Bio-Kinetic Evaluation of Upflow Anaerobic Sludge Fixed Film Reactor by Using Sago Wastewater

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ABSTRACT: Bio-kinetic study of laboratory scale up-flow anaerobic sludge fixed film reactor (UASFF) was carried out for treating Sago Wastewater. The experiment was conducted for different COD loading and different flow rates. The COD reduction efficiency was observed for 52.5% to 92.06%. The models prescribed by First order kinetic and second order kinetic model were used to estimate the process kinetic parameters. Modelling of processes is helpful in making design decisions, and therefore the various modelling techniques applied to UASFF reactor have also been included. The variation between experimental and modelled data based on one term and two term exponential data were analysed.

Keywords: Anaerobic digestion, Bio kinetic coefficients, one term exponential, Sago wastewater, two term exponential, UASFF Reactor

INTRODUCTION

Many industrial facilities use freshwater to carry away waste from the plant and into rivers, lakes and oceans. The principal contaminants of water include toxic chemicals, nutrients, biodegradable organics, and bacterial & viral pathogens can affect human health when pollutants enter the body either via skin exposure or through the direct consumption of contaminated drinking water and contaminated food. We have so many methods for the treatment of industrial waste water. But the industries need cost effective waste water treatment methods affordable to them. Sago bark, sago wastewater and sago smith are the three wastes generated from sago industry. Appropriate method of reutilizing these waste to form a value added product found mandatory.

Anaerobic digestion is a biological process that can degrade organic material by the concerted action of a wide range of microorganisms in the absence of oxygen. However, the advantages of the anaerobic digestion process in the treatment of sewage are still far from being optimized. Regardless of the temperature conditions, only around 50% to 60% of the organic matter can be degraded, leaving a large potential of increasing the biogas production [1]. A better understanding of the basic mechanisms occurring in the digester, conducting the process at high temperatures, application of different kinds of pre-treatment methods (freezing/thawing; cavitation), phase separation, and, recently, bioaugmentation has been applied to improve the anaerobic digestion.

Mass balance model proposed and validated by Bernard et al. 2001 is one of the widely accepted models to simulate anaerobic digesters. Their model was devised from several variables such as concentration of biomass, total organic carbon (TOC), COD, VFA, and alkalinity. It was developed with the following assumptions: (i) α was introduced to consider the process heterogeneity. $\alpha = 1$ describes the dynamics of the classical CSTR where the biomass is completely suspended in the liquid phase. $0 < \alpha < 1$ describes the dynamics of fluidized-bed reactors or fixed-bed reactors (FBRs); (ii) it is considered that the alkalinity is mainly due to the concentration of bicarbonate and VFA; and (iii) it is assumed that the anaerobic digestion operates under isothermal condition. Other than being validated in their own experimental study, the Batstone DJ, et al., (2002) model was seen to be consistent with a wider range of experimental verifications too (Alcaraz-Gonzalez V et al (2005) , Dimitrova Nand Krastanov M (2011), Mendez-Acosta HOet al., 2007, Rincon A, Angulo F and Olivar G (2009), Rincon A, Erazo C and Angulo F (2012). Surveys of the literature show that a key area for the further research should be towards acquiring a better understanding of the degradation pathways where bioaugmentation is applied(Mehariya S et al., 2018, Raper E et al., 2018, Zhang Q et al., 2017). The purpose of the present work is to study the transformation of digestion process in an upflow anaerobic sludge bed fixed film reactor and to determine the kinetic parameters in terms of one and two term exponential data.

EXPERIMENTAL METHODOLOGY

An experimental study of an up-flow anaerobic sludge fixed film reactor was conducted and achieved a maximum COD removal efficiency of 92.06 % with an OLR of 1.4462 kg COD /m^3/day at a HRT of 4.00 days with a volume of 30.39 litres. The experimental study was operated with organic loading rate (OLR) of 0.8723, 1.4461, 2.0667, 2.5252, 2.7548, 1.125, 1.653, 2.249, 2.869, 3.237, 1.2626, 1.7905, 2.4797, 3.0417, 3.8568, 1.3315, 1.9971, 2.5715, 3.3287, 4.0633, 1.4462, 2.1004, 2.8470, 3.3861, 4.2011 kg m^3/day in the entire period of experimental work.The experimental work was started up and loaded to an organic loading rate (OLR) of 0.551 kg COD/m3/day and attained a steady state from 10 to 14 days (Nandhini et al.,2018) .

The entire process was operated with the HRT of 1.00, 1.50, 1.75, 2.00 and 4.00 days. The up-flow anaerobic sludge fixed film reactor model was run at five different flow rates 8.111,12.166,16.2225,20.2781,24.33371/day. The pH of the experiment was in mesophilic range from 6.0 to 8.0 (Sheela and Asha 2018). The performance of the up-flow anaerobic sludge fixed film reactor model was run with the operating parameters such as OLR at HRT with respect to the -monitoring parameters such as influent COD, effluent COD, pH V.S.S and V.F.A. the comprehensive results of the experiments were evaluated in terms of % COD removal efficiency. The % COD removal efficiency of sago wastewater in the UASFFR was attained from 52.50 to 75.51 without addition of co-substrate. The maximum % COD removal efficiency was attained 92.06 at a HRT of 4 days with addition of 3g/l glucose as co-substrate.

Mathematic Modelling:

The kinetics of biodegradation are a set of empirically derived rate laws. Three equations are shown below to describe most biological reactions:

dCA/dt = -k0 Zero order
dCB/dt = -klCA First order
dCB/dt = -k2CACB Second order
k0, k1, k2 = rate constants mol/L-sec, /sec, L/mol-sec, respectively
CA, CB = some reacting species

This can be applied to the reaction of the compounds with a surface such as a metal catalyst, a soil surface or an enzyme. Two extremes of concentration can be delineated; the first is when there are few molecules of reactant (CA) and many of the surfaces. In this case, few of the available sites will be covered, so the reaction rate dCA/dt is proportional to the concentration of a (first order reaction above). Secondly, when CA is so large that every site is saturated with A, the rate is constant (zero order reaction above).

The constant and coefficient values of one term exponential equation for influent COD concentration range of 500 mg/l -2400 mg/l is shown in table no.1 the One Time Expontial Equation shows the concurrence values with experimental COD at lower influent COD. However the Two Time Expontial Equation extend its validity for all range influent COD concentration `

Table: 1 constants and coefficient of OTEE and TTEE

One Term Exponential Equation					Two Term Exponential Equation Kinetics				
Set	**Effluent COD**	**A**	**b**	**R^2**	**A**	**B**	**C**	**D**	**R^2**
1	2400	2548	_0.01336	0.8643	2963	_0.0370	471.4	0.00674	0.9953
2	1480	1512	_0.008351	0.9118	1056	_0.04336	864.6	_0.001461	0.998
3	1150	1188	_0.006382	0.9536	1242	_0.01028	30.73	0.02115	0.992
4	1050	1162	_0.009077	0.9596	1227	_0.0118	5.17	0.0348	0.983
5	560	593.1	_0.007785	0.9738	382.7	_0.02243	269.1	_0.005072	0.9979

Table: 2 Comparison of experimental, one term exponential and two term exponential equation values of COD in effluent for influent COD of 2400mg/l

Time	**COD EXP**	**COD OTEE**	**% Error**	**COD TTEE**	**% Error**
hours	**mg/l**	**mg/l**		**mg/l**	
0	2400	2548	6.16	3434.4	43.08
12	1800	2170.567681	20.55	2338.052805	29.88
24	1400	1849.04398	32.07	1625.044105	16.07
36	1075	1575.147215	46.51	1158.636481	7.720
48	1050	1341.822464	27.71	851.0669083	_18.95
60	1000	1143.059841	14.3	645.9914067	_35.5
72	970	973.7396973	0.309	507.2236152	_47.73
84	970	829.5007524	_16.63	411.5107393	_57.62

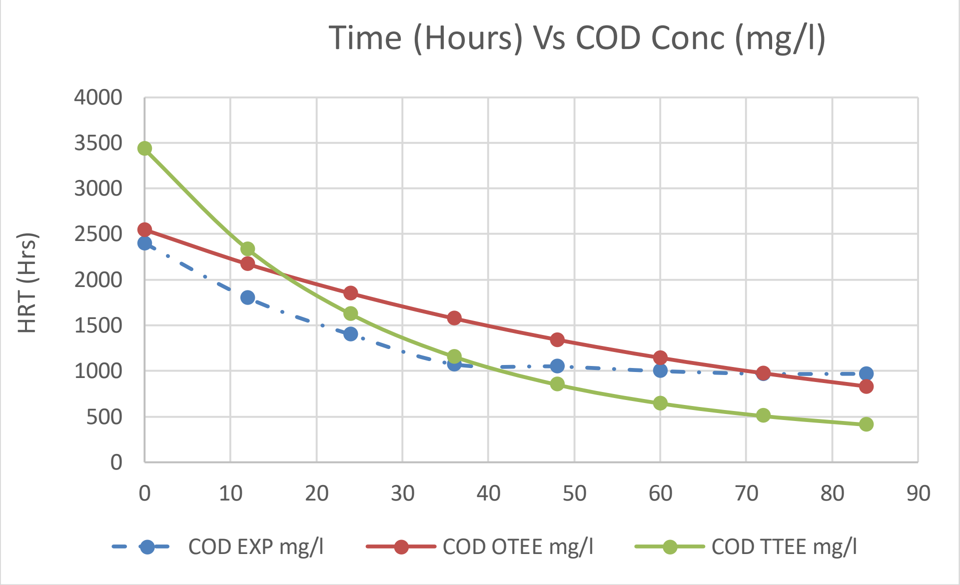

Figure: 1 Comparison of experimental, one term exponential and two term exponential equation for effluent COD values for influent COD concentration of 2400 mg/l.

Table: 3 Comparison of experimental, One term exponential and Two term exponential equation values of COD in effluent for influent COD of 1480 mg/l

Time	COD EXP	COD OTEE	% Error	COD TTEE	% Error
hours	mg/l	mg/l		mg/l	
0	1480	1512	2.162	1920.6	29.72
12	1200	1367.824167	13.916	1477.186767	23.083
24	1040	1237.396131	18.94	1207.818355	16.057
36	950	1119.404982	17.78	1041.991459	9.578
48	880	1012.664806	15.00	937.8020628	6.477
60	810	916.1027737	13.086	870.3436068	7.407
72	780	828.7483551	6.153	824.811666	5.641
84	780	749.7235636	_3.974	792.4058496	1.538

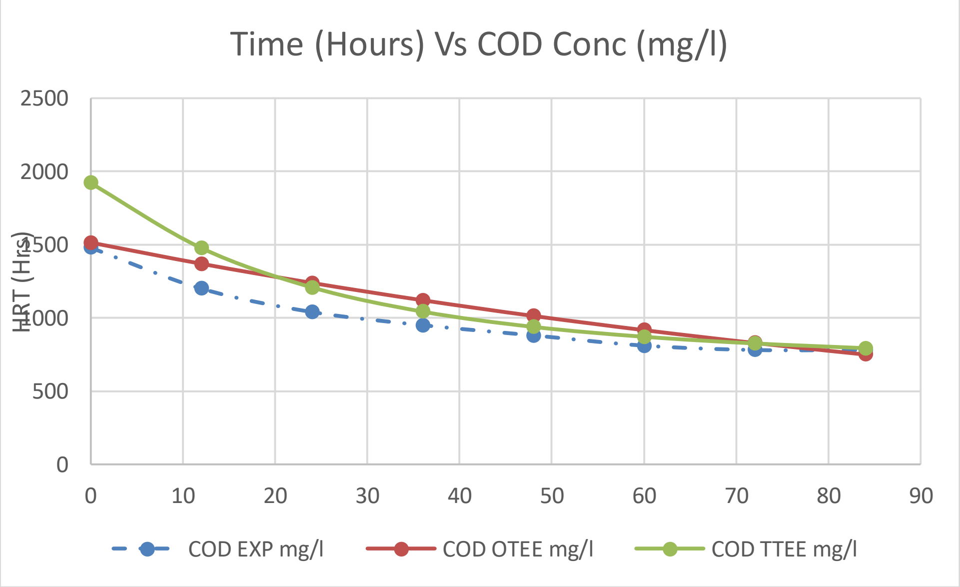

Figure: 2 Comparison of experimental, one term exponential and two term exponential equation for effluent COD values for influent COD concentration of 1480 mg/l.

Table: 4 Comparison of experimental, one term exponential and two term exponential equation values of COD in effluent for influent COD of 1150 mg/l

Time	COD EXP	COD OTEE	% Error	COD TTEE	% Error
hours	mg/l	mg/l		mg/l	
0	1150	1162	1.043	1272.78	10.608
12	990	1076.331671	8.080	1121.740737	13.23
24	940	996.9792302	5.957	988.9760959	5.106
36	850	923.47704	8.588	872.1980441	2.588
48	780	855.3937912	9.615	769.4215605	_1.410
60	730	792.3299728	8.493	678.921068	_7.123
72	700	733.9155279	4.714	599.1938074	_14.428
84	700	679.8076819	_3.714	528.928922	_24.57

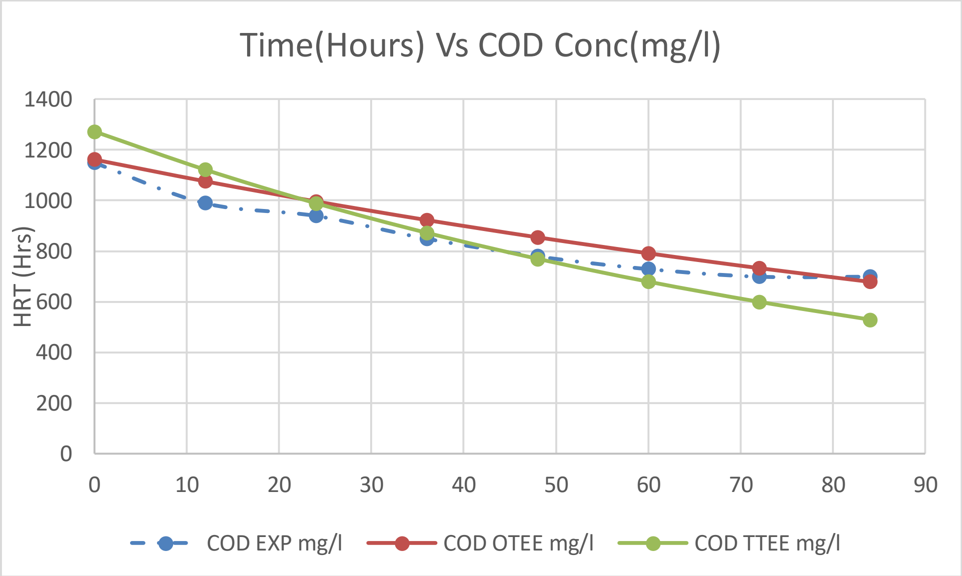

Figure: 3 Comparison of experimental, one term exponential and two term exponential equation for effluent COD values for influent COD concentration of 1150 mg/l.

Table: 5 Comparison of experimental, One term exponential and Two term exponential equation values of COD in effluent for influent COD of 1050 mg/l

Time	COD EXP	COD OTEE	% Error	COD TTEE	% Error
hours	mg/l	mg/l		mg/l	
0	1050	1162	10.67	1232.17	0.117
12	950	1042.07994	9.684	1072.846875	12.842
24	800	934.5358019	16.75	936.3021565	17.00
36	700	838.0903722	19.714	820.4316476	17.142
48	650	751.5982487	15.538	723.8771494	11.230
60	600	674.0322358	12.33	646.1706294	7.667
72	550	604.4711463	9.818	587.9851295	6.727
84	540	542.0888606	0.370	551.543513	2.037

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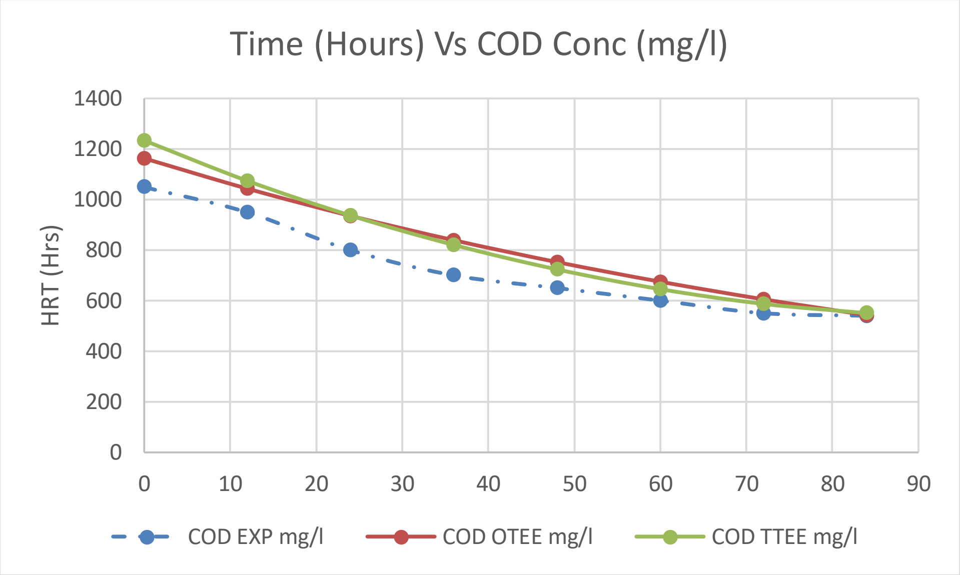

Figure: 4 Comparison of experimental, one term exponential and two term exponential equation for effluent COD values for influent COD concentration of 1050 mg/l.

Table: 6 Comparison of experimental, One term exponential and Two term exponential equation values of COD in effluent for influent COD of 560 mg/l

Time	COD EXP	COD OTEE	% Error	COD TTEE	% Error
hours	mg/l	mg/l		mg/l	
0	560	593.1	5.892	678.8	21.07
12	490	540.2019326	10.204	571.0064881	16.430
24	430	492.0217972	14.418	485.5564717	12.790
36	400	448.1388058	12.00	417.360023	4.25
48	360	408.1696998	13.33	362.5175443	0.55
60	330	371.7654032	12.424	318.0395112	_3.636
72	320	338.6079738	5.625	281.6323146	_12.187
84	300	308.4078264	2.667	251.5346024	_16.33

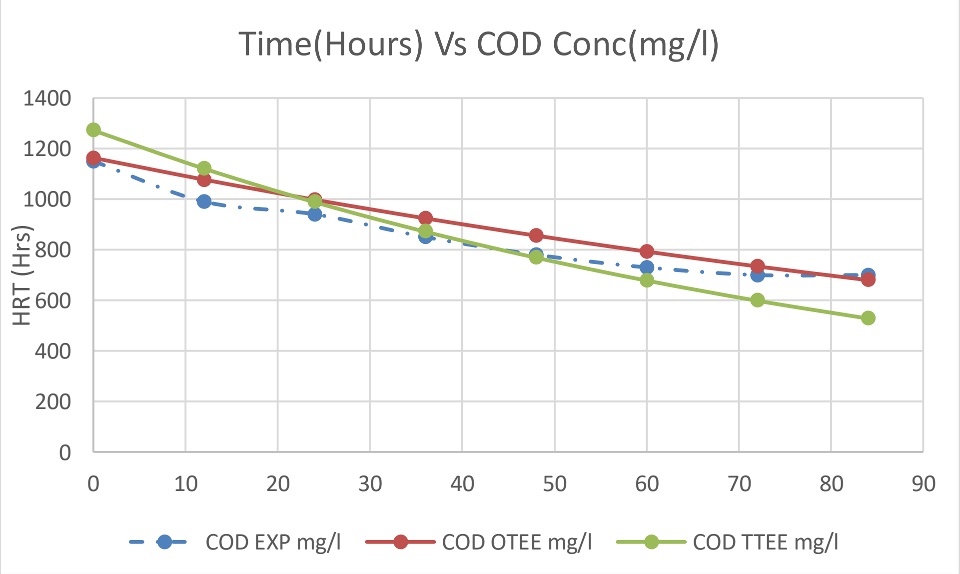

Figure: 5 Comparison of experimental, one term exponential and two term exponential equation for effluent COD values for influent COD concentration of 560 mg/l

Error analysis

Validation of any model to experimental data can be accomplished by estimating the error between model stimulated values with the matter as basis in most of the cases errors are represented in percentages. in the present work the absolute error percentage is computed using the following equation and the overall error is calculated by calculating the average of errors for all the data points.

Error percentage = 100* [exp-predicted/experimental]

Through the Two Term Expontial Equation model gives good representation of experimental values for the continuous levels, the applicability of this model may not be suitable on industrial design and control. The One Time Expontial Equation model is similar to first order kinetics with the 'a' values representing the initial COD levels. Through the R^2 values for this model for all the experimental values are relatively lesser than the One Term Expontial Equation model it is reasonable to state that the One Term Expontial Equation model is valid for all the cases. The 'a' values for all the cases is closer to the respective initial concentration.

CONCLUSION

Sago wastewater could be effectively treated using the UASFFR. By conducting experiments at the HRTs of 1.00, 1.50, 1.75, 2.00 and 4.00 days with a maximum COD removed efficiency of 92.06% was recorded. Kinetic constants for substrate removal were determined using first order kinetics and second order kinetic model Kinetic parameters were determined through linear regression using the experimental data. The One Time Expontial Equation model is similar to first order kinetics with the 'a' values representing the initial COD levels. Through the R^2 values for this model for all the experimental values are relatively lesser than the One Term Expontial Equation model it is reasonable to state that the One Term Expontial Equation model is valid for all the cases. The 'a' values for all the cases is closer to the respective initial concentration.

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