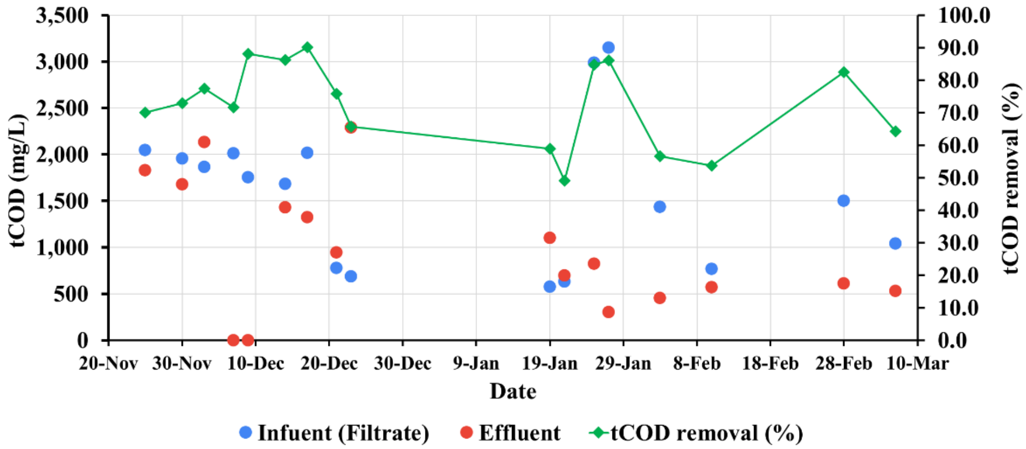

Figure 3. Total COD concentrations in the influent and the effluent to the BioCord Reactor

Table 2. COD and NH_3-N loading and removal rates

Parameter		**Average** ± SD
Airflow rate (L/min)		30
pH		7.6±0.5
DO (mg/L)		8.3±0.3
Temperature (°C)		18.2±1.4
NH_3-N	Removal (%)	36.61±34.07
	Loading rate (g/m^2.d)	0.14±0.09
	Removal rate (g/m^2.d)	0.08±0.06
	Loading rate (g/m^3.d)	9.80±6.33
	Removal rate (g/m^3.d)	5.30±4.29
tCOD	Removal (%)	72.59±12.94
	Loading rate (g/m^2.d)	8.14±0.06
	Removal rate (g/m^2.d)	6.24±3.72
	Loading rate (g/m^3.d)	569.52±279
	Removal rate (g/m^3.d)	436.93±260

3.2.2 Ammonia removal

The NH_3-N removal efficiency during the steady-state period was 36.6% on average (Table 3, Figure 4). Even though the Biocord reactor demonstrated a simultaneous COD- and ammonia-removing capability the nitrification removal is less than that of tCOD removal. The lower ammonia removal can be attributed to the higher C:N ratio of the influent. The average COD/NH_3-N ratio observed in the influent to the BioCord Reactor is 60 whereas the optimum required ratio for simultaneous COD and ammonia removal is 5 to 30. A decrease in nitrification at higher C:N ratio was reported by Hwang et al. (2009) and Kocaturk and Erguder (2016). It should also be noted that long-term exposure to higher COD concentrations will favor the development of faster-growing heterotrophs over the autotrophs, leading to a decrease in nitrification (Shewa et al., 2022).

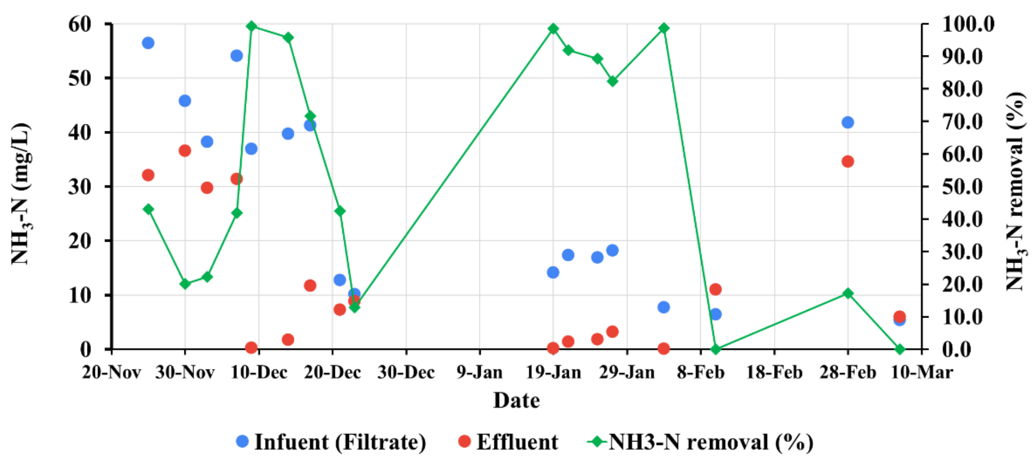

Figure 4 NH_3-N concentrations in the influent and the effluent to the BioCord Reactor.

4. CONCLUSIONS

This pilot study showed the optimal coagulant and polymer concentrations required to flocculate and consolidate/remove solids from the brewery waste stream. Higher TSS and COD removal rates were observed from the initial pH adjustment, chemical requirement with Solve 80 and 9330, dewatering step, and the BioCord Reactor system. It was found that the combined geotextile/fixed-film treatment process had a high potential to be used in full-scale applications for the treatment of brewery/high strength wastewater. Furthermore, the pilot project can be scaled up to provide a compact, low-energy solution for breweries to achieve sewer discharge limits and avoid surcharges. Future studies on the pilot will evaluate and optimize the treatment efficiency of the system with undiluted brewery wastewater.

5. ACKNOWLEDGMENTS

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