Anaerobic Treatment of Textile Wastewater using EGSB

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Abstract— In this study expanded granular sludge bed (EGSB) reactor has been used to investigate the removal efficiency of chemical oxygen demand (COD), and color of textile wastewater. Synthetic Textile wastewater was treated in an EGSB reactor seeded with non granular anaerobic sludge from UASB reactor treating sugar mill wastewater of Badagandi sugar mill at Badagandi village, Bagalkot district, Karnataka, India and active septic tank. The initial volatile suspended solid concentration was 20.40 g/L. The study was carried out at ambient temperature 29ºC to 37ºC in the laboratory scale reactors of 8.4 L effective volume. Reactor was fed with macro and micro nutrients. Successful reactor startup with granulation was achieved within 13 days of operation using Chitosan as polymer. During startup the hydraulic retention times (HRT) was kept constant for 12 hrs. A maximum COD removal efficiency of 89.95% was achieved at organic loading rate (OLR) of about 8 KgCOD/m^3/d. And the maximum bio gas production was 20.4 l/d. During operation period synthetic textile wastewater was fed step by step with increasing concentration of 25%, 50% and 75% of influent COD (5000 mg/L) respectively. Loading was increased by reducing HRT to 6 hrs, 3 hrs, 1.5 hrs and 1 hr respectively. Results indicated that anaerobic treatment of textile wastewater was possible with the supplementation of an external carbon source in the form of glucose (600mg/L). The corresponding maximum COD and color removals were 78.4% and 69% respectively for HRT of 1.5 hrs and OLR of 80 Kg COD/m^3/d at ambient temperature.

.***Key words:*** Textile wastewater, Anaerobic, EGSB

I. INTRODUCTION

Textile industries are large industrial consumers of waters as well as producers of wastewater [1]. Production processes not only, generate heavily polluted wastewater but also waste heat, solid waste and exhaust gas. Wastewater generated by different production steps of a textile mill have high pH, temperature, detergents, oil, suspended and dissolved solids, toxic and non-biodegradable matter, color and alkalinity. Textile wastewater if disposed off into the water bodies untreated can contaminate surface and subsurface water. The BOD/COD causes rapid depletion of oxygen content of the waters, create foul smell and it contains various toxicants or pollutants that are seriously harmful to natural aquatic environment when released without proper treatment [4].

Generally, textile wastewater is difficult to treat in aerobic plants, due to a high organic load and the presence of dyes. Anaerobic treatment can be a solution for both the problems. It has the capacity to decolorize the wastewater and it can handle high organic loads. Biogas can be used to provide heat and power, and will reduce energy costs needed for treatment plant operations [12].

Cotton manufacturing and dyeing are predominant in Karnataka state, which is one of the most important industrial sectors in India. Therefore in this study treatment of the cotton textile wastewater using EGSB is explored. The effect of operational conditions such as OLR, HRT, and influence of glucose concentration as co-substrate additives is also investigated. The granules used in the EGSB reactor were prepared using Chitosan as polymer.

II. MATERIALS AND METHODS

A. *Experimental Setup*

The laboratory scale EGSB reactor was fabricated using 5 mm thick acrylic pipe with internal diameter of 80 mm, external diameter of 90 mm, and overall height of 1860 mm. The reactor had a working volume of 8.4 L. The height of the reactor and gas-liquid-solid (GLS) separator were 1670 mm and 485 mm respectively. The provision of baffle arrangement was also made in the settler to guide the gas bubbles in to the separator, to capture the evolved gas and to allow the settling of suspended solids. The effluent flow line was 170 mm from top of the reactor. The effluent tube was connected to the water seal to prevent the escape of gas through the effluent. The gas outlet was connected to the wet gas flow meter through rubber tubing arrangement. Provision for sludge withdrawal was provided at the bottom of the reactor with 15 mm size tube. The lid of the bioreactor and other fittings were sealed to maintain strict anaerobic conditions inside the reactor. The reactor was supported by framed structure made up of mild steel. Schematic diagram of lab scale EGSB reactor is shown in Fig 1 with the following components.

1) *Feed Inlet:*

The reactor was provided with feed inlet tube of 15 mm diameter. The diameter was selected in such a way as to avoid choking in the inlet due to biomass growth. The inlet tube was connected to the peristaltic pump (PP 30 EX) through the silicon tubing arrangement.

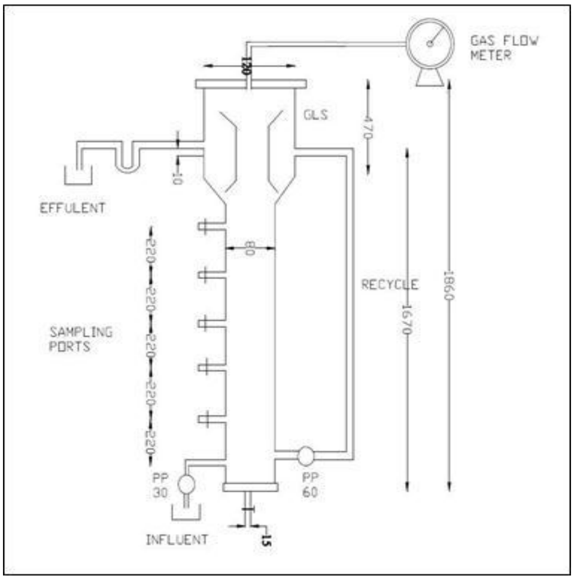
2) *Recirculation:*

The recirculation pipe was connected to the peristaltic pump (PP 60 EX). The recirculation pipe was sealed to the reactor to maintain anaerobic conditions.

Sampling Ports: Five sampling ports of 12 mm diameter at 220 mm c/c were provided along the reactor height, these sampling ports were provided in order to analyze the characteristics of wastewater (pH, Alkalinity, VFA, COD and color removal) over the reactor height.

B. *Start-Up Period*

The aim of the start-up period was to achieve granules. The reactor was inoculated with 2.7L of non granular anaerobic sludge from UASB reactor treating sugar mill wastewater of Badagandi sugar mill, at Badagandi village, Bagalkot district, Karnataka, India and active septic tank sludge. The feed contained methanol, glucose, and yeast extracts, aluminum sulphate (200 mg/L), as well as macro and micronutrients such as $CaCl_2.2H_2O$ (50mg/l), $(NH_4)_2.HPO_4$ (80mg/l), $FeCl_2.4H_2O$ (40mg/l), NH_4Cl(800mg/l), $Na_2S.9H_2O$ (300 mg/l), $CuCl_2.2H_2O$ (0.5mg/l)



All dimensions are in mm

Fig. 1: Schematic representation of an EGSB reactor

Characteristics	Value
pH	7.0+/-0.4
Total suspended solids g/l	38.4
Volatile suspended solids g/l g/l	20.4
Color	Dark grey
Volume of sludge	2.7L
Depth of sludge bed	0.556m

Table 1: Characteristics of sludge charged in to the reactor

$MgSO_4.7H_2O$ (400 mg/l), H_3BO_3 (0.5 mg/l), $MnCl_2.4H_2O$ (0.5 mg/l), $NaWO_4.2H_2O$ (0.5 mg/l), $AlCl_3.6H_2O$ (0.5 mg/l), Na_2SeO_3 (0.5 mg/l), cysteine (10 mg/l), KCl (400 mg/l), $ZnCl_2$ (0.5 mg/l), $NaHCO_3$ (3000 mg/l), $NaMoO_4.2H_2O$ (0.5 mg/l), $CoCl_2.6H_2O$ (10 mg/l), KI (10 mg/l), and $NiCl_2.6H_2O$ (0.5 mg/l), which are necessary for optimum anaerobic microbial growth [13,6,3]. Chitosan in liquid form (2ml/gm of suspended solids) is used as polymer to enhance the sludge granulation.

During the start-up period, the COD loading was gradually raised by increasing the feed concentration while keeping the influent COD constant at around 4000 mg/L. The contribution of methanol in the total influent COD was decreased from 50% to 25% on days 8 to 13, by replacing it with glucose. The yeast extract concentration in the feed was 10 mg/l and the remaining COD was supplied by methanol and glucose at different ratios. Methanol, which provided 50% of the total influent COD, initially encouraged the growth of an optimum environment [13].

C. Operation Period

In the operational period the reactor was fed with synthetic textile wastewater prepared in the laboratory. In order to better simulate the real case condition, hydrolyzed starch and dye were used. To prepare hydrolyzed starch solution, 100 g starch and 40 g sodium hydroxide were dissolved in distilled water and stirred for 15 hours at room temperature, then neutralized to pH 7 with 37% HCl, and diluted to 1 L with distilled water.

For preparation of hydrolyzed dye solution, 5g dye (pink) was dissolved in distilled water and the pH was adjusted to 12 with 1 M NaOH solution and then stirred for 1 hour at 80°C. After cooling to room temperature, the solution was neutralized to pH 7 with 37% HCl and diluted to 1 L with distilled water [6].

D. Analytical Methods

Various parameters like pH, alkalinity, volatile fatty acids (VFA), chemical oxygen demand (COD), volatile suspended solids (VSS) etc were analyzed as per standard methods (APHA/AWWA/WEF, 2000) and NEERI Manual, 1998). Bio-gas is measured by gas flow meter. Color of textile effluent is measured by UV spectrometer at 600 nm

III. RESULTS AND DISCUSSIONS

The start-up period was completed in 13 days. On 13th day granules of diameter 2 to 3.5 mm were found indicating the formation of matured granules and successful granulation within the reactor. The bed expansion was 15% during the start-up period. It was increased to and kept between 30% and 35% in the operation period. After the start-up period, the synthetic textile wastewater was fed to the reactor. The EGSB reactor was operated under different operating conditions with the aim to find out maximum OLR at which removal efficiency of COD and color in the reactor were maximum

Operational parameters	
OLR,kg COD/m^3/d	8
HRT,h	12
Expansion ,%	15
Volume of expanded bed, L	3.1

Table 2: Operational parameters at the end of start-up period for EGSB

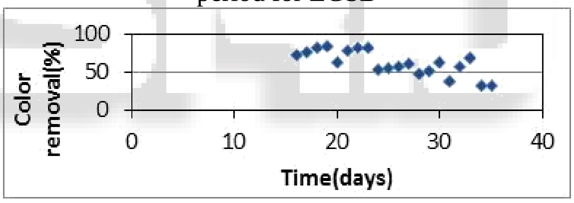


Fig. 2: Color removal efficiency during the treatment

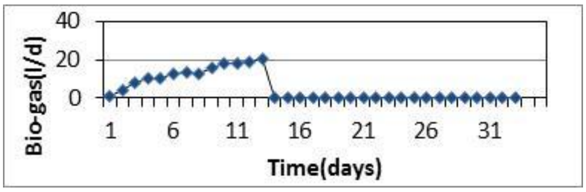


Fig. 3: Bio gas produced during the treatment

During start-up period HRT was kept constant as 12 hrs was initially preferred in order to prevent the washout of the inoculated biomass. The temperature was in mesophilic

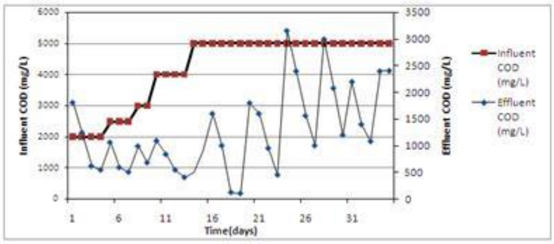


Fig. 4: Influent COD and effluent COD during the treatment

range (29ºC to 37ºC) during the study. The increments in feed concentrations were made in steps at a HRT of 12 hours until the confirmation of granulation. Feed concentration was increased from 2000 mg/L to 4000 mg/L.

Influent pH was maintained at 7 during start-up and operation period.

Initially at OLR of 4 KgCOD/m^3/d at first day the COD removal efficiency was 9.55%. Then it was increased up to 4th day and after 4th day there is drop in efficiency due to sudden increase in OLR. Feed COD was increased on 5th day. On 5th day there is drop in COD removal efficiency due to increase in OLR and then up to 7th day there is gradual increase in COD removal efficiency. On 8th day feed concentration was changed. Due to change in OLR, COD removal efficiency was decreased and it was increased on 9th day. On 10th day feed concentration was increased, which was kept constant up to granulation. On 13th day the OLR was 8 KgCOD/m^3/d. COD removal efficiency of 89.95% was obtained at organic loading rate of 8 KgCOD/m^3/d.

The ratio of VFA to alkalinity was observed between 0.2288 to 1.08 during the start-up period. At start the VFA to alkalinity ratio reached a value of 1.08 and on second day it was 0.75 indicating, system instability, during this period alkalinity was 460 mg/L and 1200 mg/L as $CaCO_3$. This can be attributed to the insufficient alkalinity generated in the reactor. Then after 2nd day the system was in stable condition as the values of VFA/Alakalinity were within the range that is from 0.25 to 0.4285. In these thirteen days maximum biogas production observed was 20.4 l/d at OLR of 8 KgCOD/m^3/d where COD removal efficiency was also maximum.

In the operation period the reactor was operated in different phases as follows.

A. *Phase I (14 to 17 days):*

In this phase, synthetic textile wastewater (25%) was fed to the reactor with methanol, glucose and yeast (75 %). Average COD concentration of textile wastewater was 5000mg/L. OLR was kept as 10 KgCOD/$m^{3/}$d. HRT applied to the reactor was 12 h. Effluent alkalinity concentration was between 1000 mg/L and 1300 mg/L (as $CaCO_3$) and VFA concentration in the effluent was lower than 520 mg/l. Which shows that reactor was in stable condition. COD removal efficiency increased from 64% to 80%. The biogas production was 400 ml on 17th day. The color removal rate was 76% on 17th day.

B. *Phase II (18 to 19 days):*

In this phase, synthetic textile wastewater (50%) was fed to the reactor with methanol, glucose and yeast (50%). HRT applied to the reactor was 12 h. Since the influent COD concentration was the same (5000 mg/l), the OLR was 10 KgCOD/m^3/ d. The COD and color removal rates were 98% and 85% respectively on 19th day, and biogas production was 300 ml/d. Here in this phase glucose addition was 1250 mg/L where the COD and color removal efficiencies were maximum. Here in this stage VFA/alkalinity ratio shows that reactor was in stable condition.

C. *Phase III (20 to 23 days):*

In this phase, synthetic textile wastewater (75%) was fed to the reactor with addition of methanol, glucose and yeast (25%). HRT applied to the reactor was 12h.Since the influent COD concentration was the same (5000 mg/l), the OLR was 10 KgCOD/m^3/ d. COD and Color removal efficiency 91% and 82% respectively. Gas production was 200 ml/d from 24th to 27th day.

D. *Phase IV (24 to 27 days):*

In this phase, synthetic textile wastewater (75%) was fed to the reactor with addition of methanol, glucose and yeast (25%). HRT applied to the reactor was 6 h. Since the influent COD concentration was the same (5000 mg/l), the OLR was 20 KgCOD/m^3/ d. Due to sudden increase in OLR the COD removal efficiency decreased to 36.8% on 24th day, and then it increased up to 80% on 27th day. There was gas production of 200 ml/d. Color removal efficiency ranged from 54 to 62%.

E. *Phase V (28 to 30 days):*

In this phase, synthetic textile wastewater (75%) was fed to the reactor with addition of methanol, glucose and yeast (25%). HRT applied to the reactor was 3 h. Since the influent COD concentration was the same (5000 mg/l), the OLR was 40 KgCOD/m^3/d. Due to sudden increase in OLR the COD removal efficiency decreased to 40%. Then it was increased to 76% on 30th day. Color removal efficiency ranged from 48 to 62.8%. There was gas production of 200ml/d.

F. *Phase VI (31 to 33 days):*

In this phase, synthetic textile wastewater (75%) was fed to the reactor with addition of methanol, glucose and yeast (25%). HRT applied to the reactor was 1.5 h. Since the influent COD concentration was the same (5000 mg/l), the OLR was 80 KgCOD/m^3/d. Due to increase in OLR, the COD removal efficiency decreased to 56%, and then it was increased up to 78.4% on 33rd day. Color removal efficiency ranges from 38 to 69%. In this stage VFA /alkalinity ratio was 0.39 which shows that reactor is in stable condition and there was gas production of 200 ml/d.

G. *Phase VII (34 to 35 days):*

In this phase, synthetic textile wastewater (75%) was fed to the reactor with addition of methanol, glucose and yeast (25%). HRT applied to the reactor was 1 hr. Since the influent COD concentration was the same (5000 mg/l), the OLR was 120 kg COD/m^3/d. Due to sudden increase in OLR the COD removal efficiency was decreased to 52% on 35th day, and color removal efficiency was also very low that is 32%. Thus the optimum value of OLR is 80 KgCOD/m^3/d at which COD and color removal efficiencies were 78.4% and 69% respectively.

As a result it was observed that further increase in OLR did not improve the COD and color removal efficiency. Therefore phase VI represented the optimum condition where textile wastewater for OLR of 80 KgCOD/m^3/d can be treated.

IV. CONCLUSIONS

Active non granular anaerobic sludge as a seed, with suitable nutrient for wastewater along with aluminum sulphate and Chitosan as natural polymer enhances the granulation. Successful granulation was achieved within a short period of 13 days resulting in granules of 2 to 3.5 mm diameter under ambient conditions (29ºC to 37ºC) using glucose as substrate.

The results indicated that the anaerobic treatment of the textile wastewater studied was found to be optimal with the addition of an external carbon source in the form of 600 mg/l glucose (with the influent COD concentration of 5000 mg/L). The observed improvement in the color removal with the addition of 600 mg/l of glucose is in agreement with the literature, which underlines the significance of external carbon source supplementation to anaerobic reactors treating dye/textile wastewater. The optimum HRT for EGSB treating textile waste is 1.5 hrs with OLR of 80 KgCOD/m3/d. In anaerobic reactor OLR of 80 KgCOD/m3/d is considered to be very good. The anaerobic treatment of textile wastewater is justified.

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