BIO-KINETICS OF ANAEROBIC TREATMENT OF SAGO AND DAIRY EFFLUENTS IN UPFLOW ANAEROBIC SLUDGE BLANKET REACTOR

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Abstract

This paper evaluated the bio-kinetics of anaerobic treatment of industrial wastewater in upflow anaerobic sludge blanket reactor (UASBR). The bio-kinetic coefficient was determined for sago and dairy effluents under nonlinear regression model using MATLAB software. This bio-kinetic model facilitated in monitoring the function of the digester over time, with the degradation of organic matter, biomass evolution, biogas composition and methane production. Further the proposed model was validated against the data reported in the published literature.

Introduction

Anaerobic treatment techniques are employed for process optimization, reaction kinetics and parameters of engineering design for treating biodegradable industrial waste streams (Orhan Yenigun et al 2005). One such technique is the Upflow Anaerobic Sludge Blanket Reactor (UASBR), which was developed in the late 1970s in the Netherlands (Lettinga and Vinken 1980, Lettinga et al., 1980). In UASBR the upflow movement of influent and the raising gas will keep the biomass in a very active and suspended state. The granular sludge blanket will immobilize the biomass in the reactor so as to envisage a long characteristic cell retention time, and this will enhance the stability and treatment efficiency of the process. Anaerobic treatment using UASBR of dairy effluent has been reported by several researchers (Ozturk et al 1993, Cordoba et al 1995, Gavala et al 1999, Nadais et al 2005, Luostarien and Rintala 2005, Abbasnezhad et al 2009, Nadeem et al 2011). While exploring the possibility of bioenergy from the sago enterprises, Bujang et al (2001) have reported that biogas of 20 tons for every day that is recuperated from the sago profluent can be utilized as extraordinary as compared to other interchange fills. While studying performance of anaerobic treatment on sago wastewater, Rangasamy Parthiban (2011) have recorded the average biogas yield of 25.4 m^3 /reactor/day and the maximum rate of generation of 198 l/d. Similar studies on anaerobic treatment of sago effluent are also available (Kwong and Fang 1996, Chairprasert et al 2003, Banu et al 2006, Priya et al 2007, Ubalua 2007).

The bio-kinetic study plays the vital role in biological treatment process design. The reaction kinetics of UASBR significantly favors its application for the treating the waste water of high COD or BOD. Different kinetic models are required to decide the bio kinetic coefficients, to arrive at the equation for effluent substrate concentration and for assessing the treatment proficiency of full scale reactors (Skiadas and Lyberatos 1999, Andreja Gorsek et al 2007). The present study evaluated the bio-kinetic coefficient for sago and dairy effluents under nonlinear regression model using MATLAB software.

Material and Methods

A laboratory model of UASB reactor with 25 litres effective volume to treat sago and dairy effluent was installed in the Department of Civil Engineering, at the Annamalai University, India. Influent flow rate and influent COD are the two major operating parameters and their dependent variables are Hydraulic Retention Time (HRT) and Organic Loading Rate (OLR). Observations were made on operating the model on continuous mode for the parameters such as influent chemical oxygen demand (COD), effluent COD, volatile suspended solids (VSS) in the sludge blanket and volume of gas collection. The experiment was conducted for COD, which varied from 1580.91 to 4578.48 mg/l for sago effluent and 1563.28 to 4571.15 mg/l for dairy effluent. The flow rates of the experiments are 4.80, 12.00, 14.40, 18.00 and 24.00 l/day which corresponded to HRT of 5.21, 2.08, 1.74, 1.39 and 1.04 days respectively. The experimental operating conditions and observations were correlated and interpretations such as volumetric loading rate, organic loading rate and biogas generation were made for studying the performance of the model.

Results and Discussion

Among several models, Heertjes and Van DerMeer model (1978) based on monod type kinetic model was attempted for the present laboratory UASBR model as it was assumed to be suitable to enumerate the kinetic parameters. The total organic loading rate is very important to evaluate the process performance as well as effluent substrate concentration. Since anaerobic microorganisms, especially methanogens are very sensitive to their environment; it is desirable to consider the amount of substrate per microorganism per unit period than the effluent concentration. The proposed equations of the model are given as

$$L_x = S_iQ/XaV = S_i / X_a\tau \qquad \text{Eq.(1)}$$

$$Se = S_i - kS_i / (k_L + Lx) \qquad \text{Eq.(2)}$$

Where,

L_x = Organic loading rate

S_i = Influent substrate concentration

S_e = Effluent substrate concentration

Q = Flow rate

τ = Hydraulic retention time

k = Maximum substrate utilization rate

k_L = Half saturation coefficient

Y = Yield coefficient

k_d = Sludge decay rate coefficient

This model was used to evaluate the kinetic parameters such as maximum substrate utilization rate ‘k’, half saturation coefficient ‘k_L’, yield coefficient ‘Y’ and sludge decay rate coefficient ‘k_d’. These parameters were evaluated for two different effluents with experimental values.

In the case of sago effluent, the maximum reduction of COD was found to be 79.95% at the volumetric loading rate of 0.7 kg COD / m^3 for a HRT of 5.21 days. The maximum gas yield was 0.32 m^3/kg COD removed for the volumetric loading rate of 0.87 kg COD / m^3.day.In the case of dairy effluent, the maximum reduction of COD was found to be 77.68% at the volumetric loading rate of 0.71 kg COD / m^3 for a HRT of 5.21 days. The maximum gas yield was 0.32 m^3/kg COD removed for the volumetric loading rate of 0.28 kg COD / m^3.day.

From the model, it was observed that the reactor could retain a high concentration of biomass (as high as 53730 mg/l as VSS) in the sludge blanket. Hence the model was found to run under very low organic loading rates for all combinations of flow rate and COD content.

The bio-kinetic parameters were evaluated independently for sago and dairy effluent streams with their experimental results. The bio-kinetic coefficients to quantify the dynamic state of biomass over the process of treatment in terms of k, k_L, Y and k_d are presented in the Table 1.

Table 1. Bio-Kinetic Parameters for Sago and Dairy Effluent

Waste Streams	**k**	**k_L**	**Y**	**k_d**
Sago	0.537	0.669	0.142	0.003
Dairy	0.575	0.736	0.135	0.003

Note:

k - Maximum Substrate Utilization Rate (kg COD removed/kg VSS/day)
k_L - Half Saturation Coefficient (kg COD/kg VSS/day)
Y - Yield Coefficient (per day)
k_d - Sludge Decay Rate Coefficient (kg VSS/kg COD)

The bio-kinetic parameters of the present study were validated with the study of Hwang et al., (1992) and the data given in the Table 2 are comparable.

Table 2. Validation of Bio-kinetic Parameters with Other Researcher

Sl.No	Bio-Kinetic Parameters	Hwang et al., (1992)	Present Study
1	K (kg COD removed/kg VSS/day)	$0.885 < k < 1.282$	$0.537 < k < 0.923$
2	k_L (kg COD/kg VSS/day)	$0.744 < k_L < 1.235$	$0.669 < k_L < 1.35$
3	K_d (per day)	$0.020 < k_d < 0.033$	$0.003 < k_d < 0.003$
4	Y (kg VSS/kg COD)	$0.144 < Y < 0.178$	$0.135 < Y < 0.142$

Conclusions

- The present study evaluated the bio-kinetics of anaerobic treatment of sago and dairy wastewaters in upflow anaerobic sludge blanket reactor (UASBR) and inferred the following: UASBR is the most suitable anaerobic treatment technique for COD removal up to 79.95% and 77.68% in sago and dairy effluents respectively.
- This suitability of UASBR is also significantly evident by bio-kinetic parameters.
- The bio-kinetic model facilitates to monitor the operation of the digester over the time, including, the degradation of organic matter, progress of biomass, biogas composition and methane generation.

- This bio-kinetics of the model facilitates to design a biogas unit and prevent a possible maintenance and digester feed.
- The proposed model is in good concordance with other model.

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