International Journal of
Scientific Engineering and Technology Research

ISSN 2319-8885
Vol.03,Issue.20
September-2014,
Pages:4050-4055

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www.ijsetr.com

A Laboratory Scale Up-flow Anaerobic Sludge Blanket (UASB) Reactor for Distillery Wastewater Treatment

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Abstract: In this study, Laboratory Scale Upflow Anaerobic Sludge Blanket (UASB) reactor was constructed to treat distillery wastewater from Mandalay Winery and Distillery Plant. The design of the reactor was considered mainly based on the diameter and height of reactor, 10.16 cm and 142.24 cm. The effective volume of the reactor was 14L organic loading rate based on the average initiated COD concentration amount of 40389mg/L. Wastewater was fed continuously with a flow rate of 0.9 L/h and hydraulic retention time was 15.6 h. Effect of the volume ratio of starter to distillery wastewater on the laboratory scale UASB reactor was varied from 9:100, 11:100, 13:100 (v:v). The removal efficiency of COD was from 64%, 72% and 82 % at 56 h respectively.

Keywords: BOD, COD, Distillery Wastewater, UASB Reactor.

I. INTRODUCTION

In Myanmar there are 35 distilleries in currently working conditions. Among them, 15 distilleries are located in Yangon and 10 distilleries are in Mandalay. These distilleries produce about 4 million gallons of alcohol are generated about 75 million gallons of wastewater annually. The characteristics and pollution potential of this wastewater depend mainly upon the feedstock used in alcohol production and type of alcohol manufacturing process. The distilleries usually use locally available feedstock. For example, there are many sugar factories in Mandalay region and these sugar feedstock produce molasses as by-product. Therefore the distillery plants in Mandalay use molasses and broken rice feedstock. In Yangon region, broken rice, corn and tapioca starch are main raw material for production of alcohol. Sometimes, palm jiggery and cane jiggery are used as feedstock [1].

Distillery wastewater is known as spent wash (in India), vinnasse (in French) and slop (in India). Wastewater from distillery contains large amounts of organic and inorganic content. This makes it have extremely high chemical oxygen demand (COD) and biochemical oxygen demand (BOD). This is in addition to having a strong odour. It contains nutrients such as nitrogen, phosphorus and potassium. It can be treated by physical, chemical, biological (aerobic and anaerobic) and microbial fuel cells. Moreover, continuous discharge of untreated distillery wastewater into nearest water bodies and land can generate the local population by suffering water-quality related illness like diarrhea or viral hepatitis. In addition, residents living near alcohol production sites are generally impact by foul smells. For example, Mandalay Industrial Zone, wastewaters from eight distilleries and two sugar factories are collected in common waste stabilization pond and diluted with water from spillway and discharged via closed and open channel into two big lakes and Dotehtawaddy River.

The local people living near open channel drain are impacted by bad smells from this wastewater and the aquatic ecosystem of these lakes is distressed by low quality incoming solution. Especially, fish is very sensitive to low pH water while the fish species are mainly impacted by received water. Moreover, the aquatic fowls inhabit in these lakes are also affected directly by drinking of unclean water and scarcity of food resources. In additions, some carnivorous species of terrestrial birds have also indirect impacts by ingestion of fish in the lakes, Mandalay City Development Committee (MWDC) is now trying to develop more effective treatment and disposal method [1]. To get the acceptable level of standard discharge for distilleries it is required to treat with both aerobic and anaerobic treatment. The key factors, temperature, hydraulic retention time (HRT), organic loading rate (OLR), pH and mixing that ensure high performance in anaerobic reactors is the right selection of operational conditions [2]. The proposed work is to treat the distillery wastewater collected from Mandalay Winery and Distillery Plant with laboratory scale UASB reactor. The objectives of this research work are to construct the laboratory scale UASB reactor, to check the efficiency of constructed reactor and to compare the removal efficiency of COD with literature.

II. MATERIAL AND METHOD

A. Materials

Polyvinyl chloride (PVC) was used to construct the laboratory scale UASB reactor. The distillery wastewater of Mandalay Winery and Distillery Company (MWDC) was selected because it is functioning annually with broken rice feedstock. The commercial grade chemical was used for the present research work.

B. Chemical Analysis

The raw distillery wastewater collected from Mandalay Region, Industrial Zone (2), Pyin Gyi Ta Gon township, MWDC used broken rice were analyzed the performance parameters such as pH, total solids, total suspended solids, biochemical oxygen demand (BOD) and chemical oxygen demand (COD).

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C. Preparation of Starter

Equal volume of cow dung and water were thoroughly mixed in a large container. The mixture 18L and 2L of distillery wastewater were filled to overflowing into a 20L plastic bottle to remove the oxygen from the bottle. The bottle to get anaerobic condition was closed with a cap tightly. The slurry after 3 weeks was filtered with 3mm aperture mesh to remove the undigested animal feed. Then it is ready to use as starter.

D. Design Calculation of UASB Reactor

In this study, laboratory scale UASB reactor was constructed by using PVC with a total working volume of 14 L. The design consideration of this reactor is based on the diameter of the reactor and calculated as follows.

Diameter and Height ratio, D : H = 1:14 [3]
Diameter of reactor, D = 4 in = 10.16 cm
Height of reactor, H = 4in x 14 = 56 in =142.24 cm
Area of reactor, A = $\pi/4 \times D^2 = 81.073\ cm^2$
Volume of reactor, V = 14 L
Biogas effluent, D_g = 1/6 x D =1.7 cm
Influent COD concentration = 41806 mg/l
Flow rate, Q = 18 L/day
Up-flow velocity, ν = Q/A = 0.0925 m/hr
OLR = 53.75 kg COD/m^3

E. Calculation for Gas-Solids-Liquid Separator

The design of the gas-solids-liquid separator device was calculated as tentative guidelines [4].

The slope of the settler bottom =55°.
Gas Deflector, W_d = 0.335 cm
Wide of Settler, B =3.9 cm
A =3.9 cm
D_h = 10cm

Scum layer baffles installed in front of the effluent weirs.

F. UASB Reactor Unit

The UASB reactor was constructed with height to diameter ratio (1:14) [3] at Department of Workshop, Mandalay Technological University. The diameter and height of reactor were 10.16 cm and 142.24 cm. The effective volume of the reactor was 14L organic loading rate based on the average initiated COD concentration amount of 40389mg/L. Five sample ports were provided at a height of 28.2 cm from the bottom of the reactor. Five sample ports were equally spaced 24.29 cm. The cone which is gas-solid-liquid separator was built at top of the reactor as shown in Fig.1. Gas deflectors were provided to guide gas bubbles into the separator to collect the gas generated and to allow the settling of suspended solids. Gas outlet was tripped with rubber bubble. Two submersible pumps were used. The first pump was for taking up wastewater from storage tank to reactor and the second pump was used for circulating wastewater inside the reactor. Starter inlet was fixed at the upper section of the reactor. Digested outlet was fixed at the bottom of the reactor to take out the digested waste. Distillery wastewater was stored in feed tank and treatment wastewater was collected in Effluent tank. Fig.2 is a schematic diagram of the experimental set up for laboratory scale UASB reactor.

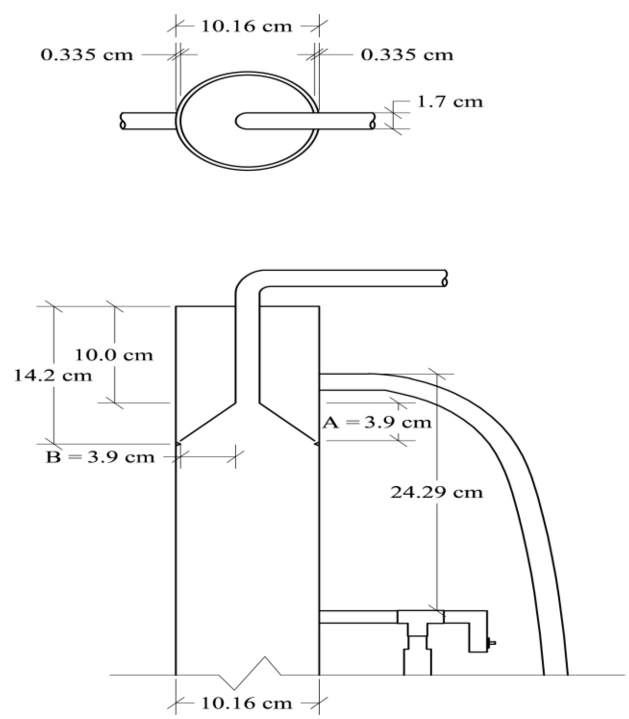

Fig.1. Section of Gas-Solid-Liquid Separator.

G. Process of Continuous Laboratory Scale UASB Reactor

At first, wastewater was taken and cooled in the storage tank down to room temperature. Then it was adjusted the desired pH 6.7±0.1 with commercial grade of sodium hydroxide. The volume percent of starter was varied from 9% of total wastewater to 13% of total wastewater with an interval of 2. The prepared starter and wastewater mixture (14 L) was fed into the reactor, circulated with a submersible pump at the temperature range 22-34 ºC and desired pH. Wastewater was fed continuously with a flow rate of 0.9 L/h and hydraulic retention time was 15.6 h. To know the removal efficiency of COD samples were collected at the time interval 1 h.

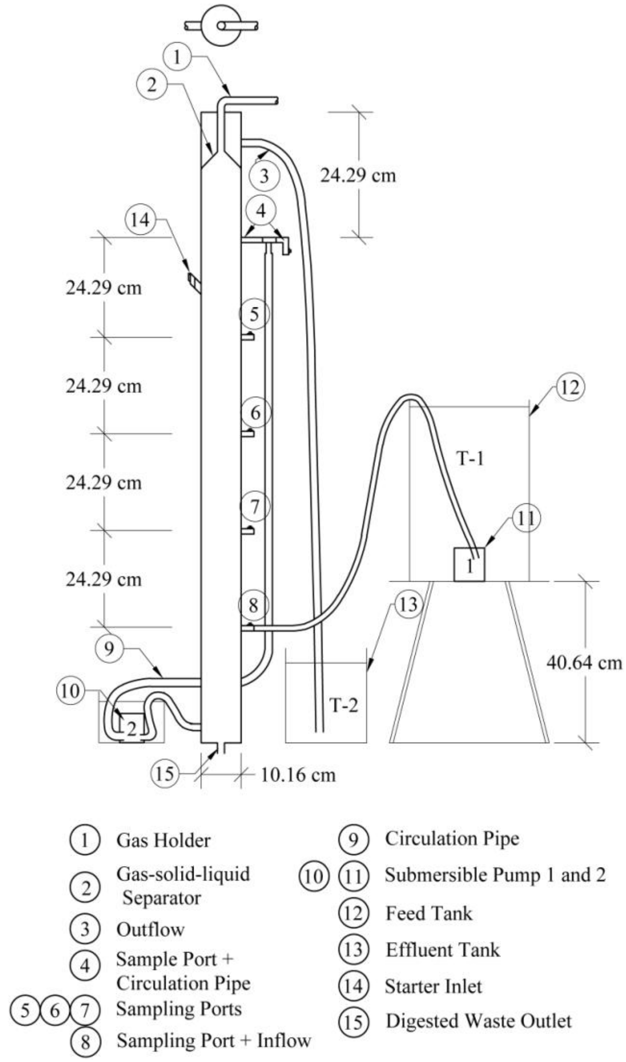

Fig.2. A laboratory scale UASB reactor.

III. RESULT AND DISCUSSION

A. Characteristics of Distillery Wastewater

TABLE I: Composition of Distillery Wastewater

Composition	MWDC (broken rice feedstock)
pH	3.2-3.8
Total solids (mg/L)	19480-28666
Total suspended solids (mg/L)	6660-10000
COD (mg/L)	31725-48972
BOD_5 (mg/L)	16500-28450

The raw distillery wastewater from MWDC distillery plant taken day by day to reach 10 days was characterized. The composition of distillery wastewater is shown in Table 1. The display equation of correlation for broken rice feedstock was BOD (30ºC, 5 day) = 0.552 COD + 1175.5.

B. Effect of Starter and Wastewater

The effect of starter and distillery wastewater on the 14 L of laboratory scale UASB reactor was investigated at the feed flow rate (9 L/h), the temperature range 22-34 ºC and pH 6.7±0.1.

Volume Ratio of Starter to Wastewater (9 :100)

Figs.3 and 4 show effluent COD and BOD concentration and removal efficiency of COD on the volume ratio of starter to total distillery wastewater (9: 100) at the feed flow rate (9 L/h), the temperature range 22-34 ºC and

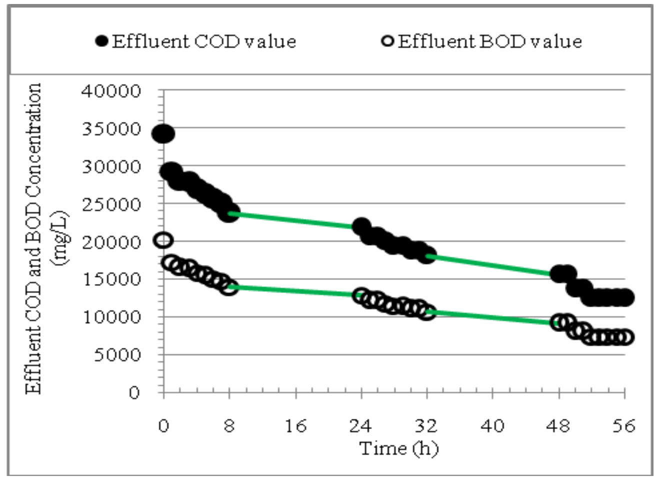

Fig.3. Effluent COD and BOD concentration for the volume ration of starter to total wastewater (9 : 100) at the temperature range 22-34 ºC and pH 6.7±0.1. The solid symbols and hollow symbols are COD value and BOD value. The solid lines are data un-collection time.

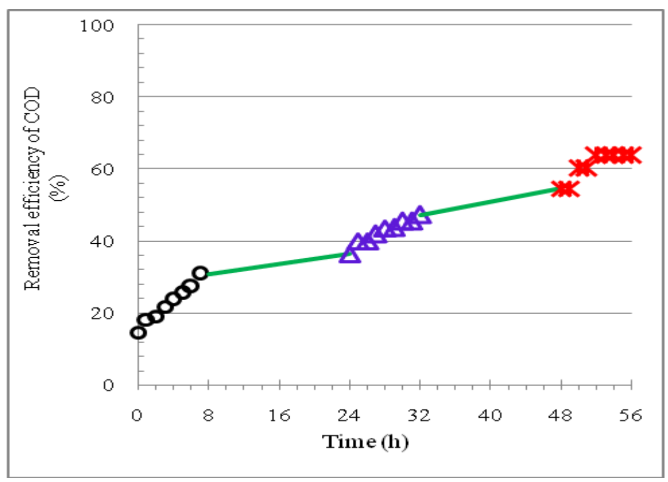

Fig.4. Removal efficiency of COD for the volume ratio of starter to total wastewater (9: 100) at the temperature range 22-34 ºC and pH 6.7±0.1.The symbols are removal efficiency of COD. The solid lines are data un-collection time.

pH 6.7±0.1. It could be observed from the figures that COD of waste is higher than BOD. Because the chemically oxidization of more compounds in distillery waste can be higher than biologically oxidization. The COD value decreases from 34320 mg/L to 23712 mg/L at 8 h data collection time for first day. The BOD value also decreases 29 % removal efficiency of the initial BOD value. Although the data collection to analyse the COD did not make in the rest time at the first day and the second day, the reactor was continuously running. At 1 day and 8h the removal efficiency of COD is 47 % and the BOD value declines from 20120 mg/L to 11509 mg/L. The COD value decreases from 34320 mg/L to 12480 mg/L at 2 days and 4 h. The total removal efficiency of COD is 64%.

Volume Ratio of Starter to Wastewater (11 :100)

The effluent COD and BOD concentration and removal efficiency of COD on the volume ratio of starter to total distillery wastewater (11 : 100) at the feed flow rate (9L/hr), the temperature range 22-34 ºC and pH 6.7±0.1 are given in

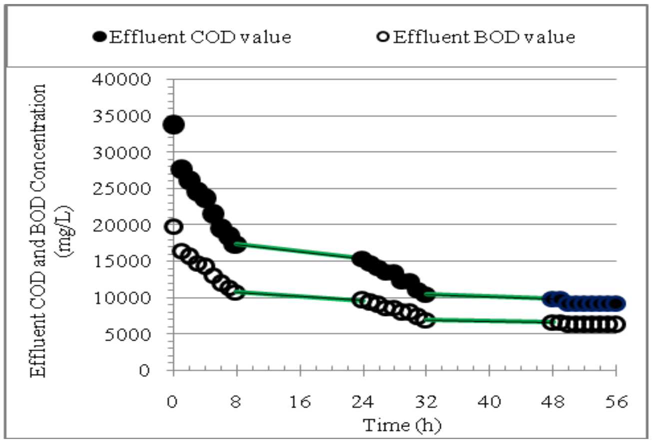

Fig.5. Effluent COD and BOD concentration for the volume ratio of starter to total wastewater (11 : 100) at the temperature range 22-34 ºC and pH 6.7±0.1. The solid symbols and hollow symbols are COD value and BOD value. The solid lines are data un-collection time.

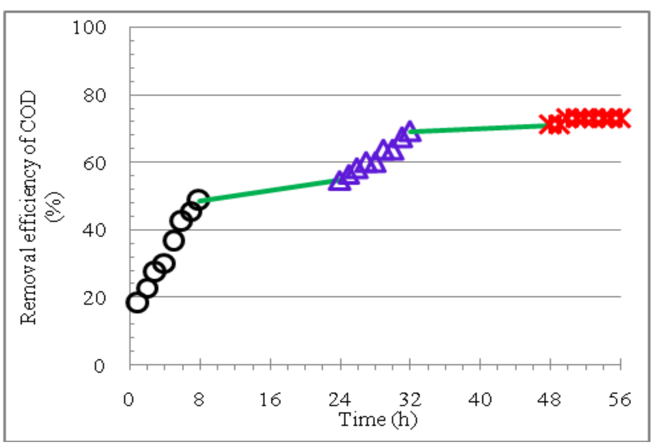

Fig.6. Removal efficiency of COD for the volume ratio of starter to total wastewater (11 : 100) at the temperature range 22-34 ºC and pH 6.7±0.1.The symbols are removal efficiency of COD. The solid lines are data un-collection time.

Figs. 5 and 6. It can be seen in Figures 4 and 5 that the COD value decreases from 33720 mg/L to 17319 mg/L and the BOD value also decreases 29 % removal efficiency of the initial BOD value at 8 h data collection time for first day. The removal efficiency of COD dramatically increases to 67 % within 1 day and 8 h and then slightly rises to 73 % for the working time 2 days and 2 h.

Volume Ratio of Starter to Wastewater (13 :100)

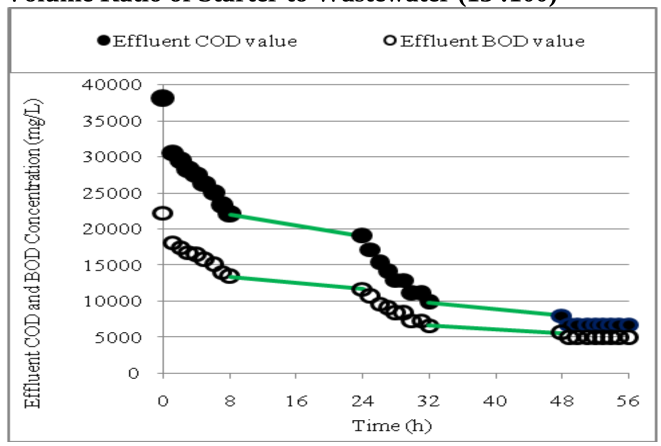

Fig.7. Effluent COD and BOD concentration for the volume ratio of starter to total wastewater (13 : 100) at the temperature range 22-34 ºC and pH 6.7±0.1. The solid symbols and hollow symbols are COD.value and BOD value. The solid lines are data un-collection time.

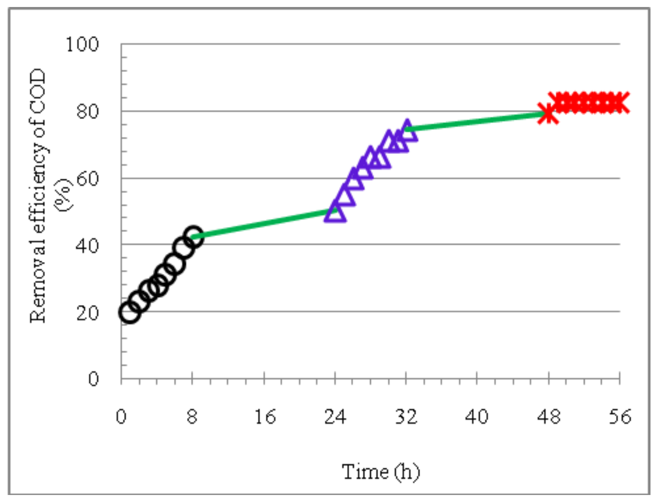

Fig.8. Removal efficiency of COD for the volume ratio of starter to total wastewater (13 : 100) at the temperature range 22-34 ºC and pH 6.7±0.1.The symbols are removal efficiency of COD. The solid lines are data un-collection time.

Figs.7 and 8 show effluent COD and BOD concentration and removal efficiency of COD on the volume ratio of starter to total distillery wastewater (13 : 100) at the feed flow rate (9 L/h), the temperature range 22-34 ºC and pH 6.7±0.1. From Figures 6 and 7, it can be observed that the COD concentration declines from 38088 mg/L to 6732 mg/L at 2 days and 2 h. The BOD value also decreases from 22200 mg/L to 4892 mg/L. Thus the removal efficiency of COD is 82 %. The removal efficiency of COD at 8 h data collection time for first day and second day are 42 % and 48 %. The removal efficiency of COD at 16 h data un-collection time for first day and second day are 14 % and 19 %.

C. Discussion on Laboratory Scaleup UASB Reactor

Table II shows the performance of laboratory scale UASB reactor obtained from literatures and experimental research work (ERW). The COD removal efficiency of experimental research work was 82% for the volume ratio of starter to wastewater (13:100). According to the result of the removal efficiency, the design of laboratory scale UASB rector is feasible to treat the distillery wastewater. In this work, the design of the reactor was based on diameter and the ratio of diameter to height is 1:14. But it should be checked this ratio for construction of pilot scale. In setting up the reactor, the influent should be lower than the point at 24.29 cm. And then the peristaltic pump should be used instead of submersible pump for the injection of wastewater.

TABLE II: Comparison with Literature and Experimental Research Work for Laboratory Scale

Waste type	Distillery Waste water	Distillery Waste water	Distillery Waste water	Distillery Waste water
HRT (H)	8	40	96	15.6
OLR (kg COD/m^3/day)	7	2.34	2.38	54
Temp: (°C)	20-34	25-29	28±1	22-34
COD removal efficiency (%)	72	78	96	82
Working volume (L)	10.5	2.36	8	14
Remark	Ref [5]	Ref [6]	Ref [7]	ERW

IV. CONCLUSION

The removal efficiencies of COD were 64%, 73% and 82% after 2 day and 2 h (56 h) at the ratio of 9, 11, 13 : 100. These removal efficiencies were obtained from the day time collection data (8 h). The removal efficiency of COD at 16 h data un-collection time was lower than at 8h data collection time because of lowering the temperature (14±2ºC) at night. Therefore, it can be observed that the reaction is mainly depended on reaction temperature. For this experiment, it can be said that anaerobic process was performed in this reactor because of the physical appearance of the effluent wastewater, pale black colour and viscous and the evolved biogas. According to the result of the removal efficiency 82% for volume ratio of starter to wastewater 13:100, it could be concluded that the design of laboratory scale UASB rector is feasible to treat the distillery wastewater.

V. ACKNOWLEDGMENT

The authors greatly acknowledge to the Mandalay Winery and Distillery Company for the supply with raw samples as well as the measurement facilities.

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