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Treatment of Brewery Waste Water in a Fluidized Bed Digester

Okonkwo P.C [1*] Okoli C.S [2]
1. Department of Chemical Engineering, Ahmadu Bello University , Zaria. Nigeria.
2. Department of Chemical Engineering, University of Uyo, Nigeria
* Email of corresponding author:chemstprom@yahoo.com

Abstract
This study examined anaerobic fluidized- bed reactor performance employed to treat brewery waste water in terms of treatment efficiency on COD and BOD_5 reduction under different hydraulic retention time (HRT). It employed a fluidized-bed digester, with liquid volumetric flow rate of 1.7 x $10^{-6}m^3/s$, superficial velocity of 0.0012 m/s and 0.00026m/s which achieved the velocity required to fluidize 20g activated carbon bed of height 0.03m with 0.384 voidage. The pressure drop across the fluidized-bed was calculated to be 1.848 N/m^2. The COD and BOD_5 concentration reduction efficiencies were monitored .The results obtained indicate that as HRT increases, the concentration of COD and BOD_5 initially at 7137.67 COD mg/l and 2177 BOD_5 mg/l decreased to final concentration of 1845.92 mg COD/l and 154.17 mg BOD_5/l respectively at10h. The COD and BOD_5 reduction efficiencies were observed to be 74.1% and 92.9% at the 10h HRT. The experimental data obtained for COD reduction in this work was used for determination of kinetic parameters from modified mixed-flow equation based on Michaelis-Menten's kinetics and the correlation coefficient was 0.944 .The maximum substrate utilization rate, r_{max} and the Michaelis-Menten's constant, K_M, were determined to be 301.5 mg COD/l. h and 1345 mg COD/l respectively. Correction factor (F) of 1.1 when applied to the data will fitted simple mixed flow Michaelis Menten kinetic model well. The deviation from typical Michaelis Menten kinetic model can be attributed to acclimatization time required for effective digestion, flow dynamics in the reactor and existence of multi-organism media which would have promoted other side reactions. Organisms identified from the anaerobic digester include *clostridium spp, peptococcus anaerobus, bfidobacteriums spp, desulphoribrio spp, corynebacterium spp, lacto.*
Keywords: Anaerobic decomposition; Brewery wastewater; Fluidized-bed reactor; Modified Michaelis-Menten's kinetics.

1.0 Introduction

Water is the largest raw material used in brewing processes . In a typical brewing process, it requires an estimate of 1113 liters of raw water to produce just 159 liters of beer. Generally, about 65% of the total water used in the brewery process ends up as wastewater while a small portion of the water is boiled off during the fermentation vessel boil or captured in the spent grain(Ockert et al 2001) . Brewery wastewater is produced through several brewery processes including fermentation , vessel and keg washes ,bottling ,as well as other wash- water used in the brewery.

Sona System Associates Business Management Limited (SSABM) is a large scale brewery industry located at Kudenda Industrial Area, Kaduna State, Nigeria. It utilizes water, malted barley, sorghum, brewer yeast and hops for its daily production of beer, thereby generating wastewater characterized with high COD and BOD_5 at the average concentration of 7137.67 mg COD/l and 2177.85 mg BOD_5/l respectively as in October 2009. Researchers observed that wastewater from brewery industries is of serious concern from pollution point of view. Of concern, brewery effluents are generally characterized by high biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), suspended solid (SS) and large variation in flow. Organic components in brewery effluent are generally easily biodegradable as these mainly consist of sugars, soluble starch, ethanol, volatile fatty acids etc. This is illustrated by the relatively high BOD/COD ratio of 0.6- 0.7(Driessen and Vereijken 2003). The world's supply of freshwater is limited and threatened by pollution from various human activities and the rising demands of water to supply agriculture, industry and cities are leading to competition over the allocation of the limited freshwater resources(Nyilimbabazi et al 2011). This then has placed much emphasis on the need to treat the brewery effluent waste water which is the focus of this study.

Complex group of organic solid (carbohydrate, protein, fat) containing C, N, O, H, P, are commonly found present in the typical brewery wastewater. Direct discharge of such wastewater to the water body without reducing its organic content to the minimum acceptable level causes death of aquatic lives, pollute the river in question thereby making it unacceptable to be used by the general public. A wide variety of industrial wastewater, brewery wastewater (Cronin and Lo 1998), and piggery wastewater Sanchez et al , pulp and paper mill effluents (Sanchez et al) were suggested to have been treated using up-flow anaerobic sludge blanket (UASB) but long period of time is needed to develop good bacterial floc for successful operation of UASB reactor system before the treatment begins(Basandorj 2007). Open pit treatment system which is currently being employed at SSABM is characterized by high sludge generation with its attendant disposal problems. Slaughter

house wastewater(Sreekirshnan et al 1991) and corn starch wastewater (Borja et al 1995) have been treated using Fluidized-bed reactor system. However, not many studies have been done on anaerobic fluidized-bed reactor system as alternative/remedy to the short comings of UASB and open pit system.

High rate anaerobic fluidized-bed treatment systems which is illustrated in Figure 1 can be used to treat varieties of industrial wastewater since it produces less sludge; has lower energy requirements and produces methane which may be burnt as an additional energy source(McCornick et al 2004). In this study, anaerobic fluidized-bed reactor treatment was chosen to treat the brewery effluent wastewater. Anaerobic fluidized-bed reactors are currently utilized to achieve several biological wastewater treatment goals.

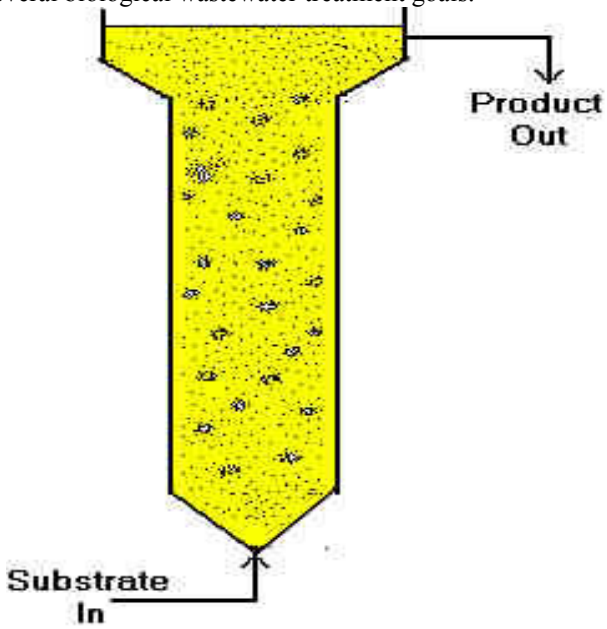

Figure 1 Scheme of Fluidized Bed Reactor

The presence of biomass concentrations upon a support material (activated carbon of size range of 75-300 µm) allows for faster reduction of BOD per unit volume than many other types of biological treatment. The activated carbon material was used because of its ability to be readily attached to by methanogenic bacteria(Parthiban 2007) . Hence, anaerobic fluidized-bed systems have been demonstrated in a number of studies to be cost-effective for liquid wastewater treatment, i.e dairy wastewater (Ozturk et al 1989), slaughter house wastewater (Borja et al 1995), and pulp and paper mill effluents (Sreekrichnan et al 2000) , for biomass conversion and for biochemical recovery and production(Fang et al 1990). This system enables high biomass hold-up to be attained for good system efficiency and stability with low hydraulic-retention time for good system economy. Unlike the conventional biofilm system in which the growth support media are fixed in space either by gravity or by direct attachment to the reactor wall, the anaerobic fluidized bed system retains the growth support media in suspension by drag forces exerted by the up flowing wastewater. The distribution of the retaining biomass is relatively uniform because of the completely mixed conditions maintained and the continuous biofilm sloughing process which counter-balances the accumulation of biomass due to growth, therefore, anaerobic fluidized-bed system can be considered as completely-mixed flow microbial system(Kalyuzhnyi et al 1997).

When a fluid is passed down ward through a bed of solids, no relative movement between the particles takes place, unless the initial orientation of the particle is unstable, and where the flow is streamline, the pressure drop across the bed is directly proportional to the rate of flow, although at higher rates, the pressure drop rises more rapidly.

When a fluid is passed upwards through a bed, the pressure drop is the same as that for downward flow at relatively low rates. When, however, the frictional drag on the particles becomes equal to their apparent weight, that is the actual weight less the buoyancy force, the particles become rearranged thus offering less resistance to the flow of fluid and the bed start to expand with corresponding increase in voidage. This process continues with increase in velocity until the bed has assumed its loosest stable form of packing. If the velocity is then increased further, the individual particles separate from one another and become freely supported in the fluid. At this stage, the bed is described as fluidized. Further increase in velocity causes the particles to separate still further from one another although the pressure difference remains approximately equal to the weight per unit area of the bed.

In practice, the transition from the fixed to the fluidized bed condition is not uniform mainly due to irregularities in the packing and, over a range of velocities, fixed and fluidized bed regions may co-exist. With liquid, the bed

continue to expand as the velocity is increased and it maintains its uniform character, with the degree of agitation of the particles increasing progressively. This type of fluidization is called particulate fluidization.
The degradation of the waste water in the biodigester is described by the following equations;
Net change =Input – output – utilization

$$(\frac{ds}{dt})_{net} V = QS_0 - QS - UXV \quad (1)$$

At steady state $(\frac{ds}{dt})_{net} V = 0$

Hence, $U = \frac{Q(So - S)}{VX}$ (2)

But V/Q = τ [hydraulic retention time (hours)]

$U = 1/\tau \ \frac{(So - S)}{X}$ (3)

Where U = specific substrate utilization (mg COD/cfu. hr)
V = Reactor volume (l)
So = initial concentration of the feed (mg/l)
S = final concentration of the feed (mg/l)
X = microbial concentration in the reactor (cfu/l)
Q=volumetric flow rate (l/h)

The organic loading rate is defined as the amount of BOD or COD applied to the reactor volume per hour. It can be mathematically represented as

$$L_{org} = \frac{QSo}{V} \quad (4)$$

L_{org} = volumetric organic loading mg BOD /lh
Q = Influent waste water flow rate l/h
S_o = Influent BOD conc, mg/l
V = Volume of the reactor (l)

The specific methane production rate (Ug) can be defined as the ratio of the product of volume of the methane produced and density of methane to the product of biomass hold-up in the reactor and the reactor volume [5].

Therefore, $Ug = \frac{Vg}{XV} \ \rho_g$ (5)

Where Vg = Volume of biogas rich in methane (L)
ρ_g = Density of methane (mg/L)
X = microbial concentration in the reactor (cfu/l)
V = Reactor volume (L)

The digestion process follow the following scheme which is also illustrated in Figure 2;

Complex Organics → Simpler Organics → Organic Acid → Methane and CO_2 (6)

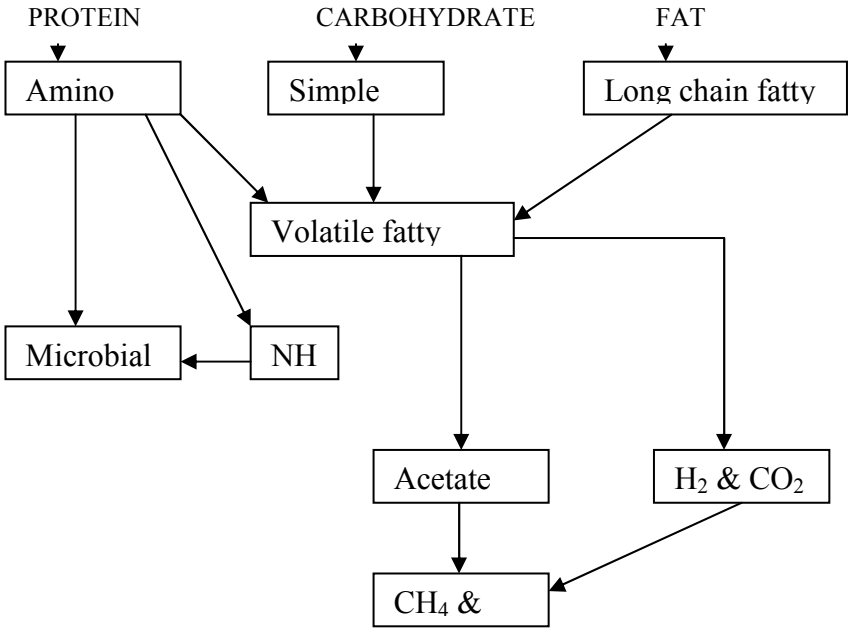

Figure 2: Process Routes For Anaerobic Microbial Degradation of Organic Matter

2.0 Materials and Methods

2.1 Instrumentation and Equipment

The anaerobic fluidized-bed reactor consists of frustum - like shaped glass material column with a total working volume of 2litres. The reactor column has total height of 1.45m with a progressive increase in internal diameter from 42 mm at the bottom to 60 mm at the top. The effluent recycle port was located at 550 mm from the top with the diameter of 22 mm. Below the effluent recycle port, is a solid trapper made of fine diffusible filter cloth located inside the reactor, about 290 mm from the bottom of the reactor. This enclosure prevents excessive washout of solids and it maintains good bacterial floccs and conducive environment for better degradation of organic matter in the reactor. Twenty gram activated carbon of size range (75-300) µm were used to serve as support material for microbial concentration in the reactor. About 12 l capacity laboratory tanks were used as effluent collection tank and feed tank respectively. The feed tank was mounted on hot iron plate which is thermostatically controlled to maintain the range of temperature (34^0C-38^OC) which was needed for the work (mesophilic temperature). The upper section of the reactor contains a conical-shaped gas-liquid separator to allow the biogas produced to vent-off into a carbon (iv) oxide absorption unit. The carbon dioxide is absorbed by bubbling the gas through a 2M solution of calcium hydroxide solution placed a 500ml flat bottom flask The biogas rich in methane gas passed through water into an inverted graduated cylinder, where it was collected and read visually through downward displacement of water. Sample ports were located along the reactor length through which reactor contents were collected for analysis .The reactor length was lagged to minimize loss in temperature of the content to the environment .The pump discharge was located very close to the reactor feed entrance point to minimize head loss.

2.2 Experimental procedure

The reactor shown in Figure 3 was initially filled with 20 g activated carbon (75-300 µm), and then the 168 h acclimatized seed sludge (100 ml) was added .The anaerobic seed used in this work was collected from lagoon process system treating brewery wastewater. Brewery wastewater obtained from Sona System Associates Business Management Limited (SSABM) located at Kudenda Industrial Area, Kaduna, Kaduna State, Nigeria, was charged raw into the feed tank. The study employed a fluidized-bed digester, with liquid volumetric flow rate of 1.7 x $10^{-6}m^3/s$, superficial velocity of 0.0012 m/s and 0.00026m/s of the minimum velocity required to fluidized 20g activated carbon bed of height 0.03m with 0.384 voidage in a recycling manner prior to continuous operation, to improve in homogenization of temperature, flow rate and the acclimatization of the cells in the digester, thereby enables the cell to get attached to the solid supports material. The pressure drop across the fluidized-bed was calculated to be 1.848 N/m^2.

The reactor length was lagged to prevent loss in temperature to the surrounding. The pH was adjusted to neutral point, and then the reactor was operated by pumping the feed from the feed tank continuously at volumetric flow of 6.28 l/h in all the experiment, the biogas produced was vented-off the reactor through the gas-liquid separator where carbon (iv) oxide was absorbed in a 2M solution of $Ca(OH)_2$ and the biogas rich in methane gas was collected over water in a well graduated measuring cylinder by downward displacement of water. IM sodium hydroxide solution was added periodically to maintain the pH range of 6.8 to 7.2 in the reactor. In each run, the same concentration of the feed was used at a particular hydraulic retention time (HRT). This continued for different HRT at the same initial feed concentrations and feed flow rate. The samples analysis were taken periodically and Lagrange interpolation technique was applied to the experimental data to bridge the gap between the period of system shut-down and the continuous process. All the chemical analyses of the parameters (chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), suspended solids (SS), dissolved solids (DS), total solids (TS), alkalinity, volatile fatty acid, nitrate, phosphorous and oil & grease) were done according to the standard Methods (APHA, AWWA, WPCF 2005).

Figure 3 Experimental Fluidized Biodigester Rig

2.2 Determination of Bacterial count

The total count was performed using plate-count method.Three serial dilution of 1ml of sample water with 9ml of brine to make 10ml in each case was prepared. From the third diluted sample,0.1ml was pippetted into freshly prepared nutrient agar medium in a Petri dish, with the help of wire loop, which is sterilized in Bunsen flame and cooled in between streaks, the primary inoculums was spreaded out at an angle of 120^0-130^0 over 4-5 segments in a petri-dish. The innoculated plates were incubated for 24 h with the base of the plate faced upward at 37^0 in an incubator (Gallenhamp,GA-216). After 24 hours, the number of colonies grown in the agar plate was counted, and the colony forming unit were calculated from Colony forming unit per mil

$$\left({}^{cfu}/_{ml}\right) = \frac{Number\ of\ colonies\ x\ dilution\ factor}{volume\ of\ the\ inoculum} \quad (7)$$

Note: Volume of the inoculum used = 0.1ml

Dilution factor = 10^3

The count was done for the sample from the reactor (X) and that of the reactor effluent (Xe)
Initial number of the bacteria seed inoculated = 0.94 x 10^9 cfu/l

2.4 Determination of volatile fatty acid

Volatile fatty acid was determined using distillation method.Two hundred ml water sample was centrifuged for 5 min at 3000 rpm.Hundred ml of the resulting supernatant liquor was measured into 500 ml distillation flask.Hundred ml distilled water was added together with three clay chips (anti-bump material). Finally, 5 ml concentrated tetraoxosulphate (vi) acid was added and the whole mixture was stirred thoroughly such that acid did not settle at the bottom of the flask. The flask was connected to distillation assembly and was distilled at the rate of about 5 ml per min. The first 15 ml of the distillate was discarded and exactly 150 ml of the distillate was collected and titrated with 0.1N Sodium hydroxide using phenolphthalein indicator.

The volatile fatty acid is given by: $VFA(mg/l) = \frac{ml(NaOH) \times N \times 60000}{ml(Sample) \times f}$ (8)

Where N= Normality of Sodium hydroxide

f = Recovery factor

3.0 Results and Discussions

The raw waste water from SSABM, located at Kudenda industrial area, Kaduna State, Nigeria was analyzed as per Standard Methods and the composition of this wastewater is in table 1 . During the continuous treatment process, the effluent waste water was collected and analysed according to standard method. The composition of the reactor effluent and some parameters of the reactor are as in Table 2.

Table 1: Summary Of Characteristics Results Of Raw Sample

PARAMETER	VALUE
Chemical oxygen demand(COD) (mg/l)	7137.67
Biological oxygen demand(BOD_5) (mg/l)	2177.85
Total solid (TS) (mg/l)	4075.33
Total dissolved solid (TDS)(mg/l)	2969.33
Total suspended solid (TSS) (mg/l)	1106
Phosphorous (mg/l)	51.13
Nitrate (mg/l)	58.8
Ph	5.17
Oil &Grease (mg/l)	0.00008

Table 2: Summary of Effluent Parameter Values

HRT(τ) (h)	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
COD (S) (mg/l)	6437.38	5939.21	5441.04	4375.14	3309.23	2907.20	2505.16	2175.54	1845.92
BOD_5(mg/l)	1349.99	1127.00	905.00	640.84	376.67	279.73	182.78	168.48	154.17
X_e (Cfu/l)X10^9	1.89	1.29	0.69	1.38	2.06	1.69	1.32	2.04	2.76
X (Cfu/l)X 10^9	2.05	2.13	2.20	2.24	2.28	2.36	2.44	2.54	2.32
E_{COD} (%)	9.8	16.8	23.8	38.7	53.6	59.3	64.9	69.5	74.1
$E_{BOD\ 5}$(%)	38.0	48.2	58.4	70.6	82.7	87.2	91.6	92.4	92.9
U(mg COD/Cfu.hr)x10^{-7}	1.71	1.88	1.93	2.47	2.86	2.56	2.37	2.14	2.88
1/S (l /mg)X10^{-4}	1.6	1.7	1.8	2.3	3.0	3.4	4.0	4.6	5.4
Sτ/S_0-S (mgCOD/l)	18.38	14.87	12.83	7.92	5.19	4.81	4.33	4.15	3.49
S/U (x 10^{10})	3.76	3.16	2.82	1.77	1.16	1.14	1.06	1.05	0.64
Ug(CH_4 /Cfu.h)x10^{-9}	0.00	2.71	5.10	5.46	5.80	6.05	6.27	4.82	4.84
N/K[$(Co/Cn)^{1/N}$ - 1]	0.1050	0.0810	0.0882	0.0996	0.1320	0.1296	0.1491	0.1410	0.1998

3.1. Effluent COD and BOD_5

The gradual change in effluent COD and BOD_5 during the anaerobic treatment of brewery wastewater in a fluidized bed reactor system is shown in Figure 4 as a function of hydraulic retention time (HRT).From Figure 4,

COD effluent concentration decreased drastically from initial concentration of 7137.67 mg/l up to final concentration of 1845.92 mg/l after 10 h of HRT. This progressive decrease of effluent COD was as a result of increase in rate of hydrolysis and acidogenesis reaction in the reactor. Hydrolysis involves breaking down of complex organic matter and its solubilization by extracellular enzymes produced by the anaerobic microbes in the reactor; hence, insoluble solids are made soluble and available for further transformation to products by other sets of anaerobic microbes. In all, after 10 h HRT, the values of COD and BOD_5 reduced to 1845.92 mg/l and 154.17 mg/l with the reduction efficiencies of 74.1% and 92.9 % respectively. High COD reduction efficiency obtained in this work was as a result of completely mixed condition achieved in the fluidized-bed reactor than any other reactor type. This condition creates high interaction between the hydrolytic bacteria and methanogenic bacteria with their various substrate, hence insoluble organic waste was made soluble and the product gases (biogas in form of methane and carbon (iv) oxide gas) were evacuated out of the reactor .

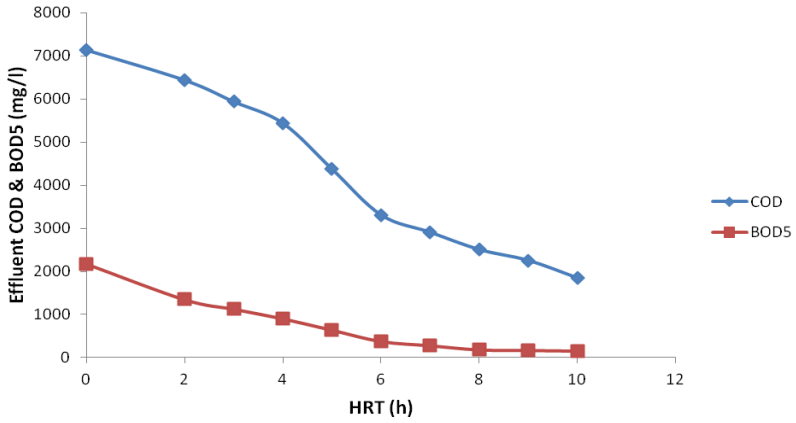

Figure 4: Effect of hydraulic retention time (HRT) on effluent chemical oxygen demand (COD) and Biological oxygen demand (BOD_5)

3.2. COD and BOD_5 Reduction Efficiency

The COD and BOD_5 percentage reduction efficiency within the time of operation (HRT) is shown in Figure 5, it was observed from the figure that the COD and BOD_5 percentage reduction increased within the time of operation, varying from 9.8 % and 38% to 74.1% and 92.9% respectively .Close examination of Table 2 reviews that reduction efficiency of the parameters (COD & BOD_5) increased progressively as HRT increased. The significant BOD_5 reduction efficiency was obtained at 9 h HRT, though the said reduction efficiency sluggishly increased with increased in HRT up to 92.9% at 10 h HRT. But the long HRT with insignificant increase in reduction efficiency can increase the treatment cost. But at the end of 10 h HRT, the highest reduction efficiency recorded in COD and BOD_5 were found to be 74.1% and 92.9% respectively. Observation of Table 2 still shows that in all the treatment periods, the BOD_5 reduction efficiency is higher than the corresponding COD reduction efficiency.

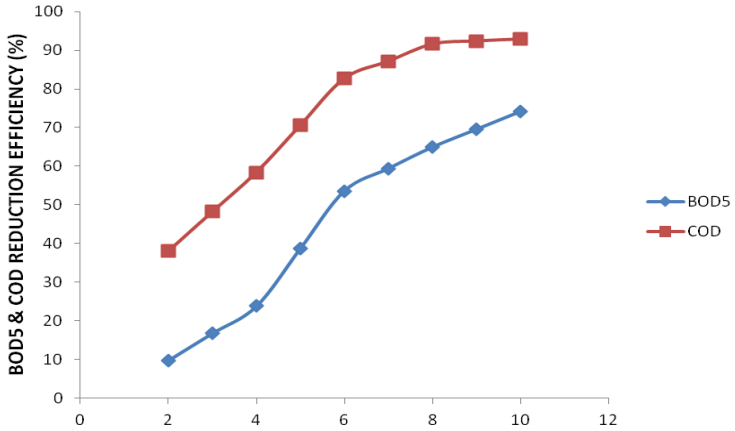

Figure 5: Effect of hydraulic retention time (HRT) on reduction efficiency of effluent chemical oxygen demand (COD) and Biological oxygen demand (BOD_5).

3.3 Kinetic Model

The kinetic models of simple Michaelis-Menten's model for mixed flow and Monod kinetic model were used to fit the data obtained from the reactor as shown in Figures 6, 7 and 8 in order to establish the kinetic model that

best describes the data. Examination of the experimental data from Table 2, reveals that the rate of substrate utilization (**U**) increases as the hydraulic retention time increases up to 6 h HRT. It then decreased with increase in HRT. The decrease in the initial rate may be as a result of high concentration of cells (Xe) which were washed-out of the reactor during this period as the treatment time increased . Table 3 summarizes the estimated values of r_{max}(mg/l.h) and K_M(mg/l) from the three different methods employed viz: Modified Michaelis-Menten equation approach , Modified Monod equation approach and Langmuir's equation approach. Examination of the behavior of the parameter values in table 3 shows that by considering the remaining data points above (see Table 2) for low substrate concentration, the parameter values changed significantly. However, in the case of M-M (Figure 6) and Monod (Figure 7), the differences in the individual values are high in terms of the r_{max} and K_m but very low value of r_{max}(mg/l.h) was obtained in the case of Langmuir's approach. In this treatment process, anaerobic microbes consumed the organic concentration of the wastewater in terms of COD, which was initially at 7137.67CODmg/l to produce products which by further conversion, produces biogas. Although both approaches show high correlation coefficient (see Figures 6,7 &8), but the value obtained by Monod in terms of Monod constant (K_{monod})(50000mg/l) is much higher than the initial concentration of the feed (7137.67CODmg/l) before the treatment commenced. Michaelis-Menten's approach in term mixed flow equation approach gave a the closest picture of microbe-substrate interaction in the fluidized-bed reactor system, meaning that the value of K_{M-M}(1345mg/l) predicted under here is still within the feed concentration limit, i.e. the initial to final stabilized concentration (7137.67mg/l to 1845.92mg/l).

Table 3: Summary of Estimated Kinetic Parameters

Method	$r_{max(mg/l.h)}$	$K_{M\ (mgCOD/L)}$	R^2
M-M equation approach(mixed flow)	301.5	1345mg/l	0.944
Monod equation approach	1.0	50,000	0.964
Langmuir	0.0000002	1400	0.958
Mixed-flow system in series	-	0.02	0.725

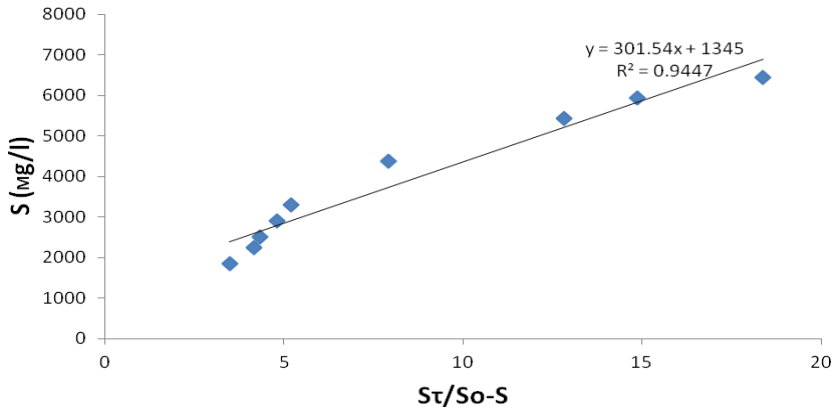

Figure 6: Modified Mixed-flow Equation Approach.

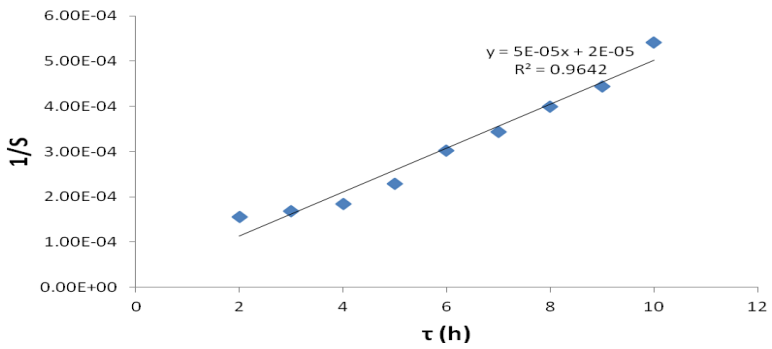

Figure 7: Modified Monod Equation Approach

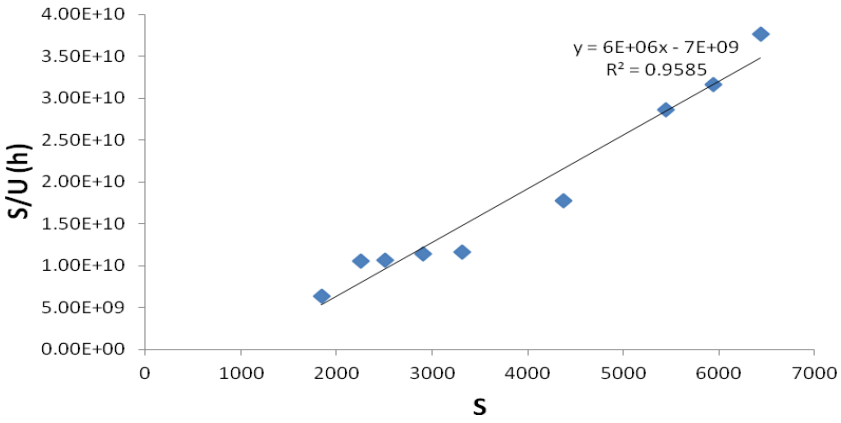

Figure 8: Langmuir's Equation Approach

The value of K_{M-M}(1400mg/l) obtained from by Langmuir approach is still within the feed concentration limit but the maximum reaction rate is very low (0.0000002). Finally, in all the approaches used to describe the inter-dependency between the cells and the substrate concentration in this reactor treatment, Michaelis-Menten's equation in term of mixed flow equation approach gave the best description of the degradation of organic substances in the fluidized-bed digester in terms of the kinetic parameters obtained, as seen in figure 3, with the value of the Michaelis-Menten constant (K_{M-M})(1345mg/l) and r_{max} of 301.5 mg/l.h. K_M value obtained in this work can be compared with the theoretical value reported by Metcalf &Eddy for completely mixed-suspended growth reactor treating soluble COD, in all the mesophilic conditions to be at the range of (200-1250) mg/l. The value of K_M obtained in this work may be an indication of successful breaking down of complex organic matter to the soluble form which the subsequent anaerobic cell transformed to products. The anaerobic cells required larger amount of substrate concentration to reach the maximum reaction rate.

4.0 Conclusion

This study has established the utility of fluidized bed digester system in the treatment of brewery effluent waste water. The fluidized bed digester system has the following advantages; low hydraulic retention time, high biomass hold up per unit volume ,cost effectiveness and more flexibility of control.

At the end of 10 h HRT, the maximum COD and BOD_5 treatment efficiency (reduction efficiency) were found to be 74.1% & 92.9% from the initial concentration of 7137.67COD mg/l and 2177.85 BOD_5 mg/l to final concentration of 1845.92 mg COD/l and 154.17 mg BOD_5/l respectively.

The results show that as the retention time increases, the rate of substrate utilization (U) increases up to 8 h HRT, but, COD and BOD decreased with retention time.

Michaelis-Menten's approach in term of mixed flow equation approach with correlation coefficient 0.944, gave the closest picture of microbe-substrate interaction in the fluidized-bed reactor system, meaning that the value of K_{M-M}(1345mg/l) predicted here for degradation of organic substance is still within the feed concentration limit, i.e. the initial to final stabilized concentration (7137.67mg/l to 1845.92mg/l). Finally, in all the approaches (Michaelis-Menten,Langmuir,Monod,Mixed-flow system in series,approach), used to describe the typical ideal mixed-flow system, only Michaelis-Menten's equation in term of mixed flow equation approach seems to be the approach that closely described the degradation of organic substances in the ideal mixed digester in terms of the kinetic parameters obtained, with the value of the Michaelis-Menten constant (K_{M-M})(1345mg/l) and r_{max} of 301.5 mg/l.h.

The deviation of 1.1 from the ideal Michaelis- Menten kinetics case is as a result of having a mixed population of bacterial which consume the substrate at different rates in the reactor ando acclimatization time required for effective digestion, flow dynamics in the reactor and existence of multi-organism media which would have promoted other side reactions.

This work has shown the potentials of fluidized bed digester in the treatment of brewery waste water. This work has provided the kinetic parameters that can be employed in the design, scale up and optimization of fluidized bed biodigester for treatment of brewery waste water.

References

APHA/AWWA/WEF,(2005) "Standard methods for eexamination of water and wastewater", *21st ed. American Public Health Association/American Water Works Assocation*, Washington DC..

Basandorj, D. (2007), Anaerobic treatment of brewery wastewater using UASB(up flow anaerobic slidge blanket) reactors seeded with activated sludge, *Strategic Technology IFOST Oct. 3 - 6*

Borja, R. Charles, B. and Zhengijian, W .(1995) Kinetic Evaluation of an Anaerobic Fluidzed-bed reactor treating slaughter house wastewater, *Bio recourse Tech*. 52 (1995) 163 – 167.

Cronin. C and Lo,K.V. (1998), Anaerobic Treatment of Brewery Wastewater
Using UASB Reactor Seeded with Activated sludge. *Bioresourecs Tech*. 64 (1998) 33-38, 1998.

Fang,H.P., Gouha,L., Jintu, Z., Quiting, J., Liang Kui, X & De, Z. (1990) Treatment of brewery effluent by UASB process. *Journal of Environ. Eng*., 16, 454-460, 1990.

Kaluzhnyi, S.V, Saucedo, J.V and Martinez, J.R, (1997), The anaerobic treatment of soft drink waste water in UASB and Hybrid reactors. *Applied Biochemistry and Biotechnology*, 66, 292 -301.

McCornnnick, P.G, Hijazi, A and Sheik ,B., (2004), " From wastewater reuse to water reclamation: Progression of water reuse Standards in Jordan" *Ministry of Water and Irrigation, Amman, Jordan, 42*

Metcalf Eddy Inc (2004), *Wastewater Engineering Treatment and Reuse* 4th ed. Mc. Graw Hill Publishing Company Ltd. 581-633, 1008-1018.

Nyilimbabazi, N., Banadda, N., Nhapi, I.,and Wali, U.G.,(2011), Characterization of Brewery Wastewater for Reuse in Kigali, Rwanda, *The Open Environmental Engineering Journal*,4,89-96

Ockert, Karl and Porter Fred .(2001), *Brewery Engineering and Plant Operation,* Green Press London. Chapter 4.

Ozturk, I., Anderson, G.K. and Saw, C.B. (1989) Anaerobic Fluidized-Bed Treatment of Brewery Waste and Bioenergy Recovery, *Water Sci.Technology*.21, 1681-1684.

Parthiban,R., P.V.R, Iyer and G. Sekara .(2007) ,Anaerobic Digestion in a tapered Fluidized Bed Reactor and Modelling using radial basis function neural network, *Biotechnology* 6 (4) 534 – 542.

Sanchez, E., Borja, B., Travieso, L., Martin, A. & Colmenarejo, M. (2005) ,Effect of organic loading rate on performance of a secondary upflow anaerobic sludge bed reactor treating piggery waste. *Bioresource. Technology*, 96, 335-334.

Saravanane, R., D. , Murthy,V. S ., and Krishaiah,K.,(2001), " Anaerobic Fluidized Bed Degradation and the Development of Kinetic Model for a Particulate Organic Matter Enriched Wastewater Sludge", *Environmental Engineering, Indian Institute of Technology (IIT) Madras Chennai*, 600 036, India.

Sreekirshnan, T. R., Ramachandran. K. B &Ghosh, P. (1991) Effect of operating variables on biofilm formation and performance of anaerobic fluidized bed reactor. *Biotech,& Bio Eng*, *37,* 435-443.

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