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Biodegradation of High Concentration Synthetic Phenolic Industrial Wastewater in a Single Stage Up-flow Anaerobic Bioreactor Packed with Granite Stones

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Abstract

The present study describes the feasibility of anaerobic biological treatment of phenol in a single stage up-flow anaerobic bioreactor packed with granite stones. The parameters considered in the study were: a) organic loading rate and b) hydraulic retention time, which may influence the phenol biodegradation. For the experiment, a jacketed reactor with an inner diameter of 6 cm was used. The reactor packed with granite stones of size ranging from 1.0 - 1.5 cm. Synthetic phenolic waste enriched with nutrients was fed and recirculated. Experiments were conducted to investigate the performance of the reactor based on a reduction in COD value and biogas production. The results indicated that higher HRT resulted in better performance while high organic loading rate lowered the microbial activity resulting in the lesser reduction in COD value and the lesser biogas productivity. At hydraulic retention time (HRT) of 24 hrs, the percentage COD removal of the reactor was 66.04 % with biogas productivity of 0.0535 ml/ml/day. However, reduction in percentage COD removal and the increase in biogas productivity was found with an increase in organic loading rate with the same HRT of 24 hours.

Keywords: Anaerobic, Biodegradation, Organic loading, Phenol, Reactor, Fixed bed, Hydraulic Retention Time, Organic Loading Rate

Introduction

Phenol and its derivatives have their applications in various chemical processes, synthesis of various products, particularly phenolic-type resins. These phenolic compounds are used as raw material and are also present in the effluents of various industries such as petrochemical units, oil refineries, insecticides manufacturing industry,resin manufacturing industry, plastic making units, pharmaceutical industry etc, and as a natural component as well as industrial wastes from processes involving their as a raw material (Kirk-Othmer, 1998: Sawyer, C.N et.al., 1987).These compounds are potentially carcinogenic and hazardous compound present in wastewater. Their presence inhibits and sometimes stops the natural biological activity of microbes, on which the stabilization of organic load in industrial and domestic effluents depends largely.

Review of Literature

USEPA has listed these phenolic compounds as primary pollutants are affecting the biological system in the degradation process (Chang et al., 1995; Rappoport, 2003; 2004). The presence of more than 1 mg/L phenol in water has an adverse effect on aquatic life, posing threat to the aquatic environment (Busca et al., 2008). Therefore, the effluent containing phenol must be treated and purified before its being discharged into the water bodies or land. Several physical, chemical, and biological and non-biological methods have been used for removal of these hazardous compounds from wastewater (Karthik et al., 2008). Biological methods being less cost effective and less perilous are preferred over other treatment techniques (Liu et al., 1996; Feng L et.al., 2009, Kinsley & Nicell, 20008). The concept of treating phenol and its degradation by biological iques to was first reported in the 1920s (Vipulanandan C, 1994). Since then, many operational guidelines have been set for reactor design

and treating the water biologically. During this process of biological degradation, existences of aerobic and anaerobic microbes/bacteria have also been studied [Young, E.T, 1999; Essa, M et.al, 1997). Anaerobic biological treatment of phenol, its derivatives and other orgnic compounds in an up-flow anaerobic sludge blanket (UASBR) been studied by many researchers (Veeresh et al. 2005; Tay et.al. 2000; Fang et.al. 1996; Chang et.al. 1995). It has also seen that the presence of a co-substrate like carbohydrates and other higher unsaturated acids can retard the toxicity of phenols and help in speedy resurgence of the process during reactor shocks in the complete biodegradation of phenol (Tay et al. 2001). Simple carbohydrates (Hwang and Cheng, 1991; Tay et al. 2001) and higher unsaturated volatile fatty acids (VFA) (Kennes et.al., 1997), were present as co-substrates while the anaerobic treatment of phenols in anaerobic reactors. (Mishu Singh, 2015). However, in absence of these, the treatment process was restricted to many physical parameters. Therefore, it is essential to consider the capability of a degradable wastewater to act as a co-substrate while treating phenolic effluents (Mishu Singh, 2014). In the present scientific note, effect of physical parameters such as change in hydraulic retention time, increased organic loading rate and recycle ratio, on the performance of a (UAFB) up-flow anaerobic fixed bed reactor while treating phenolic waste-water has been studied.

Aim of the Study

The present investigation had under taken to assess the biodegradation of phenol in up-flow anaerobic jacketed reactor with granite stones as packing material. The performance of the reactor is also evaluated in terms of BOD & COD reduction, bio gas production and kinetic parameter Biogas productivity with change in Hydraulic Retention Time and Organic Loading Rate. Effect of recycle rate on the degradation of treated phenolic waste is also studied to check the performance of the double-jacketed reactor.

Material and Methods

Start up

To achieve the objectives of this work, a jacketed reactor made up of the glass of working volume of 900 ml with inner diameter 6.0 cm and the total length of 30 cm was used. On top, water column was connected to a gas tube connected to for the measurement of daily biogas production during experimental studies. The temperature of the column was maintained 40±2 0C by flowing water in the outer jacket using a thermostat water bath. Treated effluent was continuously recycled for partial fluidization of the sludge. A 5-litre tank was placed in order to collect the effluent and recirculate it to by the use of a peristaltic pump. The reactor was packed with granite stones of size 1.0- 1.5 cm. The pH of the solution was maintained 7.5 throughout the experiments.

Operation

The reactor was fed initially with the developed adapted mixed culture and synthetic wastewater having maximum COD 300 mg/L. Feeding time was taken 7 days. After every 7 days, the synthetic phenolic wastewater was fed with increased COD and finally the full-strength wastewater with COD 5000 mg/L was fed into the reactor with granite stones packing at a rate of 25 ml /hr to maintain the HRT 24 hours. In this way, microorganisms and the biofilm were well grown under control at different phenol concentrations. The continuous feeding and recycle of the synthetic effluent was carried out by the peristaltic pumps. Three pumps were been calibrated for different flow rates. The performance of the reactor was evaluated with different organic loading rates and different HRT ranging from 2 to 24 hours. At each stage, the experiments were performed when the bioreactor attained steady-state conditions.

Synthetic Waste and inoculum

To ensure adequate experimental control of the system a synthetic waste feed was used during the phases of the research. Synthetic wastewater, containing phenol as the sole carbon source for growth of microorganism and biofilm, urea as the nitrogen (N) and potassium dihydrogen phosphate as the source of phosphate (P), entered into the reactor throughout the operation and minor elements for biomass were added into the synthetic wastewater. The composition of wastewater was determined based on the ratio of COD/N/P: 100/2.5/0.5. The synthetic phenolic wastewater contained 1278 mg/L BOD and 5000 mg/L COD. Besides these, inorganic ion like Na+, K+, Ca2+, Mg2+ and Fe3+ were added in small quantities. The phenol concentrations for treatment ranged from 100 to 5000 mg/L during the treatment process. Samples were daily collected from the recycled liquid and analyzed for COD and BOD reduction.

Results and Discussion

Effect of Hydraulic Retention Time (HRT) on COD reduction and Biogas productivity:

Anaerobic biodegradation of wastewater treatment process can be cost effective only when it shows highly efficient in a short period of time, otherwise, it may not meet the requirements. Reduction in COD and biogas productivity was evaluated at HRT of 2, 4, 8, 14 and 24 hours under steady- state conditions. The steady state reached between 9th to 13th days for different HRTs in the reactor packed with granite stones. The percentage COD removal and biogas productivity different HRTs is shown in Table 1. The reactor operated for a period of 20 days. The experimental data show that maximum COD reduction of 66.04% occurred at 24 hours. Biogas production decreased with increase in HRT. The minimum biogas production of value 44.5 ml/day was observed at HRT 2 hrs. Biogas productivity decreased from 0.0741 to 0.0535 ml/ ml/day. The corresponding graphs are shown in Figure 1 and Figure 2.

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Table 1: Effect of Hydraulic Retention Time on Performance Characteristics of Single Stage Reactor Using Granite Stone Packing at Steady State

S.No	Feed Rate (ml/hr)	HR (Hrs)	COD of treated effluent (mg/L)	%COD Reduction	Biogas production (ml/day)	Biogas productivity (ml/day/day)
1	300	2	3321	33.58	44.5	0.0741
2	150	4	3133	37.34	42.8	0.0713
3	75	8	2887	42.26	38.0	0.0633
4	45	14	2444	51.12	35.8	0.0596
5	25	24	1698	66.04	32.1	0.0535

Figure 1: Effect of Hydraulic Retention Time on % COD Reduction

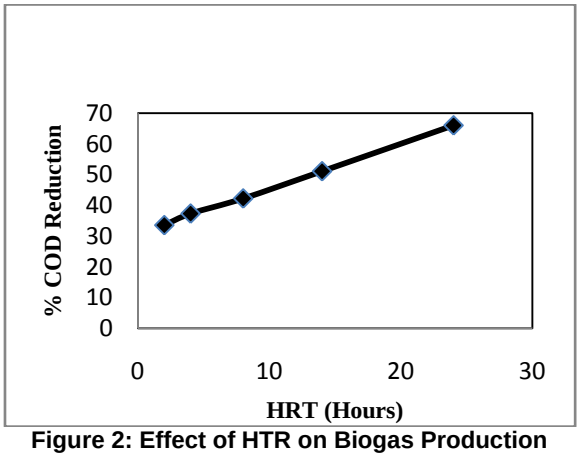
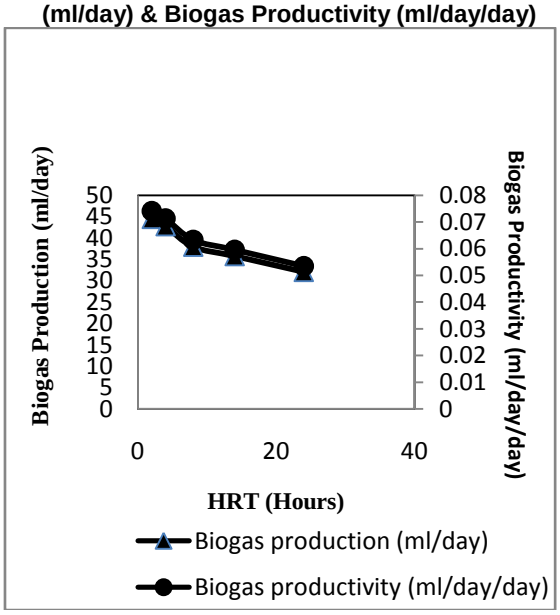


Figure 2: Effect of HTR on Biogas Production (ml/day) & Biogas Productivity (ml/day/day)



Effect of Organic Loading Rate on COD Reduction and Biogas Productivity

To observe the effect of organic loading rate on COD reduction, experiments were carried out at different OLRs ranging from 2.902 to 5.802 kg/ COD/m3d. The steady state reached beween10th-14th days for different OLRs. Percentage COD reduction and Biogas productivity at different organic loading rates are shown in Table 2. The COD of the treated effluent varied from 1022 to 2949 mg/L with the increase of OLR from 2.902 to 5.802 kg/COD/m3d. It was observed that percentage reduction in COD was from 65.35 to 49.17 %, biogas production varied from 22.0 to 37.2 ml/day and biogas productivity changed from 0.0366 to 0.0620 ml/ml/day with the same increase in loading rates. The corresponding graphs are shown in Figure 3 and Figure 4 respectively.

Table 2: Effect of Organic Loading Rate on Performance Characteristics of Single Stage Reactor Using Granite Stone Packing at Steady State

S. No	Influent COD (mg/L)	Organic Loading Rate (kgCOD/m^3d)	COD of treated effluent (mg/L)	% COD Reduction	Biogas production (ml/day)	Biogas productivity (ml/day/day)
1	2950	2.950	1022	65.35	22.0	0.0366
2	3319	3.319	1222	63.18	24.3	0.0405
3	3934	3.934	1566	60.19	28.0	0.0466
4	4508	4.508	1893	58.00	31.4	0.0523
5	5000	5.000	2289	53.22	33.0	0.0550
6	5802	5.802	2949	49.17	37.2	0.0620

Figure 3: Effect of Organic Loading Rate on % COD Reduction

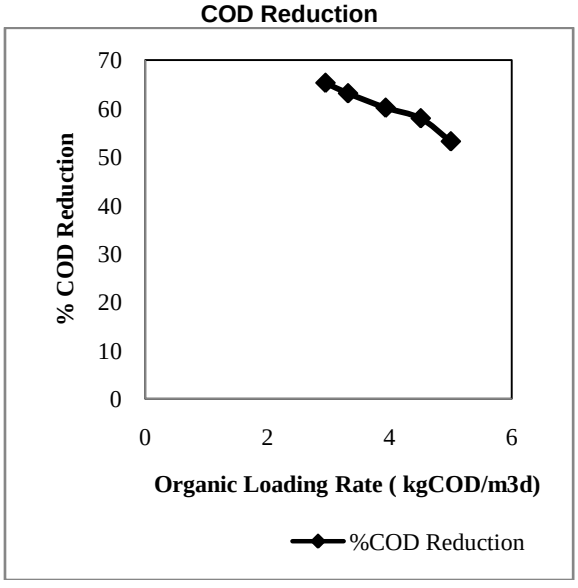
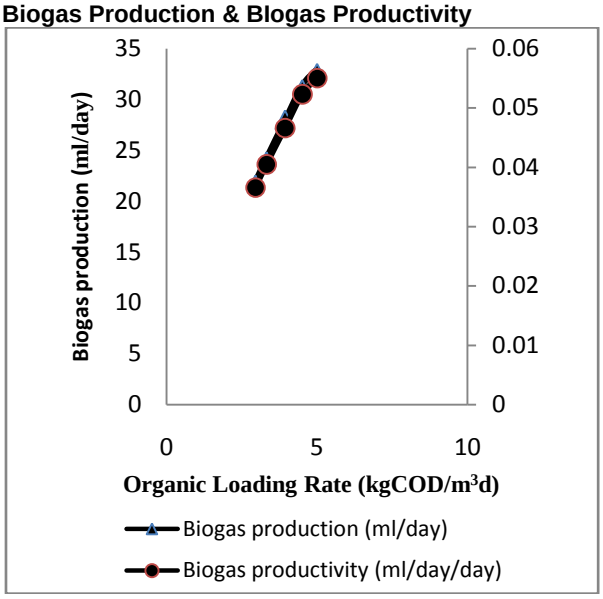


Figure 4: Effect of Organic Loading Rate on Biogas Production & Biogas Productivity



Effect of Recycle Rate on Performance Characteristics of Single Stage Reactor

Reactor performance was studied at different recycle rates at HRT 24 hours. The recycle ratio varied from 6 to 19. The steady state reached between 8th to 11th days for the reactor. The characteristics of the treated effluent at steady state are given in Table 3 and Table 4. During the experiment, the values of BOD and COD ranged from 536 to 305 mg/L and form 2200 to 1240 mg/L respectively with the increase of recycle rate from 150 to 475 ml/hour. The results show that the percentage BOD and COD reduction varied from 58.05 to 76.13% and 56.0 to 75.20 % respectively with the increase of recycle rates from 150 to 475 ml/hour. It was observed that biogas production varied from 11.5 to 13.5 ml/day and biogas productivity changed from 0.0191 to 0.0225 ml/ml/day with the same increase in loading rates. The corresponding graphs are shown in Figure 5 and Figure 6 respectively.

Table 3: Effect of Recycle Rate on Performance Characteristics of Single Stage Reactor using Granite Stones as Packing Material

S. No	Recycle rate (ml/hr)	Recycle ratio	BOD of treated effluent (mg/L)	COD of treated effluent (mg/L)	Biogas production (ml/day)
1	150	6	536	2200	11.5
2	225	9	488	2044	12.5
3	300	2	428	1813	13.3
4	375	15	383	1566	14.3
5	475	19	305	1240	13.5

Table 4: Evaluation of the Kinetic Parameters

S. No	Recycle rate (ml/hr)	% BOD Reduction	% COD Reduction	Biogas Productivity (ml/ml day)
1	150	58.05	56.0	0.0191
2	225	61.81	59.12	0.0208
3	300	66.51	63.74	0.0220
4	375	70.03	68.68	0.0236
5	475	76.13	75.20	0.0225

Figure 5: Effect of Recycle Rate On % BOD and % COD Reductio in Single Stage Attached Film Fixd Bed Bioreacotor

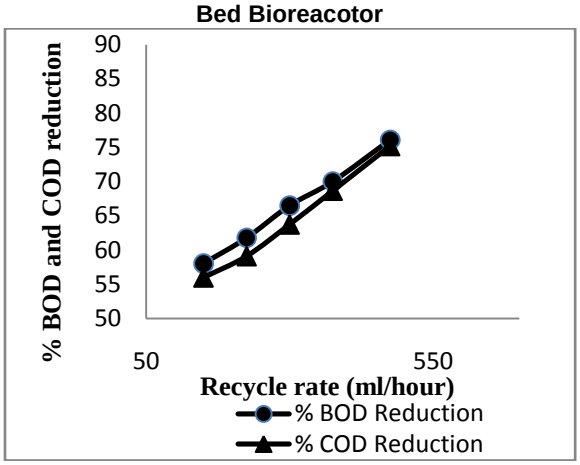
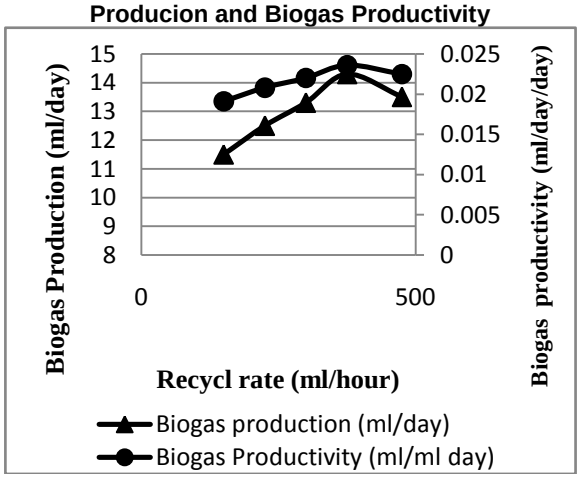


Figure 6: Effect of recycle rate on biogas Producion and Biogas Productivity



Conclusion

In the present work, an up flow anaerobic fixed bed single stage bioreactor was developed and its performance was checked. the process was developed and studied removal. The results intergraded that a bioreactor at the optimum condition can be an effective technology for phenol removal from synthetic wastewater. For the successful performance of the reactor, mixed microbial fixation and bio-film formation on the support surface are two of the most significant factors, Since they affect the levels of removal of every toxic waste concentration in a synthetic wastewater. The results showed that the reactor provides improved COD removal efficiencies better than the conventional up-flow reactors. The optimum HRT for the process is 24 h, at which the

removal efficiencies of COD was greater than 66.04 %. At the same HRT, with the maximum organic loading rate of 5.802 kgCOD/m3d, % COD removal was found to be 49.17%. on increasing the substrate loading rate, biogas production rate has been increased until the maximum utilization rate was observed. However, recycling of the treated effluent also helped in enhancing the performance of the reactor.

Abbreviation

BOD: Biological Oxygen Demand
COD: Chemical Oxygen Demand
HRT: Hydraulic Retention Time
OLR: Organic Loading Rate
UAFB: Up-flow Anaerobic Fixed Bed
UASB: Up-flow Anaerobic Sludge Blanket
USEPA: United States Environmental Protection Agency
VFT: Volatile Fatty Acids

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