P: ISSN No. 2231-0045 RNI No. UPBIL/2012/55438 VOL.-IV, ISSUE-II, November-2015
E: ISSN No. 2349-9435 Periodic Research

Effect of Physical Parameters on Performance Characteristics on Degradation of Synthetic Phenolic Waster Water in Single Stage Attached Film Fixed Bed Bio-Reactor

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Abstract

The treatment of toxic and inhibitory phenolic compounds using biological techniques have been pursued vigorously as a promising and widely accepted treatment process due to its ease of handling, a greater degree of stabilization of waste and properly operated to prevent the production of secondary pollutants. Up-flow anaerobic bioreactors (UAFB) has been widely used for the treatment of high organic load industrial waste water. The treatment of synthetic phenolic wastewater by a single stage anaerobic fixed bed bioreactor with granite stones packing at four different temperatures was studied. The effect of hydraulic retention time on COD reduction and other steady state characteristics and kinetic parameters from these characteristics was also studied. A recirculated single stage up-flow anaerobic bioreactor was operated at all the above-given temperatures with initial BOD 1462 mg/l and initial COD 5720 mg/l for a digestion period of 25 days with a working volume of 1000 ml. The performance of the reactor was monitored after every five days and analyzed in terms percentage COD, BOD, TS, TDS, VS removal and biogas production. The removal efficiency of BOD, COD, TS, TDS and VS reached a maximum value of 63.20%, 61.24%, 44.88%, 47.67% and 53.12% respectively. With the change in HRT, the maximum COD reduction was found to be 66.04% at 24 hrs HRT at 40^{0}C with initial COD of 5000 mg/l. Specific biogas yield increased up to 0.0162 ml/mg COD_r.

Keywords: Phenol, Anaerobic, Fixed Bed Bio-Reactor, Waste Water, Up-Flow Anaerobic Sludge Blanket.

Abbreviations: BOD -Biochemical Oxygen Demand, COD- Chemical Oxygen Demand, TDS - Total Dissolved Solids, VS - Volatile Solids, UAFB - Up-Flow Anaerobic Fixed Bed Bioreactor.

Introduction

It has been reviewed that aromatic compounds are plentiful in the environment (Lettinga et al., 2001, Colleran et al., 2002, G. Collins, 2005). One group of these products is phenolic compounds. It has been demonstrated that phenol can be degraded, under anaerobic conditions, to methane and carbon dioxide as reviewed in several reports (Guieysse. et al. , 2001, Li and Fang, 1996. However, at some concentrations, phenol may promote inhibitory effects in methanogenic bacteria, diminishing methane production and carbon degradation (Rebaca and Gerbens, 1999). Therefore, phenolic compounds are problematic for the anaerobic treatment of wastewater. One report (Hernandez, 2003) sets that various alternatives (dilution, ozonation, UV-H_2O_2) have been proposed to eliminate toxicity and improve phenol's anaerobic biodegradation. Previous works on phenol anaerobic biodegradation have been carried out in batch (Banks and Wang, 1999) and continuous operation: fluidized bed (Mc Hugh et al., 2004.), UASB (Chang et al., 1995) and expanded bed reactor (Collins et al., 2005)

Treatment of phenol and cresols in up-flow anaerobic sludge blanket (UASBR) has been reviewed by Veeresh et al. (2005). It has been reported that the anaerobic bacteria have the capability to degrade phenol as a sole substrate (Fang et al. 1996; Chang et al. 1995; Tay et al. 2000) and use of a co-substrate is not a prerequisite. However, the presence of a co-substrate retards/prevents the toxic effects of phenols during shocks, helps in complete biodegradation of phenol (Tay et al. 2001) and facilitates fast recovery of the process. Pure substrates such as glucose (Hwang and Cheng, 1991; Tay et al. 2001) and volatile fatty acids (VFA) (Kennes et.al., 1997) have been used as co-substrates in the anaerobic treatment of phenols in UASBR. The use of pure substrates restricts the practical applicability of the process. Therefore, it has been deemed necessary to assess the potentials of a readily degradable wastewater as a co-substrate in the treatment of phenolic waste. The present technical note describes the performance of a (UAFB) up flow anaerobic fixed bed bioreactor treating synthetic wastewater.

Materials and Methods

Synthetic wastewater containing phenol was produced with COD: N: P ratio of 100: 2.5: 0.5, using urea and potassium dihydrogen phosphate as a chief source of nitrogen and phosphorous respectively. The phenolic wastewater contained BOD (biochemical oxygen demand) of value 1278 mg/l and COD (chemical oxygen demand) of value 5000 mg/l. In this study synthetic phenolic wastewater was prepared as and when required. The composition was maintained by diluting it with distilled water. To support the growth of microorganisms, nutrients like nitrogen and phosphorous were added in a ratio of COD: N: P of 50: 2.5: 1. Synthetic wastewater containing phenol was used as a sole carbon source. Urea and potassium dihydrogen phosphate were used as a chief source of N and P. Besides this inorganic ions like Na^+, K^+, Ca^{2+}, Mg^{2+} and Fe^{3+} were added in small quantities.

An anaerobic mixed culture was developed from cow dung in yeast extract media by digesting it up to two weeks at 35^{0}C temperature, which was further enriched in the synthetic medium of acetic acid. Acetic acid was added to inhibit the growth of acidogenic bacteria. The methanogenic culture was enriched in the acetic medium. This culture so obtained was used as inoculums for the batch process. As phenol is toxic to micro-organisms and is a good disinfectant, its higher concentration may prevent microbial growth in waste water may prevent microbial growth or, at least, make it difficult to sustain, so the mixed culture was thus developed was adapted to the phenolic wastewater. For adaption the concentration of phenol was gradually increased from 100 mg/l to 1000 mg/l. This experiment was carried out for 14 days at 35^{0}C temperature. The biogas production was measured each day to ensure the bacterial activity. Phenolic waste water and the developed adapted mixed culture was mixed in definite proportion and was introduced into the single stage attached film fixed bed bioreactor and was allowed to ferment anaerobically for a period of 25 days at four different temperatures 30^{0}C, 35^{0}C, 40^{0}C and 45^{0}C respectively. 100 ml seed material was used in each digester. pH was adjusted by adding lime when required.

The single stage anaerobic attached film fixed bed reactor with a working volume of 1000 ml was packed with granite stones of size 1.0 cm to 1.5 cm in diameter. The reactor consists of a jacketed column to maintain the temperature by flowing water in the outside jacket using a thermostat water bath. The reactor was initially fed at a rate of 25 ml/hr to maintain the HRT of 24 hours. Continuous recycle of the treated effluent (phenolic wastewater) was done for the partial fluidization of the sludge by a peristaltic pump. These pumps were calibrated for different flow rates. Reactor performance was evaluated on the basis of COD, BOD, TS, TDS, VS and biogas production at four different temperatures 30^{0}C, 35^{0}C, 40^{0}C and 45^{0}C.

In an experiment, the effect of a change in hydraulic retention time (HRT) on COD reduction and other steady state characteristics and kinetic parameters from these characteristics was studied. HRT varied from 2 to 24 hrs. The steady state reached between 9th -13 th days for different HRT in the reactor.

Results and Discussions

Phenols are known to be highly toxic to the microorganisms. After the development of methanogenic culture, 100 ml inoculum was mixed with waste water having phenol concentration 100 mg/l. After two weeks 100 ml inoculum was taken from this experiment and waste water with 200 mg/l phenol concentration was inoculated. In this manner highest concentration of phenol i.e. 1000 mg/l was digested and % COD removal of 59.33% was achieved. This can be seen in the table- 1 and fig -1**.**

A. Effect of change in Temperature

The characteristics of the treatment mixture viz. BOD, COD, TS, TDS and VS at different digestion time at four different temperatures 30^{0}C, 35^{0}C, 40^{0}C and 45^{0}C are shown in the table -2, table-3, table-4 and table-5 respectively. Fig-2, fig-3, fig-4, fig-5 and fig-6 represent effect of digestion time on %BOD, %COD, %TS, %TDS and %VS reduction respectively.

At 30^{0}C BOD and COD of the treatment mixture ranged between 1462 mg/l to 625 mg/l and 5720 mg/l to 2882 mg/l respectively. The total dissolved solids ranged from 254 mg/l to 160 mg/l, total dissolved solids ranged from 172 mg/l to 100 mg/l and volatile solids ranged from 128 mg/l to 68 mg/l, with the increase in digestion time from 01 to 25 days. The value of percentage BOD reduction varied from 23.05 to 57.25% while percentage COD reduction varied from 18.63 % to 49.61%. The value of total solids, total dissolved solids, and volatile solids ranged between 12.59% to 37.00%, 16.27 % to 41.86 % and 21.87% to 46.87% respectively.

At 35^{0}C BOD and COD of the treatment mixture ranged between 1462 mg/l to 575 mg/l and 5720 mg/l to 2318 mg/l respectively. The total dissolved solids ranged from 254 mg/l to 152 mg/l, total dissolved solids ranged from 172 mg/l to 98 mg/l and volatile solids ranged from 128 mg/l to 62 mg/l, with the increase in digestion time from 01 to 25 days. The value of percentage BOD reduction varied from 19.56% to 60.67 % while percentage COD reduction varied from 17.74 % to 59.47%. The value of total solids, total dissolved solids, and volatile solids ranged between 11.02 % to 40.15 %, 12.79 % to 43.02 % and 18.75% to 51.56% respectively.

At 40^0C BOD and COD of the treatment mixture ranged between 1462 mg/l to 481 mg/l and 5720 mg/l to 1957 mg/l respectively. The total dissolved solids ranged from 254 mg/l to 132 mg/l, total dissolved solids ranged from 172 mg/l to 78 mg/l and volatile solids ranged from 128 mg/l to 50 mg/l, with the increase in digestion time from 01 to 25 days. The value of percentage BOD reduction varied from 28.45% to 67.09 % while percentage COD reduction varied from 24.44 % to 65.78 %. The value of total solids, total dissolved solids, and volatile solids ranged between 15.57 % to 48.03 %, 20.93 % to 54.65 % and 26.56 % to 60.93% respectively.

At 45^0C BOD and COD of the treatment mixture ranged between 1462 mg/l to 538 mg/l and 5720 mg/l to 2217 mg/l respectively. The total dissolved solids ranged from 254 mg/l to 140 mg/l, total dissolved solids ranged from 172 mg/l to 90 mg/l and volatile solids ranged from 128 mg/l to 60 mg/l, with the increase in digestion time from 01 to 25 days. The value of percentage BOD reduction varied from 24.62% to 63.20% while percentage COD reduction varied from 20.69 % to 61.24%. The value of total solids, total dissolved solids, and volatile solids ranged between 12.59% to 44.88%, 18.60 % to 47.67% and 20.31% to 53.12% respectively.

B. Effect of Hydraulic Retention time on COD and Biogas Production

Effect of change in the effect of a change in hydraulic retention time (HRT) on COD reduction and steady state characteristics and kinetic parameters from these characteristics for the reactor with granite stones as packing material is shown in table-7. With variation in HRT from 2 -24 hrs, it was observed that the maximum COD reduction occurred at HRT 24 hrs and was found to be 66.04%. The corresponding graph is shown in Fig-7. Biogas production value decreased with increase in HRT. Table -8 shows the effect of HRT on the biogas productivity and specific biogas yield respectively. The value of biogas productivity decreased from 0.0741 to 0.0535 ml/ml/day, while the specific biogas yield increased from 0.0036 to 0.0162 mg/ml COD_r with an increase in HRT from 2 to 24 hours. Fig-8 and Fig -9 show the change of kinetic parameters with change in HRT.

Conclusion

This work studied the anaerobic degradation of phenolic wastewater at four different temperatures 30^0C, 35^0C, 40^0C and 45^0C and with a change in hydraulic retention time from 2 to 24 hours. Degradation of phenol, chemical oxygen demand (COD), biochemical oxygen demand (BOD), total solids (TS), total dissolved solids (TDS), volatile solids (VS), biogas productivity and specific biogas yield were evaluated. The final results indicate that there was a steady increase in the percentage reduction of BOD, COD, TS, TDS and VS from 5^{th} to 20^{th} day but the rate of percentage reduction decreased after the 20^{th} day at all the four different temperatures. Cumulative biogas production and rate of biogas production during the digestion process indicated that there was a steady increase in the yield of biogas from 7^{th} day onwards and it attained a peak value on 20^{th} treatment then after it started decreasing. The biogas production and reduction in effluent characteristics at various temperatures observed showed that optimum temperature for a reduction in effluent characteristics and biogas production was at 40^0C. It was also observed from the results that treatment efficiencies increased with the increase of retention time at 40^0C. Methane content in the biogas varied The average composition of the biogas at the end of digestion with HRT 24 hrs at 40^0C was: CH_4 content varied from 62.2 to 64.1%, CO_2 varied from 34.0 – 36.5 %, O_2 varied from 0.3 – 0.5% and CO varied from 0.4- 0.7%.

Table-1
Percentage Phenol Removal during Adaptation of Phenolic Wastewater

S. No.	Initial Phenol Conc. (mg/l)	Initial COD (mg/l)	Final COD (mg/l)	% COD Removal
1.	100	804	699	13.05
2.	200	1627	1363	16.22
3.	300	2082	1620	22.19
4.	400	2877	2047	28.84
5.	500	3958	2493	37.01
6.	700	4495	2425	46.05
7.	800	5746	2722	52.62
8.	1000	6728	2736	59.33

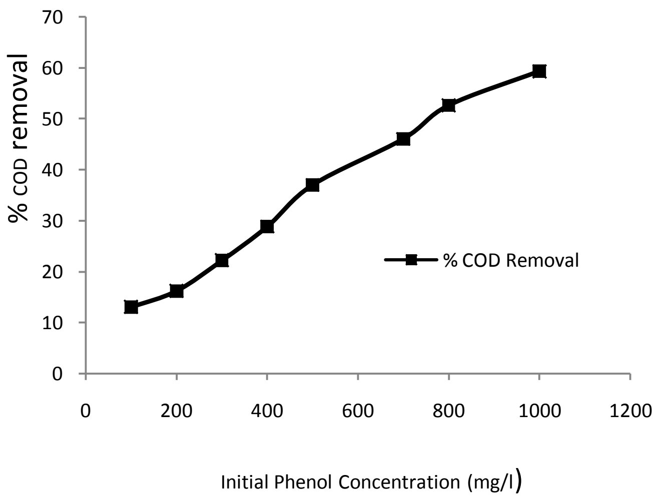

Fig-1. Percentage COD Removal during Adaptation of Phenolic Wastewater

Table-2
Percentage Reduction of BOD at 30^0C, 35^0C, 40^0C and 45^0C Temperature

S. No.	Digestion Time (days)	% BOD Reduction			
		At 30°C	At 35°C	At 40°C	At 45°C
1.	5	23.05	19.56	28.45	24.62
2.	10	36.73	29.13	40.56	36.38
3.	15	48.29	42.81	49.52	47.87
4.	20	54.58	49.84	60.09	57.85
5.	25	57.25	51.50	67.78	63.20

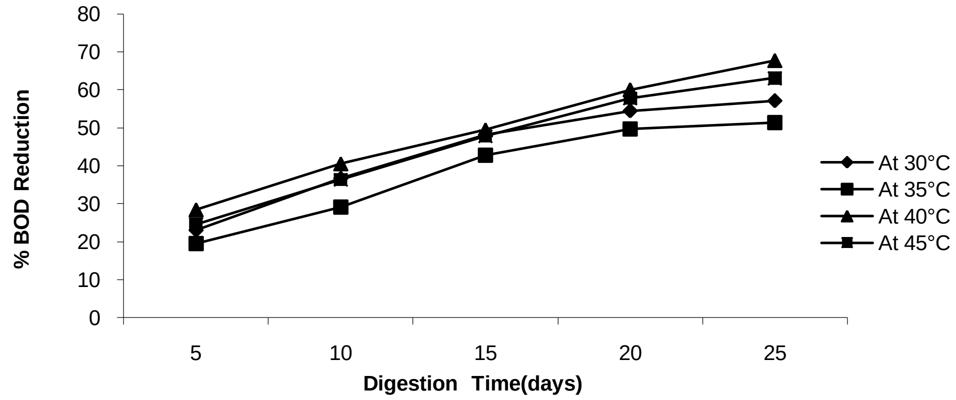

Fig-2.Effect of Digestion Time on % BOD Reduction at Four Different Temperatures

Table-3
Percentage Reduction of COD at 30^0C, 35^0C, 40^0C and 45^0C Temperature

S. No.	Digestion Time (days)	% COD Reduction			
		At 30°C	At 35°C	At 40°C	At 45°C
1.	5	18.63	17.74	24.44	20.69
2.	10	33.46	28.70	36.53	33.93
3.	15	42.36	40.85	46.76	42.79
4.	20	49.33	49.84	55.85	54.09
5.	25	49.61	59.47	65.78	61.24

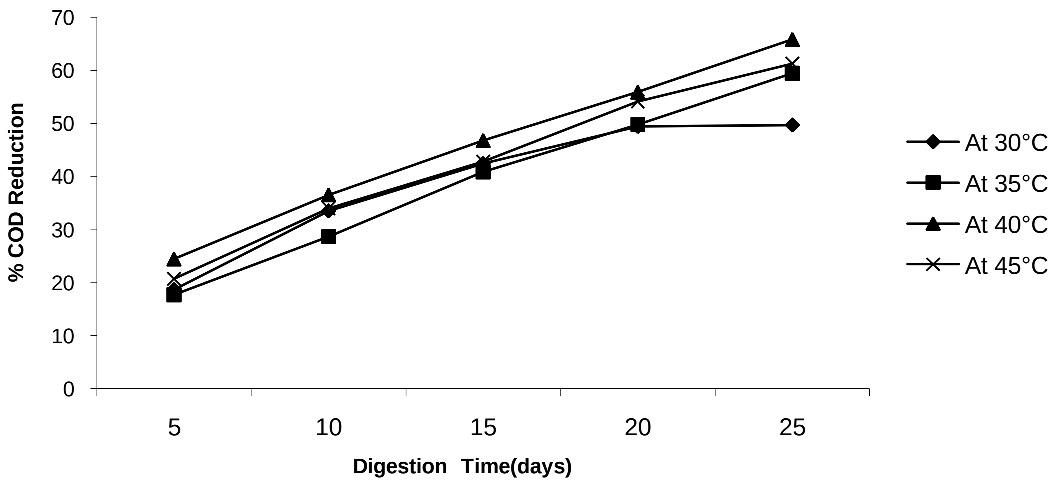

Fig-3. Effect of Digestion Time on % COD Reduction at Four Different Temperatures

Table-4
Percentage Reduction of Total Solids at 30^0C, 35^0C, 40^0C and 45^0C Temperature

S. No.	Digestion Time (days)	% TS Reduction			
		At 30°C	At 35°C	At 40°C	At 45°C
1.	5	12.59	11.02	15.74	12.59
2.	10	22.04	22.04	28.34	24.40
3.	15	30.70	29.92	36.22	34.64
4.	20	36.22	36.22	42.51	40.15
5.	25	37.00	40.15	48.03	44.88

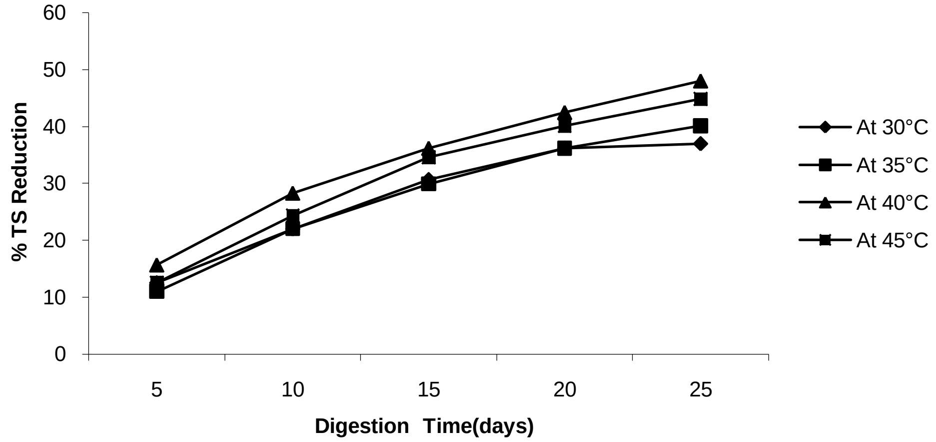

Fig-4. Effect of Digestion Time on % TS Reduction at Four Different Temperatures

Table-5

Percentage Reduction of Total Dissolved Solids at 30^{0}C, 35^{0}C, 40^{0}C and 45^{0}C Temperature

S. No.	Digestion Time (days)	% TDS Reduction			
		At 30°C	At 35°C	At 40°C	At 45°C
1.	5	16.27	12.79	20.93	18.60
2.	10	25.58	22.09	31.39	26.74
3.	15	32.55	31.39	43.02	38.37
4.	20	40.69	38.37	50.00	44.18
5.	25	41.86	43.02	54.65	47.67

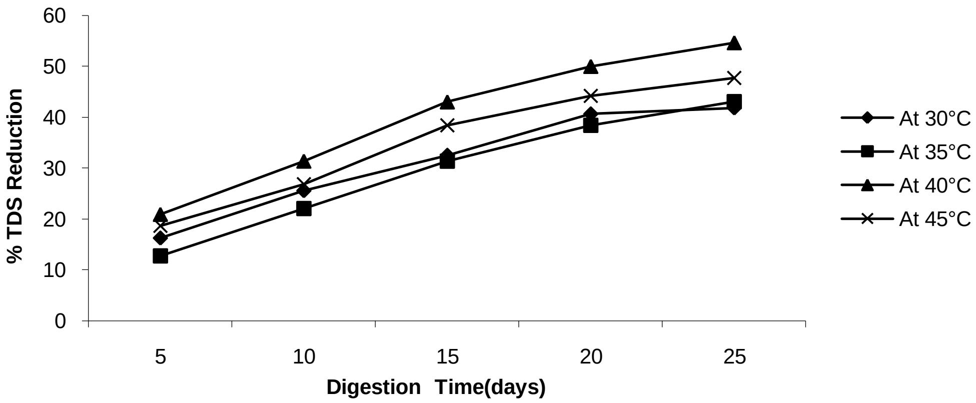

Fig-5. Effect of Digestion Time on % TDS Reduction at Four Different Temperatures

Table:6

Percentage Reduction of Volatile Solids at 30^{0}C, 35^{0}C, 40^{0}C and 45^{0}C Temperature

S.No.	Digestion Time(days)	% VS Reduction			
		At 30°C	At 35°C	At 40°C	At 45°C
1.	5	21.87	18.75	26.56	20.31
2.	10	29.68	29.68	35.93	32.81
3.	15	35.93	43.75	46.87	42.18
4.	20	43.75	48.43	56.25	51.56
5.	25	46.87	51.56	60.93	53.12

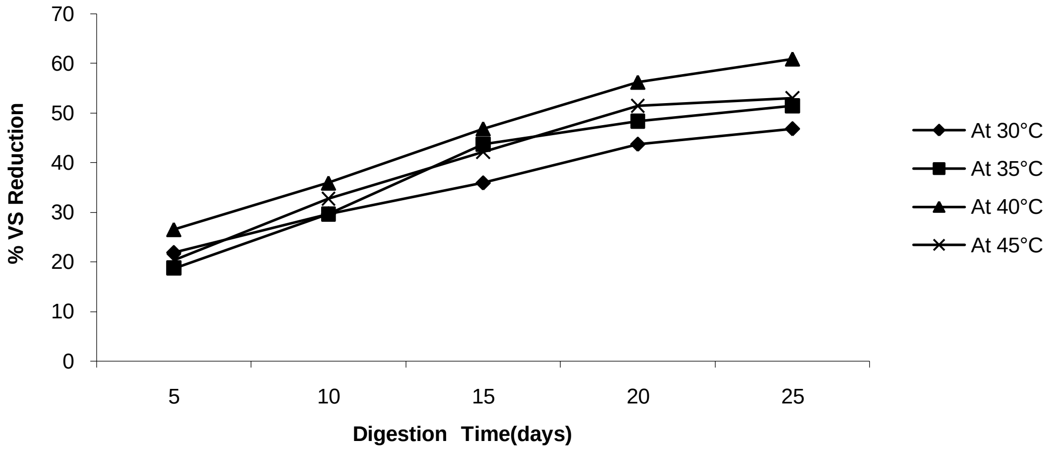

Fig-6. Effect of Digestion Time on % VS Reduction at Four Different Temperatures

Table-7
Effect of Hydraulic Retention Time on Performance Characteristics of the Reactor at 40^{0}C

S. No	Feed Rate (ml/hr)	Hydraulic Retention Time (hrs)	COD of Treated Effluent (mg/l)	% COD Removal
1.	300	2	3321	33.58
2.	150	4	3133	37.34
3.	75	8	1887	42.26
4.	45	14	2444	51.12
5.	25	24	1698	66.04

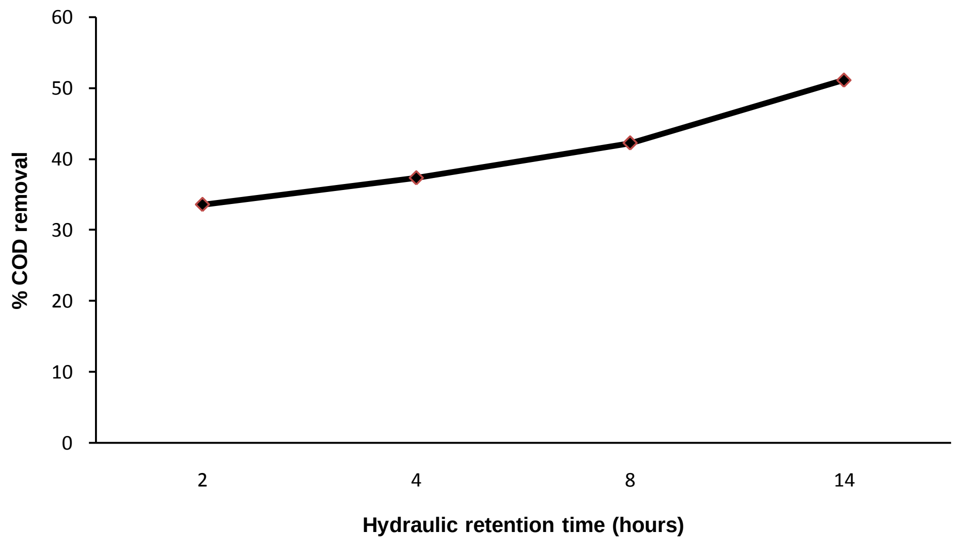

Fig-7. Effect of Hydraulic Retention Time on %COD Reduction

Table:8
Evaluation of Kinetic Parameters from Table -7

S. No	Hydraulic Retention Time (hours)	% COD removal	Biogas productivity (ml/ml/day)	Specific biogas yield (mg/ml/COD_r)
1.	2	33.58	0.0741	0.0036
2.	4	37.34	0.0713	0.0063
3.	8	42.26	0.0633	0.0099
4.	14	51.12	0.0596	0.0129
5.	24	66.04	0.0535	0.0162

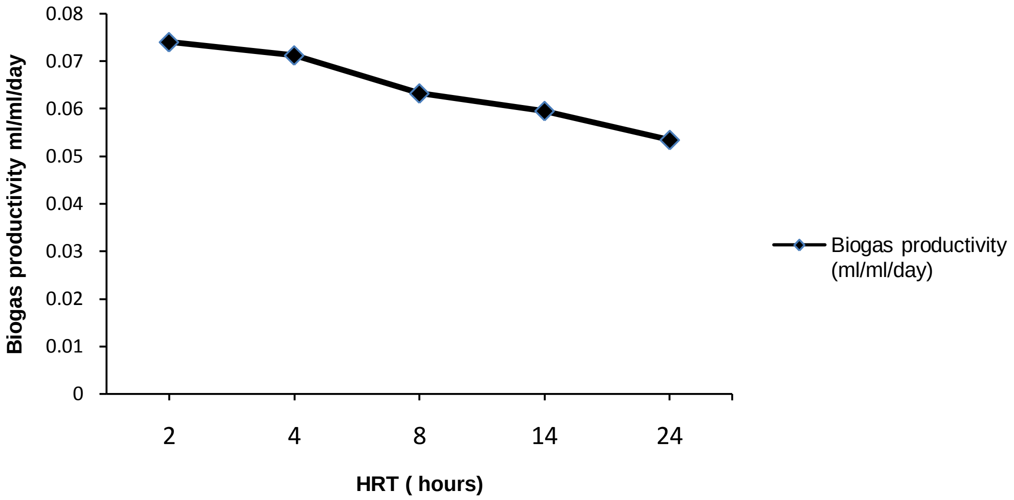

Fig-8: Effect of Hydraulic Retention Time on Biogas Productivity

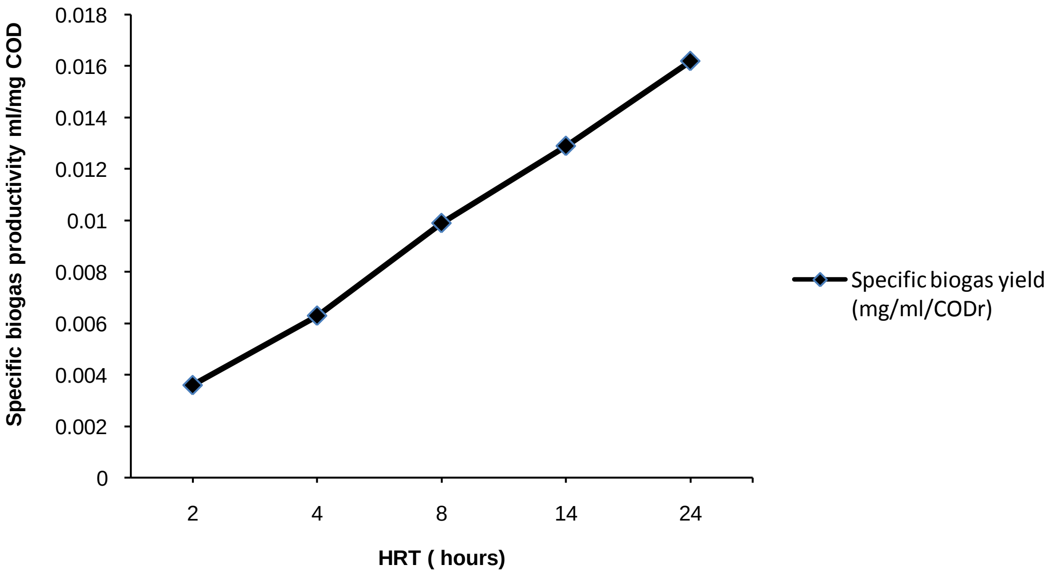

Fig-9: Effect of Hydraulic Retention Time on Specific Biogas Productivity

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