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Performance Evaluation of Up-flow Anaerobic Sludge Blanket Reactor and Aerobic Digestor of Raj Brewery, Bhairahawa, Nepal

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Abstract
Large amount of wastewater is produced from brewery plants which must be treated before discharging into the environment. This research aims to study the chemical oxygen demand removal efficiency of the UASB technology and the aerobic digestor and estimate the biomethane potential that could be generated from the brewery wastewater by using UASB reactor. During the study, it was found that an average of 11.0 Nm^3 methane was generated daily by the UASB plant at 48 hours hydraulic retention time and at volumetric loading rate of 84 m^3. The methane yield was found to be around 0.14-0.16 m^3/kg COD removed. The chemical oxygen demand (COD) value at the influent ranged from 165 to 3950 mg/l and the COD value at the effluent ranged from 121 to 2230 mg/l after digestion in the UASB reactor. During the observation period, the overall efficiency of the UASB reactor in terms of COD removal was found to be 52.5%. The efficiency of the UASB reactor in terms of COD removal fluctuated from 4% to 83.64 %. The concentration of volatile fatty acid (VFA) was found to range from 85.71 to 874.28 mg/l. The alkalinity was found to range from 575 to 872 mg/l. The VFA to alkalinity ratio was found to range from 0.14 to 2.46. The VFA/ alkalinity ratio was found comparatively higher during observation period, which hindered the operation of plant at optimal level. The COD removal efficiency of the aerobic treatment plant ranged from 22 % to 95 % during the observation period the average efficiency was found to be 78.5%. The average pH, BOD, COD and TSS value of treated wastewater from the effluent treatment plant were found to be 7.82, 37.94 mg/l, 100.93 mg/l and 21.33 mg/l respectively and within the disposal guidelines set by Government of Nepal. UASB technology appears to be environmentally friendly and promising technology for treating brewery wastewater, which produces large amount of wastewater and contains high organic materials.

Keywords
Brewery Wastewater, Up-Flow Anaerobic Sludge Blanket, Bio Methane, Chemical Oxygen Demand

1. Introduction

Brewery plant produces a large amount of wastewaters that contains high concentrations of organic pollutants, low concentrations of nutrients and have large variations in these parameters [1]. In particular, brewery effluent is generally characterized by high COD, BOD and TSS concentrations and wide variations in flow and strength [2]. This is because the effluent stream is made up of the combined discharges of the brewing and packing sections, whose production rates vary independently of one another. The packing process produces a high flow, high pH, weak waste primarily composed of spilled beer and caustic bottle cleaning solutions, while the brewing process produces a low flow, neutral pH, and high strength alcohol-carbohydrate-protein waste. In general, the pH of the effluent is a function of production activities and may range from pH 7 – 12. However, within a few hours (7 – 16 hours) hydrolysis and anaerobic activity usually reduces the pH to about 4 to 8 since the effluent has a poor buffering capacity [3].

Therefore, brewery wastewater tends to be very difficult to treat due to wide variations in strength in terms of COD, pH and flow. If the brewery effluents are not properly treated or untreated, they can cause water pollution and spread foul odor around the plant. The wastewater from brewery has to be treated to bring down the levels of COD and BOD and to remove odour before being discharged into the environment. Various anaerobic treatment

technologies can be applied to remove organic pollutants, odour and generate biogas which may be burned as additional energy resource.

Among the various anaerobic wastewater treatment technologies, up-flow anaerobic sludge blanket (UASB) reactors have achieved considerable success and these reactors have been applied to treat a wide range of effluents [4]. The UASB process was developed by Lettinga and coworkers in the late 1970s [4]. It is primarily used for the treatment of highly concentrated industrial wastewaters [5]; however, it can also be used for the treatment of low strength wastewater. As compared to aerobic technologies, anaerobic treatment systems such as UASB are being encouraged because of several advantages, including plain design, uncomplicated construction and maintenance, small land requirement, low construction and operating cost, low excess sludge production, robustness in terms of COD removal efficiency, ability to cope with fluctuations in temperature, pH and influent concentration, quick biomass recovery after shutdown, and energy generation in the form of biogas or hydrogen[6]. Hence, adoption of anaerobic wastewater treatment technologies like UASB reactor, which generates biogas from wastewater and removes organic pollutants and odor, is essential for the continued competitiveness of the brewery industries through generation of biogas.

The purpose of this work was to evaluate the performance of the UASB Reactor and the Aerobic Digestor in terms of pollutant removal from brewery wastewater, to estimate the amount of biomethane generated from brewery wastewater and to determine the quality of treated water in terms of COD, BOD, TSS and pH value, discharged from the plant after treatment at Raj Brewery Bhairahawa, Nepal.

2. Methodology

The study was conducted in the effluent treatment plant of Raj Brewery Located at Hakwui, Bhairahawa. The UASB reactor used in this study was cylindrical with internal diameter of 6.7 meters and height of 5.5 meters. The capacity of the UASB reactor was 193.8 cubic meter. The feed substrate consisted of spent wash obtained from the brewery itself. The flow rate of spent wash was maintained at 3-4 m^3/hr with a hydraulic retention time of 48 hours. The pH of the spent wash before treatment were adjusted by adding either NaOH or HCl to maintain the pH around 7.Both the feed buffer tank and the reactor were maintained at ambient temperature. The organic loading rate varied widely during the study period as the waste concentration in terms of COD and BOD varied and the flow rate of effluent from brewery also varied.

Samples of wastewater from the brewery effluent and after treatment in the UASB reactor and after post treatment in the aerobic digestor were collected on a daily basis using a sterilized plastic bottles and transported to the laboratory facilities at the plant for physiochemical analysis within 48 hours. Grab samples were collected daily to for determination of COD, pH of the effluent before and after digestion in the UASB reactor. VFA and alkalinity of the effluent from the UASB outlet were also measured. The effluent from the UASB outlet were further treated aerobically and COD, BOD, TSS and pH of were also measured.

The pH was measured using the pH meter. BOD was measured with HACH BOD TRAK II tester. COD was measured with Hach COD kit. VFAs were measured using distillation method. Alkalinity was measured using titration method and Total Suspended Solids were measured by oven drying and filtration method.

Estimation of Pollutant Removal Efficiency The pollutant removal efficiency of UASB and ETP plant were measured using the equation 1 below.

$$\text{Removal Efficiency} = \frac{C_{influent} - C_{effluent}}{C_{influent}} \times 100 \quad (1)$$

Biomethane Potential Estimation COD indirectly measures the amount of organic matter, and for that reason, it can be applied to estimate the CH_4 yield of biomass substrate [7]. This method is based on the assumption that 1 mole of methane requires 2 moles of oxygen to oxidise carbon to carbon-dioxide and water. [7].

$$\text{Carbon Source} \longrightarrow CH_4 + CO_2 \quad (2)$$

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O + \text{heat} \quad (3)$$

The mass of one mole of methane is 16g. The 2 moles of O_2 have a mass of 64g. So, each gram of methane represents 4 grams of COD (64g/16g = 4g) (Forgacs, 2012). Under normal conditions (1 atmosphere pressure and 0 degree celcius) 0.25 grams of CH_4 take up a volume of 350 milliliters.

Based on a theoretical amount of 0.35 liters methane produced per gram COD removed, COD equivalent of the total methane gas produced could be calculated.

The actual methane production was measured by water displacement setup. A tube was used to connect the gas outlet pipe from reactor to an inverted cylinder of known volume immersed in a 3 M KOH solution to absorb CO_2 and H_2S. Methane produced was collected in the cylinder which allowed volumetric methane measurements at atmospheric pressure.

3. Results and Discussion

The characteristics of influent spent wash is shown in the Table 1 below. The wastewater pH varied from 5.17-10.1. The variation in concentration of brewery wastewater COD was 339- 4110 mg/l during the observation period.

Table 1: Brewery Wastewater Characteristics

SN	Characteristics	Values
1	Discharge (m^3/hr)	3 to 4
2	pH	5.17 to 10.1
3	BOD (mg/l)	199 to 2420
4	COD (mg/l)	339 to 4110

The variations in the COD concentration and pH of brewery wastewater for each day is a result of variation in the activities and practices of the brewery plant. The pH inside the UASB reactor varied from 6.18- 8.56.

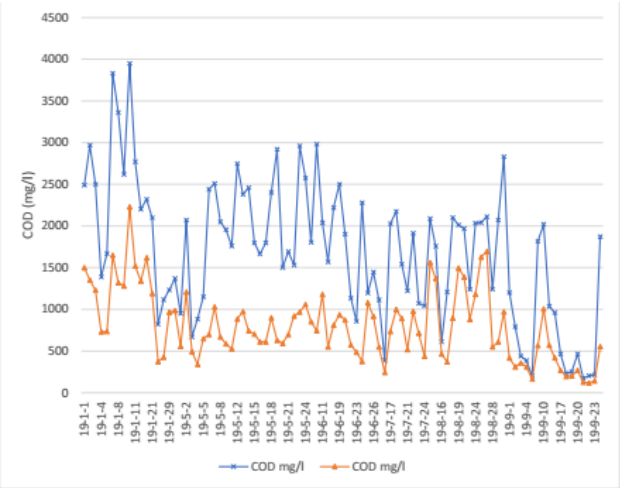

Figure 1: COD values before and after anaerobic digestion in UASB Reactor

Figure 1 shows the COD values in mg/l before and after digestion in the UASB reactor with 48 hours of hydraulic retention time. The COD value at the inelt ranged from 165 to 3950 mg/l and the COD value at the outlet ranged from 121 to 2230 mg/l.

Figure 2 shows the actual values of the methane gas generated by the UASB reactor. An average of 11 Nm^3 of gas was generated daily. The methane generation varied widely as it depends on the concentration of COD in the brewery wastewater generated. Based on the sample measurement of the biomethane generated, the actual biomethane yield was found to be 0.14-0.16 m^3/kg of COD removed.

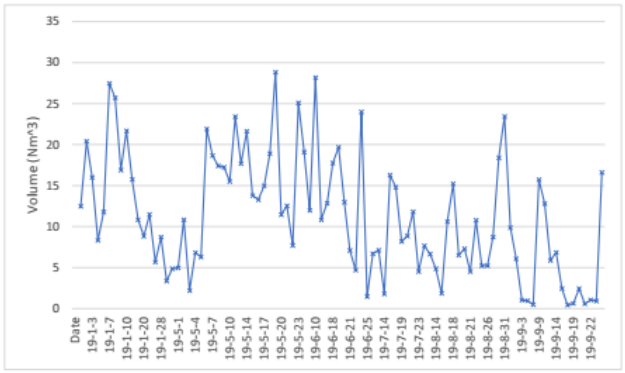

Figure 2: Volume of Methane Generated Daily in Nm^3

The COD removal efficiency of UASB reactor at various organic loading rate and at various VFA/Alkalinity ratio is shown in Figure 3. The COD removal efficiency of the UASB reactor at 48 hours HRT ranged from 4.0 % to 83.64 % during the observation period. The lowest efficiency was observed at OLR of 0.46 Kg/m3.d and VFA/Alkalinity ratio of 1.19. The highest efficiency was observed at OLR of 1.12 Kg/m3.d and VFA/Alkalinity ratio of 0.7.

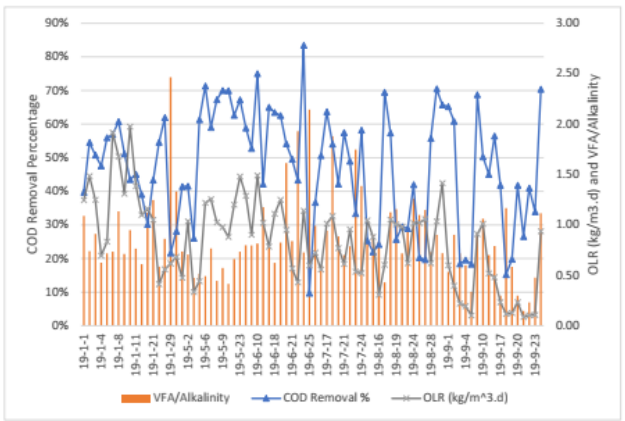

Figure 3: COD Removal Efficiency (UASB) at various OLR and VFA/Alkalinity ratio

During the observation period, the overall efficiency of the UASB reactor in terms of COD removal was found to be 51.5 %. The concentration of VFA was found to be 86 to 1457 mg/l. The alkalinity was found to be 400 to 1540 mg/l. The VFA to alkalinity ratio was found to range from 0.14 to 2.46. The lower efficiency observed during the period can be attributed to various factors such as lower organic loading rate value due to variation in activities and operation of brewery plant as well as the high VFA to alkalinity ratio.

Figure 4 shows the COD values in mg/l before aerobic digestion in the aeration tank and after aerobic digestion and treatment. The COD value at the influent ranged from 340 to 1930 mg/l and the COD value of the treated water in the aerobic digester ranged from 38 to 475 mg/l.

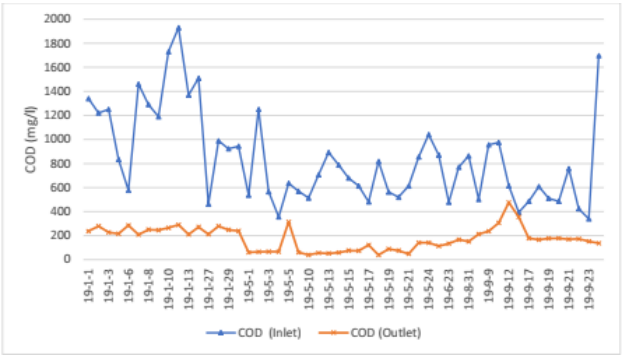

Figure 4: COD at the Inlet and Outlet of Aerobic Reactor

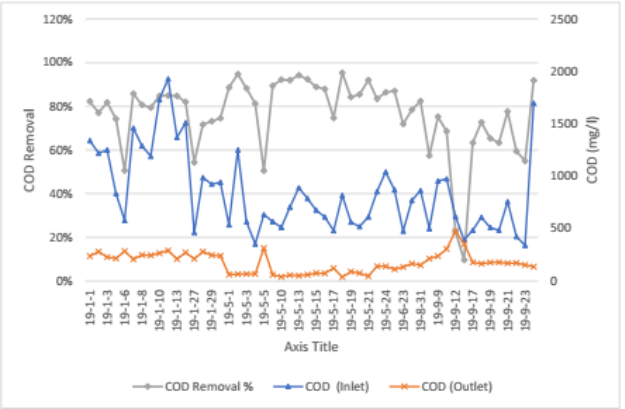

Figure 5: COD Removal Efficiency of Aerobic Reactor

The COD removal efficiency of aerobic digestion and treatment plant is shown in the Figure 5. The COD removal efficiency ranged from 22 % to 95 % during the observation period. The COD values of the effluent from the aerobic digestor was fairly consistent. During the observation period, the overall efficiency of the aerobic treatment plant in terms of COD removal was found to be 78.5 %.

Figure 6 shows the pH, BOD, COD, TSS values of the treated water from the effluent treatment plant. All those values were within the limit set by Government of Nepal regarding the wastewater discharge.

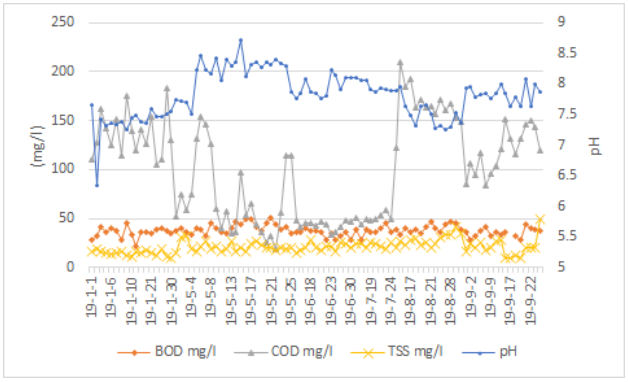

Figure 6: pH, COD, BOD and TSS values of treated water

4. Conclusion

The amount of bio-methane that is generated from brewery spent wash was calculated to be around 11 Nm^3 per day at 48 hours HRT and volumetric loading rate of 84 m^3 under various organic load. The methane yield was found to be around 0.14-0.16 Nm^3 per kg of COD removed. The overall efficiency of the UASB reactor in terms of COD removal was found to be 52.5 % at 48 hours HRT. The overall COD removal efficiency of the aerobic treatment plant was found to be 78.5 %. The average pH, BOD, COD and TSS value of treated wastewater from the effluent treatment plant were found to be 7.82, 37.94 mg/l, 100.93 mg/l and 21.33 mg/l respectively and within the disposal guidelines set by Government of Nepal. The treatment of brewery spent water through UASB technology offers several environmental benefits. It not only reduces the GHG gas emitted in the atmosphere due to capturing of methane but also reduces the consumption of other fuels. It also reduces the organic contents in the wastewater and produces treated water which could be used for irrigation. Hence, UASB technology in combination with aerobic treatment could be adopted by brewery and other industries, which produces large amount of wastewater, for mitigating problems caused by wastewater.

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