Open Access

© 2023, Centre for Advanced Research in Agricultural Sciences
Research Journal of Agricultural Sciences
Volume 14; Issue 05 (Sep-Oct 2023); pp 1322–1328

ISSN: 0976-1675 (P)
ISSN: 2249-4538 (E)

Full Length Research Article

Substrate Degradation Kinetics in Up-flow Anaerobic Sludge Blanket Reactor and Microbial Fuel Cell

Saner A. B.*[1] and Priyanand Agale[2]

[1] Department of Civil Engineering, Matoshri College of Engineering and Research Centre, Nashik - 422 105, Maharashtra, India
[2] Department of Civil Engineering, Government Polytechnic, Aurangabad - 431 005, Maharashtra, India

Abstract

Distillery waste water has potential to produce energy in the form of biogas which contains methane. Present study is based on the Kinetics of anaerobic treatment of distillery wastewater by UASBR followed by MFC. UASB was feed with varying organic loading rate of distillery wastewater ranging from 8.07g COD/L·d to 22.94g COD/L·d for a duration of approximately 500 days. Different mathematical models such as Monod, Grau's second order, modified Stover-Kincannon model and First order kinetic models were applied to determine the substrate removal kinetics of anaerobic UASB reactor and MFC. Linear regression was applied to determine Kinetic parameters through experimental data. The substrate removal rate constant (K_2) of Grau's second order was 1.95 per day By applying modified Stover-Kincannon model, the maximum removal rate constant (μ_{max}) was 5 g/ L·d and saturation value constant (K_B) was 19.61 g/ L·d respectively. By applying Monod model, at steady state condition, determine the kinetic coefficient (K) as 2.738 gCOD/L, the endogenous decay coefficient (K_d) as 0.0381 d-1, the maximum growth rate of microorganisms (μ_{max}) as 0.06279 per day and the growth yield coefficient(Y) was 0.272 g VSS/g COD respectively. The outcome of this study will help in simulation of anaerobic model to usable methane and good effluent quality during the treatment of industrial wastewater.

***Key words*:** Up-flow anaerobic sludge bed reactor, Distillery wastewater, Kinetic models, Organic loading rate

Water is one of the most valuable natural resources in the world. Unfortunately, it is being rapidly contaminated and urgent measures need to be taken for avoid its damage. In many countries, wastewater is released directly to lakes and rivers without treatment, and environmentally and economically feasible methods for wastewater treatment, are therefore, urgently needed. A large number of technologies have been developed to achieve pollutant removal from wastewater. Both aerobic and anaerobic wastewater treatment systems are currently in use. The anaerobic treatment of wastewater does not consume energy but can even produce energy through methane generation. The two major advantages of anaerobic wastewater treatment, which explain its progress at the expense of the classic aerobic treatment, are less sludge growth and considerable energy saving.

The Up-flow Anaerobic Sludge Blanket (UASB) reactor is considered to be one of the most successful anaerobic systems, capable of forming dense aggregates by auto immobilization and consequently allowing high-rate reactor performance [1]. Its primary use is in the treatment of high concentration industrial wastewaters, but it can also be used in the treatment of municipal wastewater which has lower contaminant strength (Leitão, 2004). Because of its simple design, easy construction and maintenance, low operating cost and ability to withstand fluctuations in pH, temperature and influent substrate concentration, it has gained in popularity.

MATERIALS AND METHODS

Substrate

Distillery spent wash collected from a distillery situated at Kopargaon, Maharashtra.

Up-flow anaerobic sludge bed reactor

The UASB process consists of an up-flow of wastewater through a dense sludge bed with high microbial activity. In the reactor, the solids profile varies from very dense and granular particles with good settle ability close to the bottom (sludge bed), to more dispersed and light sludge particles close to the top (sludge blanket).

The UASB reactor can be divided into four components: the sludge bed, the sludge blanket, the gas-solids-liquid separator (i.e., 3-phase separator) and the secondary settling compartment above the separator. The sludge bed is situated in

Received: 27 Mar 2023; Revised accepted: 05 Sep 2023; Published online: 21 Sep 2023

Correspondence to: Saner A. B., Department of Civil Engineering, Matoshri College of Engineering and Research Centre, Nashik - 422 105, Maharashtra, India; E-mail: dramolsaner@gmail.com

Citation: Saner AB, Agale P. 2023. Substrate degradation kinetics in up-flow anaerobic sludge blanket reactor and microbial fuel cell. *Res. Jr. Agril. Sci.* 14(5): 1322-1328.

the bottom of the reactor and consists of a dense sludge with exceptional settling characteristics; it is therefore kept in the reactor. Above the sludge bed is the sludge blanket, with solids presenting lower concentrations and settling velocities. The sludge blanket consists of sludge particles in a mixture with the biogas formed, and is thus held in suspension. It is in these two compartments, the sludge bed and the sludge blanket, that the incoming wastewater is biologically degraded.

Table 1 Data which is used for calculation

Days	OLR (mg/l/d)	Theta (days)	S_0 (mg/l)	S (mg/l)	X (mg/l)
75-141	8070	2.527881	20400	15071.6	301800
142-230	10180	2.514735	25600	10176	301800
231-322	12750	2.031373	25900	10942.5	301800
323-453	15340	2.033898	31200	9800	301800
454-581	17830	2.007852	35800	10200	301800
582-591	18950	1.963061	37200	12600	301800

Reactor operation

Use kinetic models for the kinetic analysis of reactor

Several mathematical models are reviewed in literature. Here we use these models for finding the kinetic parameter for particular reaction system. We can use these models and fit our data with models and finding parameters. Data is given in (Table 1) which is fit with models.

Here we assume seventy-five day is our starting days and assume zeroth day because before this, system was unstable and have lot of variation in parameters. And hydraulic retention time (HRT) assume as constant because very little change was in value of HRT. Major changes were in organic loading rates which affect the performance of reactor. Then we studied following steps in our study.

- Study of the effect of organic loading rate (OLR) and hydraulic retention time (HRT) on the performance of the reactor.
- To determine the kinetic parameter by using model equation.
- To determine the kinetics of substrate utilization and bacterial growth

Phase 1 Study of the effect of organic loading rate (OLR) and hydraulic retention time (HRT) on the performance of the reactor

The volumetric organic load is the amount of organic matter applied daily to the reactor, per volume unit:

$$\mathrm{OLR} = \frac{QS_0}{V} = \frac{S_0}{\mathrm{HRT}(\theta)} \quad \text{.........(2.1)}$$

Where,

OLR = organic loading rate (kgCOD/m3·d)

S_0 = influent substrate concentration (kgCOD/m3)

In this study, OLR varied by changing the influent COD concentration and by changing the flow rate. Changing the flow rate implies changing the HRT and the up-flow velocity. From the equation (2.1) OLR and HRT are inversely proportional means OLR will increase then HRT will decrease.

Phase 2 To determine the kinetic parameter by using model equation

This study is used to find the kinetic parameter by using model equation which is reviewed in literature. Several models have been reviewed in literature which is used for finding rate constant for the reaction in system. Like as:

1) First order model
2) Grau's Second order model
3) Stover- Kincannon model
4) Methane production kinetics
5) Monod model

Phase 3 To determine the kinetics of substrate utilization and bacterial growth

Monod model is used for the kinetics of substrate utilization and bacterial growth. Equation describing growth is very similar to that describing enzyme kinetics (Michaelis-Menten model of enzyme kinetics)

$$q = \frac{q_{max}S}{K_s+S} \quad \text{............ (2.2)}$$

The relationship between specific growth rate and substrate concentration can be described in a similar manner.

$$\mu = \frac{\mu_{max}*S}{K_s+S} - K_d \quad \text{.................. (2.3)}$$

μ = Specific growth rate, day^{-1}

μm = Maximum specific growth rate, day^{-1}

Ks = Half velocity constant, equals the substrate concentration at which μ = ½ μm

S = Essential (limiting) growth substrate

K_d = Decay rate constant

RESULTS AND DISCUSSION

Phase 1 Study of the effect of organic loading rate (OLR) and hydraulic retention time (HRT) on the performance of the reactor

Data in (Fig 2) shows the COD removal with change in OLR. At low organic loading rate COD removal was low as well as OLR increased removal of COD also increased. But after around five eighty days COD removal decreased with increasing organic loading rate because it attains optimum COD removal around five eighty days.

Phase 2 To determine the kinetic parameter by using model equation

Kinetic consideration

Individual substrate and bacterial population. Such a treatment is extremely complex yielding equations with many unknown parameters. The six main groups of bacteria are divided into two major groups: acid producing microorganism and methane producing microorganisms [2-3].

Kinetic models are normally divided into two classes: structured and unstructured. Structured models take metabolic pathways into consideration and are generally complicated. Unstructured kinetic models are much simpler than the structured ones. In the unstructured kinetic models, microorganisms are usually considered to be a component or reactant in the system. The unstructured kinetic models are the most frequently use for modelling microbial systems because they are simple, but are good enough for technical purposes [4].

There are several mathematical models in the literature for biological processes, like Monod, First-order, Grau's Second-order, Modified Stover-Kincannon model, Contois

Model, Chen and Hashimoto, Lawrence and McCarty, Bhatia *et al*. Model etc. [5-6]. Lawrence and McCarty model used simplest Monod-type substrate degradation equation and suggest that substrate consumption is growth associated process [7]. Bhatia *et al*. Model indicate that methogenesis is independent of cell growth [7].

Study of kinetics of anaerobic biological treatment yields the rate at which microorganism degrade a specific waste, and therefore provide the basic information required for sizing biological anaerobic reactors. There are several mathematical models in the literature for biological processes, such as First order, Grau's Second order, Modified Stover- Kincannon, Monod model, Contois model.

General kinetics equation is $-\frac{ds}{dt} = kC_A^n$

$-\frac{ds}{dt}$: Substrate removal rate
k: rate constant
n: order of reaction
C_A : Concentration of substrate

Table 2 Kinetic parameter calculation by using first-order model

Days	OLR (mg/l/d)	Theta (days)	S_0 (mg/l)	S (mg/l)	X (mg/l)	$(S_0$-S)/S
75-141	8070	2.527881	20400	15071.6	301800	1.97
142-230	10180	2.514735	25600	10176	301800	1.51
231-322	12750	2.031373	25900	10942.5	301800	1.36
323-453	15340	2.033898	31200	9800	301800	2.18
454-581	17830	2.007852	35800	10200	301800	2.50
582-591	18950	1.963061	37200	12600	301800	1.95

Table 3 Kinetic parameter calculation by using Second-order model

Days	OLR (mg/l/d)	S_0 (mg/l)	S (mg/l)	X (mg/l)	E	Θ (days)	θ/E	K (day^{-1})
75	8070	16592	4877.6	301800	0.70602	0	0	----
75-141	8070	20400	15071.6	301800	0.26119	2.52788	9.67809	0.1349
142-230	10180	25600	10176	301800	0.6025	2.51473	4.17383	0.02890
231-322	12750	25900	10942.5	301800	0.57751	2.03137	3.51746	0.022736
323-453	15340	31200	9800	301800	0.68589	2.03389	2.96531	0.05346
454-581	17830	35800	10200	301800	0.71508	2.00785	2.80785	0.08833
582-591	18950	37200	12600	301800	0.66129	1.96306	2.96853	2.8449
592-616	22940	47800	31400	301800	0.34309	2.08369	6.07321	8.66016
							Average	1.950521

Table 4 Kinetic parameter calculation by using Modified Stover- Kincannon model

Days	OLR (mg/l/d)	S_0 (mg/l)	S (mg/l)	X (mg/l)	1/OLR (10^3)	V/(Q*(Si-Se)) (10^3)
75-141	8070	20400	15071.6	301800	0.12391	0.47442
142-230	10180	25600	10176	301800	0.09823	0.16304
231-322	12750	25900	10942.5	301800	0.07843	0.13581
323-453	15340	31200	9800	301800	0.06518	0.09504
454-581	17830	35800	10200	301800	0.05608	0.07843
582-591	18950	37200	12600	301800	0.05277	0.07979
592-616	22940	47800	31400	301800	0.04359	0.12705

Table 5 Methane production of lab-scale UASB reactor at different OLRs

Days	OLR (mg/L d)	CH_4 production rate (L/d)	1/OLR	1/M
75-141	8070	2.39	0.000124	0.416704
142-230	10180	6.51	9.82E-05	0.153423
231-322	12750	10.66	7.84E-05	0.093758
323-453	15340	14.29	6.52E-05	0.069943
454-581	17830	21.63	5.61E-05	0.046228
582-591	18950	21.97	5.28E-05	0.045517

First order model

Here first order model was used for calculating kinetic parameter for the observed value which are given below in (Table 2). The assumption of first- order kinetics for substrate removal was valid only at low substrate concentration.
First order model equation is used here [4];

$$\frac{(S_0-S)}{\theta_H} = k_1 S............ (3.1)$$

Rearranging above equation

$$\frac{(S_0-S)}{S} = k_1 \theta_H................ (3.2)$$

(Fig 3) $(S_0$-S)/S versus θ_H gives k_1 as slope, which are kinetic parameter for First-order model. The value of $k_1$in this study is0.862 d^{-1} with low regression coefficient (R^2) 0.634. This shows that our reaction is not a first order reaction.

Grau's Second-order model

In Grau's second- order model, we calculate kinetic parameter with respect to retention time. It describes substrate removal rate with respect to retention time. Here E is equal to $(S_0$-S)/S_0 shows removal of COD.
We assume here that our reactor was getting steady state at seventy fifth day that's why we take theta is equal to zero at seventy fifth day.

Second order model equation is given below [8];

$$\frac{\theta}{E} = a + b\theta \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.3)$$

Where a and b are constant. Rate constant (K_2) is calculated form equation (3.4)

$$K_2 = S_0/a * X_0 \ldots\ldots\ldots\ldots\ldots\ldots (3.4)$$

Plot theta versus theta/E gives the values of a and b. Value of a is used for calculating value of K_2. From the second-order model, value of a and b are **0.024** (day) and **1.563** respectively. Value of rate constant (K_2) is **1.950** day^{-1}. From the plot, it give the high regression coefficient (R^2=0.96) with linear equation so we can say that order of reaction in our reactor is second order model. By using this model we can find the volume of reactor by using modelling equation for reactor.

Table 6 Kinetic parameter calculation for microbial growth by using Monod equation

OLR	Theta	S_0	S	X	X_E	Θ_c	1/ Θ_c	$(S_i-S_e)/(\theta*X)$
8070	2.52788	20400	15071.6	301800	29109	26.2088	0.03815	0.00698
12750	2.03133	25900	10942.5	301800	29109	21.0606	0.04748	0.02439
15340	2.03389	31200	9800	301800	29109	21.0873	0.04742	0.03486
17830	2.00785	35800	10200	301800	29109	20.8172	0.04803	0.04224
18950	1.96306	37200	12600	301800	29109	20.3528	0.04913	0.04152
22940	2.08369	47800	31400	301800	29109	21.6036	0.04628	0.02607

Table 7 Kinetic parameter calculation for substrate utilization by using Monod equation

OLR	Theta	S_0	S	X	$1/S_e$ $(1*10^5)$	Θ_c
8070	2.52788	20400	15071.6	301800	6.635	26.2088
12750	2.03133	25900	10942.5	301800	9.139	21.0606
15340	2.03389	31200	9800	301800	10.2	21.0873
17830	2.00785	35800	10200	301800	9.804	20.8172
22940	2.08369	47800	31400	301800	3.185	20.3528

Table 8 Kinetic parameter calculation by first order model

HRT (θ, days)	S_0 (mg/L)	S (mg/L)	$(S_0-S)/S$
8	5200	800	5.50
9	9000	1800	4.00
12	15000	1600	8.38
6	20000	3600	4.56
5	20500	4600	3.46
11	21000	2600	7.08
12	43400	6000	6.23

Table 9 Kinetic parameter calculation by using Second-order model

HRT (θ, days)	S_0 (mg/L)	S (mg/L)	E	HRT/E	K_2
8	5200	800	0.85	9.45	0.03
9	9000	1800	0.80	11.25	0.03
12	15000	1600	0.89	13.43	0.09
6	20000	3600	0.82	7.32	0.11
5	20500	4600	0.78	6.45	0.22
11	21000	2600	0.88	12.55	0.07
12	43400	6000	0.86	13.93	0.09

Table 10 Kinetic parameter calculation by using Modified Stover- Kincannon model

HRT (θ, days)	S_0 (mg/L)	S (mg/L)	(S_0-S)	$\theta/(S_0-S)$	θ/S_0
8	5200	800	4400	0.001818	0.001538
9	9000	1800	7200	0.00125	0.001
12	15000	1600	13400	0.000896	0.0008
6	20000	3600	16400	0.000366	0.0003
5	20500	4600	15900	0.000314	0.000244
11	21000	2600	18400	0.000598	0.000524
12	43400	6000	37400	0.000321	0.000276

Modified Stover-Kincannon model

Stover- Kincannon model suggested that the substrate removal rates (COD) were affected by the organic loading rate entering the reactor. Here we operate reactor at an average OLR value for a time period in continuous mode.

Stover- kincannon model equation given below:

$$\frac{V}{Q(S_0-S)} = \frac{K_B}{U_{max}} * \frac{V}{QSi} + \frac{1}{U_{max}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.5)$$

Plot 1/OLR versus/ ($Q*(S_0-S)$) gives the values of μ_{max} (maximum utilization rate constant) and K_B (saturation value constant).

Saturation value constant (K_B) and maximum utilization rate (R_{max}) were calculated from figure 5 as 25.13 g/l.d and 5 g/l.d with regression coefficient (R^2= 0.82).

Methane production kinetics

The methane production rate can therefore be expressed as follows [9]:

$$M = \frac{M_{max}(\frac{QS_0}{V})}{M_B + (\frac{QS_0}{V})} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.6)$$

By rearranging equation (3.6), we get

$$\frac{1}{M} = \frac{M_B}{M_{max}} * \frac{V}{QS_i} + \frac{1}{M_{max}} \quad (3.7)$$

The rate of methane production is a direct measure of the metabolic activity of the methanogenic bacteria and an important parameter in monitoring anaerobic reactor performance. The specific methane production rate should have a direct relationship with the substrate loading removal rate.

(Fig 6) gives the kinetic constants M_{max} and M_B in terms of intercept and slope respectively. It shows value of M_{max} and M_B 4.09(L/ L d) and 19.75 (g/ L d) with regression coefficient (R^2= 0.87).

By using equation (3.6), we can find the predicted value of specific methane production rate with constant M_{max} and M_B. (Fig 7) shows the relation between specific methane production rate and organic loading rate with high regression coefficient (R^2= 0.987).

From the phase 2, we can conclude that a second order reaction is going on the reactor with rate constant value 1.95 per day. We fed large amount of COD on daily basis and we found that a high value of COD was utilizing per day with maximum utilization rate (5 g/L d) that means was large amount of COD consume by bacteria per day. Then for bacterial kinetics we studied phase 3.

Phase 3 To determine the kinetics of substrate utilization and bacterial growth

Monod model

The Monod equation is used for the growth of microorganisms. The relationship between the specific growth rate and the rate limiting substrate concentration can be expressed by the Monod Equation.

Kinetics of bacterial growth

At steady state the specific growth rate (μ) of the micro-organism is equal to the dilution rate (D). The dilution rate is defined as the rate of flow of medium over the volume of culture in the bioreactor.

For a continuous system, bacterial growth kinetic equation is given below:

$$\frac{(S_0 - S)}{\theta_H * X} = \frac{1}{Y} * \left(\frac{1}{\theta c}\right) + \frac{1}{Y} * K_d \quad (3.8)$$

By rearranging above equation

$$\frac{1}{\theta_c} = Y_m \left[\frac{(S_i - S_e)}{\theta * X}\right] - K_d \quad (3.9)$$

Above equation (3.9) give the value of yield and bacterial decay rate constant in terms of intercept and slope of the line from (Fig 7).

The plot of $1/\theta_c$ versus $(S_0\text{-}S)/(\theta * X)$ yielded a straight line (R^2=0.8164) whose slope gives biomass yield coefficient (Y=0.272) and intercept gives bacterial decay coefficient (K_d = 0.0381 d^{-1}).

Kinetics of substrate utilization

Monod equation is also used in determining the parameter for substrate utilization by using bacterial growth parameter which occurs from bacterial growth kinetics.

Equation used for kinetic of substrate utilization:

$$\frac{\theta_c}{1 + \theta_c * K_d} = \frac{K_S}{\mu_{max}} * \frac{1}{S} + \frac{1}{\mu_{max}} \quad (3.10)$$

The plot of $1/S_e$ versus $\frac{\theta_c}{1+\theta_c * K_d}$ yielded a straight line (R^2=0.9237) whose slope gives maximum growth rate (μ_{max}= 0.626 day^{-1}) and intercept gives kinetic coefficient (K_s = 27.294 g COD/L). (Fig 9) indicates negative K_s value with regression coefficient of 0.9237. As stated by [10], the negative value of these constants might be ascribed to maximum degree of degradation.

From phase 3, we found yield coefficient (Y) which shows the amount of sludge produced after treatment of wastewater. We also found the growth rate and decay rate of the bacteria in continuous system which shows the bacterial activity in the system.

Microbial fuel cell

A microbial fuel cell is a bio-electrochemical system that generates current by using bacteria as catalysts to oxidize organic and inorganic matter. Current generation is result of electrons produced by bacteria from this substrate [11].

Microbial fuel cells utilize microorganisms to degrade organics present in the wastewater and converting stored chemical energy to electrical energy in a single step.

Anode chamber

Anode chamber is filled with mixed culture wastewater, bacteria. In anode chamber anaerobic digestion of wastewater occur due to presence of bacteria. Production of carbon di oxide, H^+ ions and electrons will occur.

Cathode chamber

Electrons will pass through the wire and collect at cathode. Due to presence of oxygen or air (aerobic nature) these electrons will combine with hydrogen and produce water. Hydrogen will pass through membrane from anode chamber to cathode chamber.

Proton exchange membrane

Hydrogen will pass through membrane from anode chamber to cathode chamber.

In microbial fuel cell, we have an anode chamber in which anaerobic digestion is occurred. For this anaerobic digestion system, we used kinetic models from literature for kinetic analysis of the system.

Kinetic models:

1) First order model
2) Grau's Second order model
3) Modified Stover-Kincannon model
4) Monod model

Kinetic analysis

First order model

Here first order model was used for calculating kinetic parameter for the observed value given below in (Table 8). The assumption of first- order kinetics for substrate removal was valid only at low substrate concentration [12].

First order model equation is used here:

$$\frac{(S_0 - S)}{\theta_H} = k_1 S \quad (4.1)$$

From (Fig 10), we found first order rate constant value (k_1= 0.61) with low regression coefficient (R^2= 0.67).

Grau's second order model

In second- order model, we calculate kinetic parameter with respect to retention time. It describes substrate removal rate with respect to retention time. Here E is equal to $(S_0\text{-}S)/S_0$ shows removal of COD.

Second order model equation is given below [12];

$$\frac{\theta}{E} = a + b\theta \quad (4.2)$$

Where a and b are constant. Rate constant (K_2) is calculated form (5.3)

$$K_2 = S_0 / a * X_0 \quad (4.3)$$

From (Fig 12) we found the value of constant a and b which was 1.25 and 1.04 respectively. By using equation (4.3) and value of a, we calculate the value of rate constant K_2 (0.092 day^{-1}).

Modified stover-Kincannon model

Stover-Kincannon model suggested that the substrate removal rates (COD) were affected by the organic loading rate entering the reactor. Here we operate reactor at an average OLR value for time period in continuous mode.

Stover-Kincannon model equation given below:

$$\frac{V}{Q(S_0-S)} = \frac{K_B}{U_{max}} * \frac{V}{Qsi} + \frac{1}{U_{max}} \quad \text{.........................} \quad (4.4)$$

From (Fig 12), we found the value of maximum utilization rate (U_{max}) and saturation value constant (K_B) were 0.09.

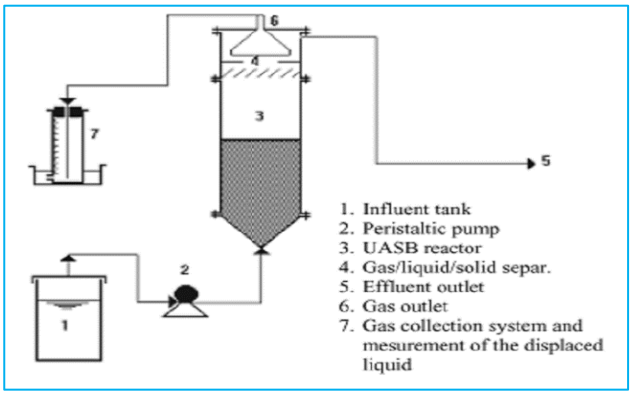

Fig 1 Schematic diagram of laboratory UASB reactor

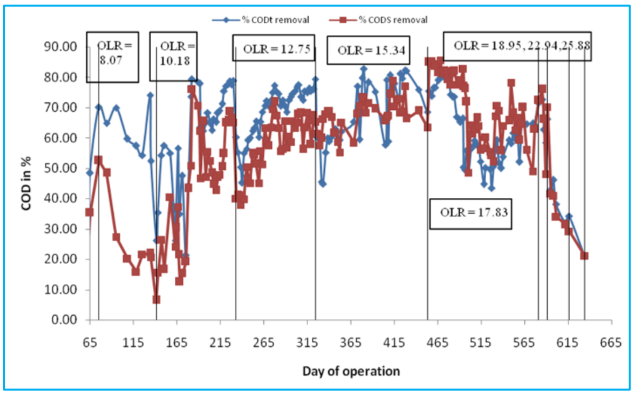

Fig 2 COD removal with change in OLR and no. of days

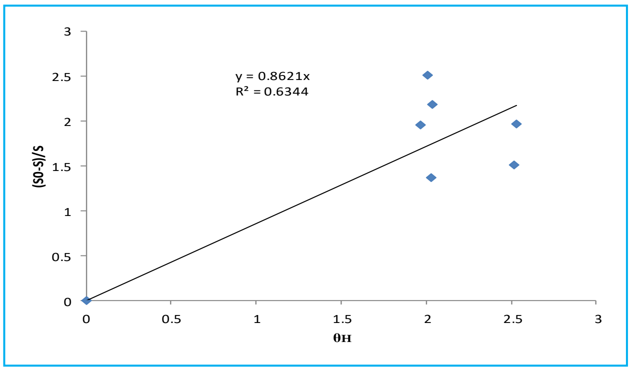

Fig 3 Plot between $(S_0\text{-}S)/S$ vs θ_H for First order model kinetics

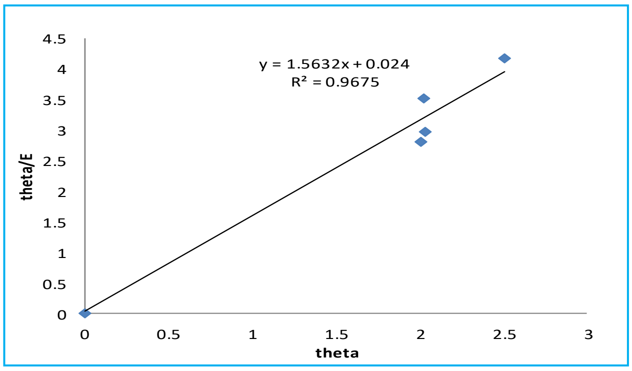

Fig 4 Second – order kinetic model

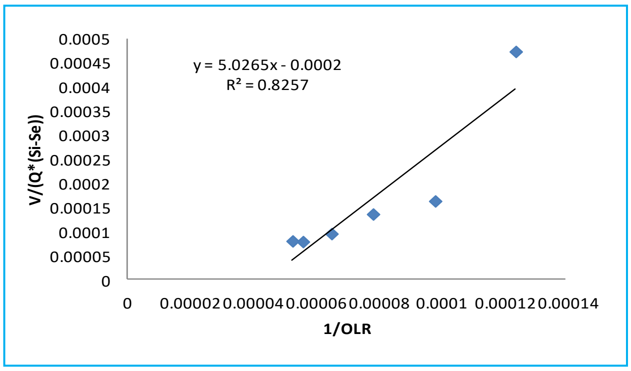

Fig 5 Determination of kinetic constants for modified stover-kincannon model

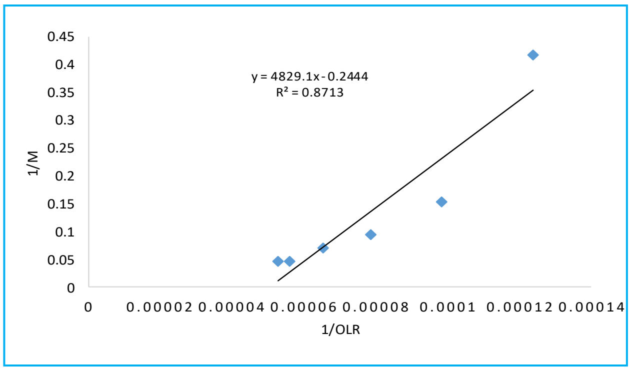

Fig 6 Determination of methane production kinetic constants

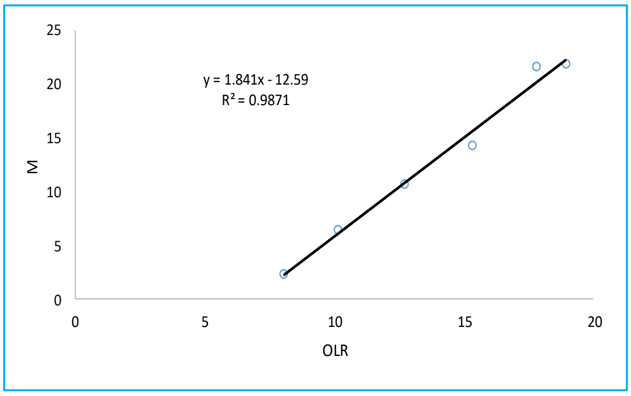

Fig 7 Specific methane production rate versus total organic loading rate with

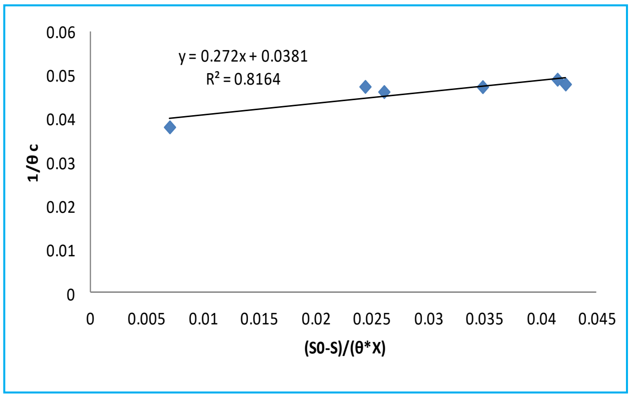

Fig 8 Determination of kinetics of biomass growth (yield and decay coefficient)

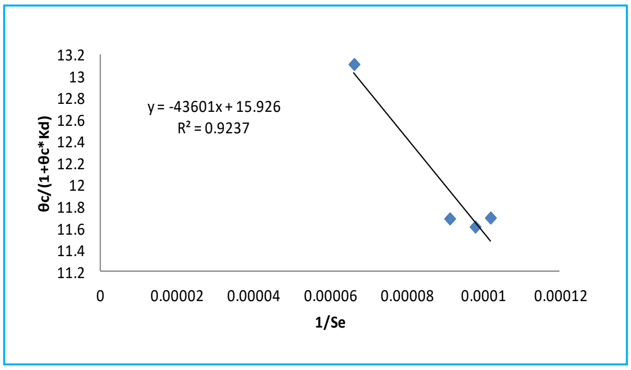

Fig 9 Kinetics of substrate utilization for substrate removal rate and maximum biomass growth rate

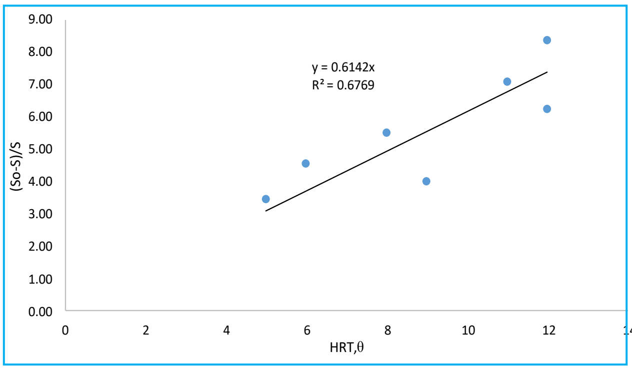

Fig 10 Plot between $(S_0\text{-}S)/S$ vs θ_H for First order model kinetics

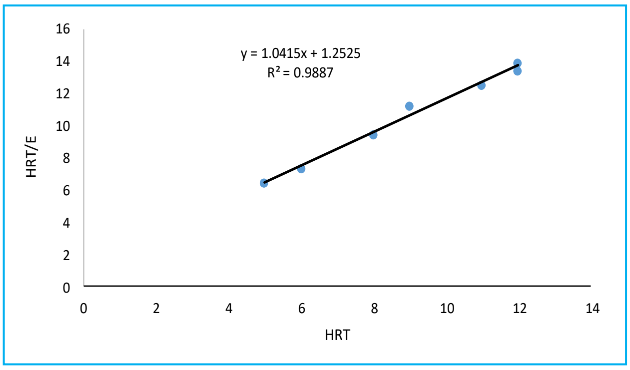

Fig 11 Grau's Second – order kinetic model

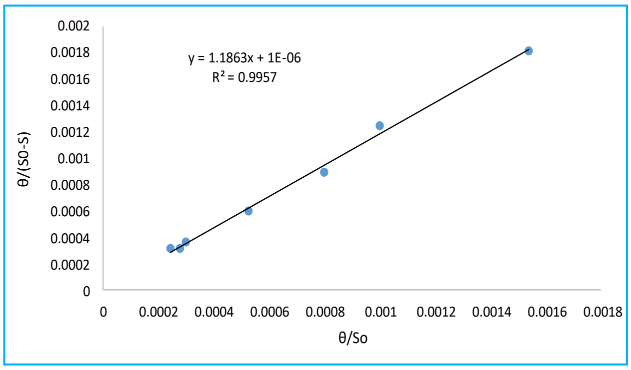

Fig 12 Determination of kinetic constants for modified stover-kincannon model

CONCLUSION

Treatment performance of the UASB reactor was evaluated at different organic loading rates and hydraulic retention times using distillery wastewater and kinetic analysis was carried out according to experimental results. After attaining steady-state conditions, organic loading rate increased stepwise. Kinetic parameters were calculated through linear regression using experimental data. Evaluation of kinetic parameters in the models was done by using mean values of influent and effluent COD obtained at steady state conditions. Simulated data and observed data was in good agreement in models, such as, Grau's second order model (R^2=.96), Monod model ((R^2=.98) and Stover – Kincannon model ((R^2=.82) with high regression coefficients. High regression coefficient confirmed the suitability of models between observed and simulated data. The results are indicating the validation of models for describing the bio-kinetic behaviour of the reactor.

LITERATURE CITED

1. Kalyuzhnyi SV, Fedorovich VV, Lens P. 2006. Dispersed plug flow model for upflow anaerobic sludge bed reactors with focus on granular sludge dynamics. Jr. Ind. Microbiol. Biotechnology 33(3): 221-237. doi: 10.1007/s10295-005-0217-2.
2. Jeyaseelan S. 1997. A simple mathematical model for anaerobic digestion process. *Water Science and Technology* 35: 185-191.
3. Borja R, Martin A, Sanchez E, Rincon B, Raposo F. 2005. Kintic modelling of the Hydrolysis, acidogenic and methanogenic steps in the anaerobic digestion of two-phase olive pomace. *Process Biochemistry* 40(5): 1841-1847.
4. Panadian M, NGO H, Pazhaniappan S. 2011. Substrate removal kinetics of an anaerobic hybrid reactor treating pharmaceutical wastewater. *Journal of Water Sustainability* 3: 301-312.
5. Gupta SK, Singh G, Gupta SK. 2007. Biodegradation of distillery spent wash in anaerobic hybrid reactor. *Water Research* 41(4): 721-730.
6. Buyukkamaci N, Filibeli A. 2002. Determination of kinetic constant of an anaerobic hybrid reactor. *Process Biochemistry* 38: 73-79.
7. Hwang SH, Hansen CL, Stevens DK. 1992. Biokinetics of an upflow anaerobic sludge blanket reactor treating whey permeate. *Bioresource Technology* 41(3): 223-230.
8. Ayşe B, Nurdan K, Burcu Ö, Elif ÖY, İpek Ö, Alev G, Ayşe FT, Eylem A, Funda E, Hadice SŞ, Nalan O, Yeşim Ö, Ömer T, Mehmet P, Züleyha B, Turhan E, Eda Ç, Metin A, Eylem SÖ, Sibel AN, İrem Ş, Can A. 2022. The evaluation of disease awareness, caregiver burden, and workday loss in caregivers of COPD patients. *Turkish Journal of Medical Sciences* 52: 346-353.
9. Hanqing YU, Wilson F, Tay J. 1998. Kinetic analysis of an anaerobic filter treating soyabean wastewater. *Water Resource* 32(11): 3341-3352.
10. Converti A, Borhgi AD, Arni S, Molinari F. 1999. Linearized kinetic model for the simulation of the mesophilic anaerobic didsetion of pre- hydrolyzed woody wastes. *Chem. Eng. Technology* 22: 429-437.
11. Logan BE. 2008. *Microbial Fuel Cell*. John Wiley & Sons.
12. Yu H, Wilson F, Tay JH. 1983. Kinetic analysis of an aerobic filter treating soybean wastewater. *Water Research* 32: 3341-3352.