Effect of temperature on biodegradation of textile dyeing effluent using pilot scale UASB Reactor

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***Abstract*— *This study deals with the effect of temperature on treatment of real textile dyeing effluent using pilot scale two-phase Upflow Anaerobic Sludge Blanket (UASB) reactor with sago effluent as co-substrate under recycle mode. The temperature of the reactor was varied viz. 35, 40, 45 and 50 ^{0}C. The feed of the reactor was 30% of methanogenic outlet recycled and 70% of 70/30 (sago/textile dyeing effluent) mixing ratio were given at the bottom of the reactor. The reactor was operated at 24 h of HRT. The performance of the bioreactor was evaluated by monitoring the removal of Chemical Oxygen Demand (COD), removal of color, Volatile Fatty Acid (VFA) and biogas production. The overall COD and color removal were achieved maximum of 98.4% and 99.3% respectively. Based on temperature, the biogas production (0.512 m^3/d) was maximum at 45^{0}C. From the VFA and alkalinity ratio values obtained indicate that the reactors were operated under steady state. The results shows, that the sago and textile dyeing effluent have wide variation in their characteristics were treated on combination, whereas the recycle ratios maintain the stability of reactor. This new technology supports the effective utilization of sago effluent in destruction of dyeing effluent; the optimum temperature for efficient reactor operation was 45^{0}C.*

***Keywords*— Textile dyeing, sago, UASB, temperature, recycle.**

I. INTRODUCTION

Textile industries are found in most countries and their numbers have increased, particularly in Asia. The annual world production of textiles is about 30 million tonnes requiring 700,000 tonnes of different dyes (Asia et al. 2006) which cause considerable environmental pollution problems. The textile industry which is one of the largest water consumers in the world, discharges wastewater containing various pollutants such as degradable organics, colors, nutrients, pH altering agents, salts, sulfur, toxicants and refractory organics (Wouter et al. 1998). Under typical reactive dyeing conditions, 20–50% of the dye remains in the spent dye bath in its unfixed hydrolyzed form, which has no affinity for fabric, resulting in colored effluents (Lewis 1999; Georgiou et al. 2005). The most commonly used dyes today are reactive dyes for cotton dyeing. Reactive dyes are easily hydrolyzed, resulting in a high portion of unfixed dyes that have to be washed off during the dyeing process (Sen and Deminer 2003) as the discharge of dye house wastewater into the environment is aesthetically displeasing, impedes light penetration, damages the quality of receiving streams and toxic to aquatic life. It is difficult to remove color from the effluents by conventional wastewater treatment systems (Sandhya and Swaminathan 2006; Gnanapragasam et al. 2011). As McCurdy et al. (1991) stated there is no universal method for the removal of color from dye waste; the alternatives depend upon the type of dye wastewater. Anaerobic treatment alone has been shown to remove COD and color from textile dyeing effluents and has the advantage of lower sludge production and lower energy demand compared to aerobic treatment.

There are recent reports which are available for treatment of real textile dyeing effluent in anaerobic systems. Among the anaerobic processes, Upflow Anaerobic Sludge Blanket (UASB) reactor has been widely used to treat variety of industrial and domestic wastewaters all over the world. One common feature offered by all the high-rate processes is their ability to provide high Solid Retention Time (SRT) in relation to Hydraulic Retention Time (HRT). High biomass concentration is maintained in a reactor with relatively low treatment time. The granular sludge with good settling velocities and mechanical strength, and suitable for the treatment of wastewater containing xenobiotic and recalcitrant compounds, and it promotes adaptation of bacteria in toxic compounds, and as well as it can be used for treatment of wastewater previously considered unsuitable for anaerobic treatment (Somasiri et al. 2006). Somasiri et al. (2008) had already reported the colour and COD removal, reactor performance, and stability in textile wastewater treatment by upflow anaerobic sludge blanket reactor at mesophilic temperature. The aim of this study is to decolourize the real textile wastewater containing textile dye using starch industry effluent as co-substrate in hybrid bi-phasic UASB reactor by varying the temperatures as 35, 40, 45 and 50 ^{0}C. The whole processes were operated at the optimum recycle ratio of 70:30 (Gnanapragasam et al. 2010).

II. MATERIALS AND METHODS

2.1 Biomass

The methanogenic granular sludge with unknown microorganisms used in this experiment was procured from the anaerobic digester treating sago effluent at M/s Perumal SAGO factory, Salem, Tamilnadu, India. Before loading the reactor, granular sludge was clearly washed, filtered through a fine mesh ASTM 16 to remove all floating and suspended contents. The volatile suspended solids content of the sludge was estimated as per the standard methods and found to be 60, 000 mgL^{-1} (APHA-AWWA-WPCF, 2005).

2.2 Wastewater

Real untreated wastewater from sago industry and textile dyeing industry was collected at Salem, Tamilnadu, India. Ten samples were collected from each industry for duration of three months and the mean values of the parameters are given in Table 1. The analysis of the wastewater was carried out according to standard methods (APHA-AWWA-WPCF, 2005).

TABLE 1
CHARACTERISTICS OF WASTEWATERS

S.No.	Parameters**	Textile dye effluent	Sago Effluent
1	pH	12.8	4.5
2	Total Suspended Solids	420	640
3	Total Dissolved Solids	3520	1200
4	Chlorides	1520	400
5	Sulphates	180	123
6	BOD	175	2400
7	COD	1600	6000

****All values except pH are mgL^{-1}**

2.3 Experimental Setup

In order to study the operational and performance of UASB reactor, a two-phase UASB reactor was fabricated. The acidogenic and methanogenic reactors were fabricated with 1:4 volumetric ratios. The first phase was an acidogenic reactor (300 mm inner diameter and 820 mm height) was made up of plexi-glass with working volume of 56 L which was maintained at room temperature (30±5^{0}C). A stainless steel methanogenic reactor (350 mm inner diameter and 2400 mm height) with working volume of 230 L. Two heaters were fixed, one at 300 mm and another at 900 mm from the bottom of the reactor which was interconnected for maintaining the temperature of the sludge bed. The heaters were connected to the temperature controller to vary temperatures and monitored by temperature probe connected to the Programmable Logic Control (PLC). The reactor was operated at effluent recycle mode. Feed of the reactor consists of 70% of real sago wastewater and 30% of real textile dye effluent which was optimum (Senthilkumar et al. 2011) and the methanogenic outlet from the reactor was recycled, the optimum recycle ratio was 30% (Gnanapragasam et al. 2010). With the above optimum values the studies were carried out by increasing the temperature of the reactor viz. 30, 35, 45 and 50^{0}C. The feed was given at bottom of the acidogenic reactor and the outlet from acidogenic phase was immediately pumped to the methanogenic reactor. Sampling ports were provided at equal spacing of 400 mm from bottom of the reactor to the top. On the top of the reactor, gas deflection was attached. The Gas-Liquid-Solid Separator (GLSS) consisted of an inverted conical funnel at top of the water column for the collection of biogas. In addition to the GLSS arrangement, a packed medium consisting of a PVC spirals size of 26 mm, surface area 500 m^2 m^{-3} and void ratio 87% has been provided a height of 200 mm locating at 1770 mm from the bottom of the reactor. The spiral will retain the biomass in addition to giving polishing effect to the effluent. The sludge granules trapped in GLSS and the spirals will return to the reactor as soon as the gas entrapped inside the granules is released. Biogas generated was measured using wet gas flow meter. At steady state of the bioreactor performance parameters like COD, pH, color removal were relatively constant (<10%).

III. RESULT AND DISCUSSION

3.1 Color removal

The Figure 1 shows color removal efficiency at different temperatures (35, 40, 45 and 50 ^{0}C) using two-phase upflow anaerobic sludge blanket reactor with optimum mixing and recycle ratio. The colour removal efficiency in acidogenic reactor varies from 42.8-44.2 %. From the Figure 4 the color removal efficiency was 96.2% at 35^{0}C, 98.2% at 40^{0}C, 99.3% at 45^{0}C, and 82.4% at 50^{0}C. The maximum overall colour removal achieved was 99.3% at 45^{0}C. From the above result shows that as the temperature of the sludge bed increases the colour removal efficiency were increased. This indicates that the mesophilic organisms are capable of degrading textile dyeing wastewater. Haroun and Idris (2009) had studied the treatment of textile dye wastewater at various temperatures using anaerobic fluidized bed reactor, the maximum removal of color was 65% achieved at optimum temperature of 37^{0}C. Maximum overall color removal of 94% were achieved by Somasiri et al. (2006) treating textile dye wastewater containing acid dyes in UASB reactor system under mixed anaerobic granular sludge at the optimum temperature of 38^{0}C. Somasiri et al. (2008) had reported maximum colour removal of 95% in textile wastewater treatment by upflow anaerobic sludge blanket reactor at mesophilic temperature

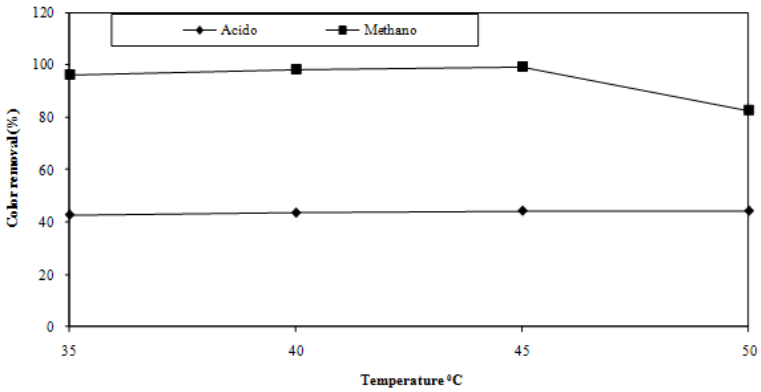

FIG. 1 COLOR REMOVAL EFFICIENCIES DURING THE PROCESS

3.2 COD removal

The effect of temperature on removal of COD at the optimum recycle ratio was investigated using upflow anaerobic sludge blanket reactor. Figure 2 shows the concentration of COD for inlet, acidogenic reactor outlet and methanogenic reactor outlet were 5120-5200 mg/L, 3040-3280 mg/L and 160-960 mg/L respectively. COD removal efficiency at different temperature was shown in Figure 3. From the Figure 3 it was evident the COD removal efficiency in methanogenic reactor increases as the temperature increases 96.1% (35^{0}C), 97.2% (40^{0}C), 98.4% (45^{0}C) and 80.6% (50^{0}C). The maximum removal of COD (98.4%) was achieved at 45 ^{0}C. Asia et al (2006) had also reported under mesophilic condition (35±2^{0}C) the COD reduction was about 89 % treating textile sludge using anaerobic technology. Panswad and Luangdilok (2000) had studied by varying the temperature as 20^{0}C, 28-33^{0}C (Room temperature) and 40^{0}C in decolorisation of reactive dyes with different molecular structures. Higher reduction of COD of about 98 % was achieved by Haroun and Idris (2009) by treating textile wastewater with an anaerobic fluidized bed reactor. Somasiri et al. (2008) had reported maximum COD removal of 98 % in textile wastewater treatment by upflow anaerobic sludge blanket reactor at mesophilic temperature.

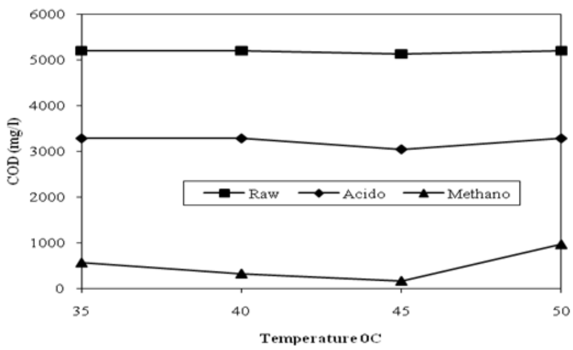

FIG. 2 CONCENTRATION OF COD DURING THE PROCESS

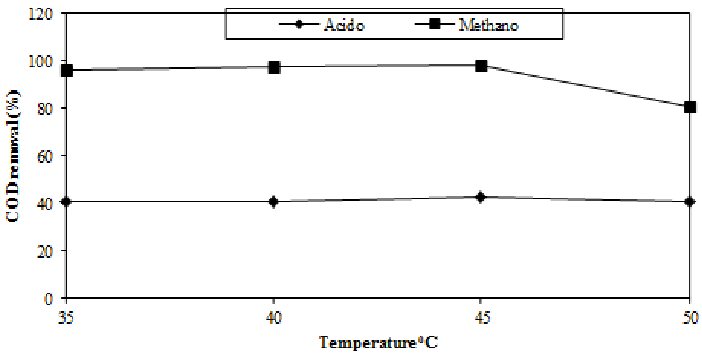

FIG. 3 COD REMOVAL DURING THE PROCESS

3.3 Biogas production

The Figure 4 shows biogas generation at different temperatures 35, 40, 45 and 50^0C. The maximum biogas production was about 0.512 m^3/d were achieved at 45^0C (Figure 4) in methanogenic reactor. The biogas production increases as the temperature increased at 35^0C were 0.386 m^3/d, at 40^0C were 0.456 m^3/d and at 45^0C were 0.512 m^3/d; whereas, at 50^0C the biogas production was decreased to 0.439 m^3/d. Gnanapragasam et al. (2010) had achieved 0.335m^3/d of biogas using same reactor with recycle of methanogenic outlet at room temperature (30±2 ^{0}C). The biogas production was high under mesophilic conditions rather than thermophilic conditions i.e. the biomass get decayed when the temperature were increased from 45^0C to 65^0C (Jayantha and Ramanujam 1996).

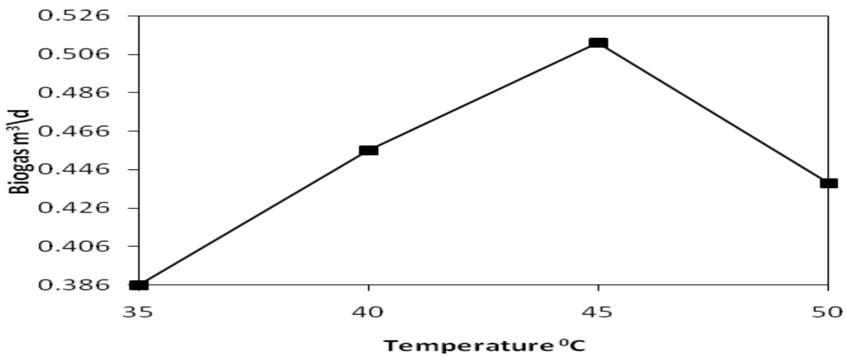

FIG. 4 BIOGAS PRODUCTION DURING THE PROCESS

3.4 Volatile fatty acid/Alkalinity

Volatile fatty acid (VFA) and alkalinity ratio for both the acidogenic and methanogenic reactor at different temperature were shown in Figure 5. The ratio of volatile fatty acid and alkalinity for the outlet of acidogenic reactor varies from 1.48-1.51 and for methanogenic outlet varies from 0.031-0.036. Senthilkumar et al (2009) had reported that for stable operation of the upflow anaerobic sludge blanket reactor VFA/Alkalinity ratio for acidogenic reactor must be in the range of 1.3-1.5 and for methanogenic reactor must be in the range of 0.04-0.09. From Figure 5 it is clear that in this study both the acidogenic and methanogenic reactor was under stable conditions in all the temperatures.

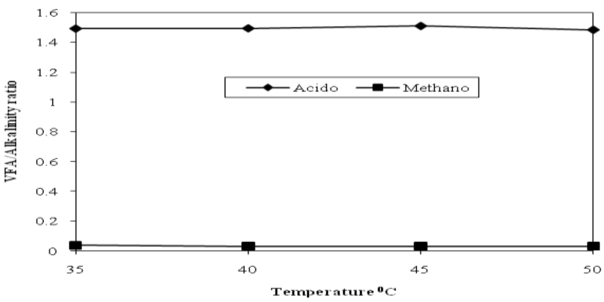

FIG. 5 VFA/ALKALINITY RATIO DURING THE PROCESS

IV. CONCLUSION

Anaerobic treatment is now feasible for a wide variety of wastewaters and the successful operation of anaerobic digestion process is a knowledge intensive task. For tropical countries UASB concept has flexibility for low and high strength wastewaters under varying atmospheric conditions. Overall COD and color removal efficiency of 97% and 96 % at 45^0C, 24 h HRT. Volatile fatty acid and alkalinity ratio was under control and the reactor was operated at stable conditions. Maximum production of biogas was about 0.512 m^3/d. By increasing the temperature here achieved the higher removal of COD and also more production of biogas. From the results it was clear that upflow anaerobic sludge blanket reactor was more efficient at increased temperature.

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