

Performance Evaluation of Anaerobic Biodegradation of Synthetic Phenolic Waste Water in Single Stage Fixed Bed Bio- Reactor

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Abstract: *Biological treatment systems are supposed to be advanced in the sense that they are more effective and involve a greater degree of stabilization of waste. 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 and properly operated to prevent the production of secondary pollutants. Upflow anaerobic bioreactors (UAFB) have been widely used for the treatment of high organic load industrial wastewater. The treatment of synthetic phenolic wastewater by a single stage anaerobic fixed bed bioreactor with granite stones packing at a temperature of 30^oC, 35^oC, 40^oC and 45^oC was 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 could reach to a maximum value of 63.20%, 61.24%, 44.88%, 47.67% and 53.12% respectively. The result showed that the maximum biogas production in the reactor reached 0.0077 liters /liter /day at a temperature of 40^oC.*

Keywords: Phenol, anaerobic, fixed bed bioreactor, wastewater, up flow anaerobic sludge blanket.

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

1. Introduction

It 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-H₂O₂) 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 upflow 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) upflow anaerobic fixed bed bioreactor treating synthetic wastewater.

2. 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 ion like Na⁺, K⁺, Ca²⁺, Mg²⁺ and Fe³⁺ 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^oC 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 adaptation 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°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°C, 35°C, 40°C and 45°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 a stone 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°C, 35°C, 40°C and 45°C.

3. 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**

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 |

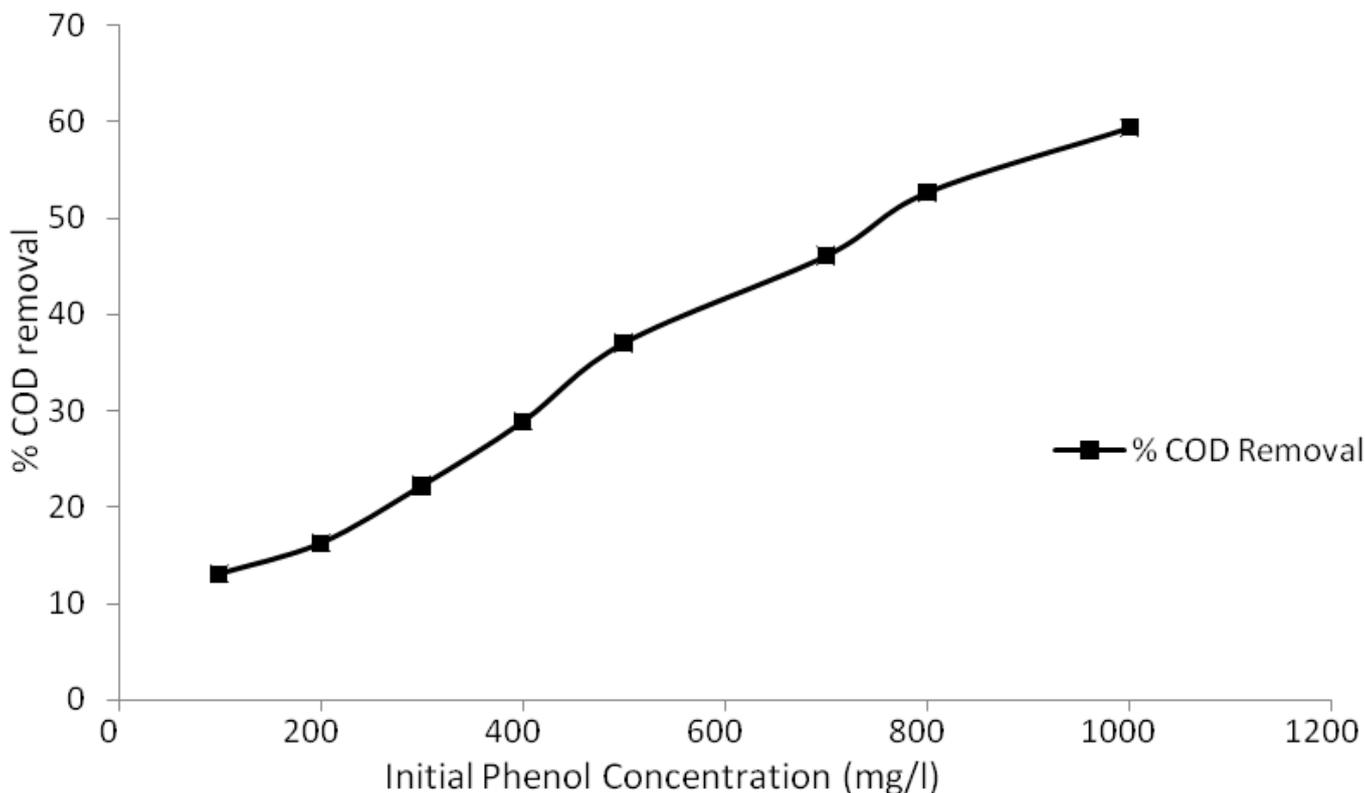


Figure 1: Percentage COD Removal during Adaptation of Phenolic Waste water

The characteristics of the treatment mixture viz. BOD, COD, TS, TDS and VS at different digestion time at four different temperatures 30°C, 35°C, 40°C and 45°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 the effect of digestion time

on %BOD, %COD,%TS, %TDS and %VS reduction respectively.

At 30°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°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°C 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°C 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.

Table 2: Percentage Reduction of BOD at 30°C, 35°C, 40°C and 45°C 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 |

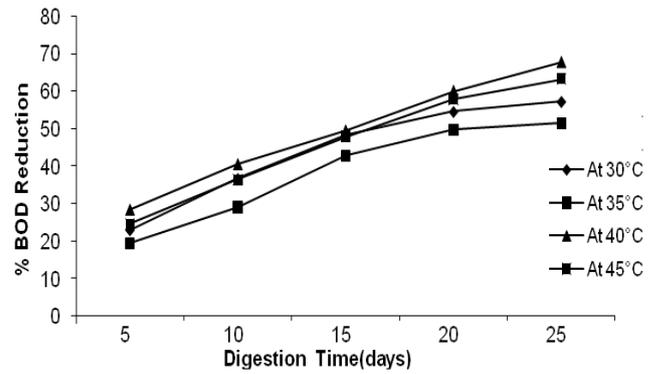


Figure 2: Effect of digestion time on % BOD Reduction at four different temperatures

Table 3: Percentage Reduction of COD at 30°C, 35°C, 40°C and 45°C 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 |

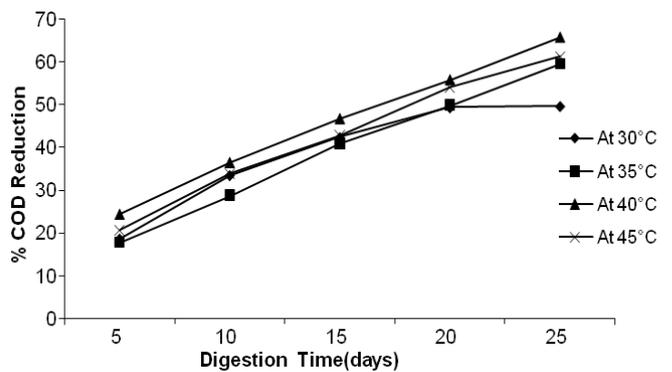


Figure 3: Effect of digestion time on % COD Reduction at four different temperatures

Table 4: Percentage Reduction of Total Solids at 30°C, 35°C, 40°C and 45°C 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 |

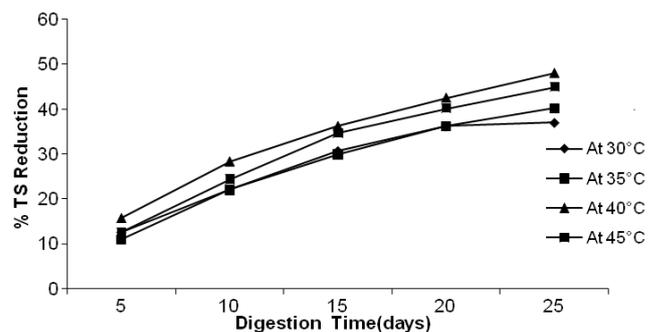


Figure 4: Effect of digestion time on % TS Reduction at four different temperatures

Table 5: Percentage Reduction of Total Dissolved Solids at 30°C, 35°C, 40°C and 45°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 |

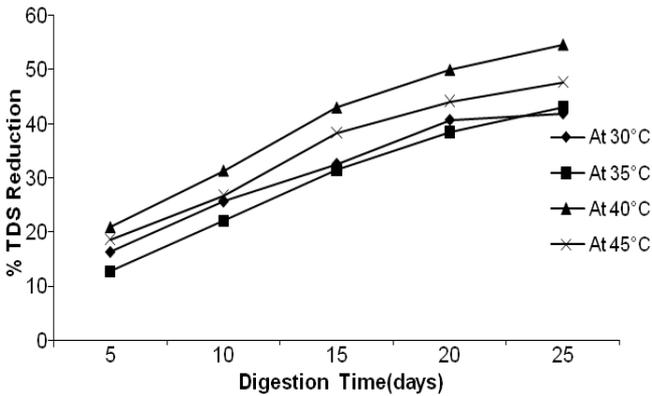


Figure 5: Effect of digestion time on % TDS Reduction at four different temperatures

Table 6: Percentage Reduction of Volatile Solids at 30°C, 35°C, 40°C and 45°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 |

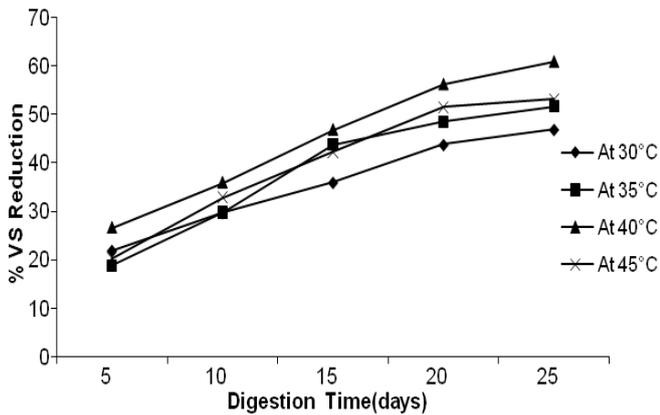


Figure 6: Effect of digestion time on % VS Reduction at four different temperatures

4. Results

Results indicate that there was a steady increase in the percentage reduction of BOD, COD, TS, TDS and VS from 5th to 20th day, but the rate of percentage reduction decreased after a 20th day at all the four different temperatures. Cumulative biogas production and rate of biogas production during the digestion process was also measured. The results indicate that there was a steady increase in the yield of biogas from 7th day onwards and it attained a peak value on

20th treatment then after it started decreasing. The decrease in the biogas production was because of a decrease in organic matter in digestion mixture. The biogas production and reduction in effluent characteristics at various temperatures observed can be depicted as-

Reduction at 40°C > Reduction at 45°C > Reduction at 35°C > Reduction at 30°C

It showed that optimum temperature for reduction in effluent characteristics and biogas production was at 40°C. The average composition of the biogas at the end of digestion at 40°C was: CH₄ content varied from 63.0 - 63.8 %, CO₂ varied from 32 - 33 %, O₂ varied from 0.5 - 0.7 % and CO varied from 0.3- 0.7%.

5. Conclusion

This work studied the anaerobic degradation of phenolic wastewater at four different temperatures 30°C, 35°C, 40°C and 45°C. Degradation of phenol, chemical oxygen demand (COD), biochemical oxygen demand (BOD), total solids (TS), total dissolved solids (TDS), volatile solids (VS) and biogas were evaluated. Phenol is not degradable under acidogenic conditions by acidogenic bacteria. There was a steady increase in the percentage reduction of BOD, COD, TS, TDS and VS from 5th to 20th day, but the rate of percentage reduction decreased after the 20th day. There was a steady increase in the yield of biogas from 7th day onwards and it attained a peak value on 20th treatment then after it started decreasing.

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