Development of a novel anaerobic reactor for treating textile dyeing wastewater

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Abstract

For purposes of improving the quality of the discharged effluent by means of saving chemical and power costs, this paper reports on an experimental program which combines wastewater treatment system of anaerobic acetogenic pre-treatment followed by aerobic polishing to treat textile processing wastewater. By operating bench-scale reactors in controlled conditions, using real life wastewater from textile processing facilities, and by monitoring reactor performance, kinetics of transformation, treated water quality, this experimental program has shown that anaerobic acetogenic pre-treatment is capable of successfully pre-treating textile processing wastewater achieving substantial waste stabilization. The efficacy of the process showed over ninety percent decrease of chemical oxygen demand a parameter describing waste strength and substantial removal of colour from textile processing wastewater.

Keywords: Acetogenic; Anaerobic; Pre-treatment; Textile Wastewater; Energy Conservation

1. Introduction

In recent years, Bangladesh textile industry has gone through an unprecedented growth. Bangladesh is now the one of the leading manufacturers and suppliers of readymade garments in the world. Substantial part of its economy is based on textile earnings. Unfortunately, the growth has happened in an unplanned manner and the sustainability of the industry is under threat due to shortage in resource mainly water and energy. Leading houses of retail and the Government of Bangladesh is asking the textile manufacturers to operate in a sustainable manner. This calls for efficient wastewater treatment in an energy efficient manner. The existing wastewater treatment systems are energy intensive and heavily dependent on imported technology and chemicals [1-5].

In this paper we are reporting on a bench scale experimental program using a novel application of anaerobic acetogenic treatment for the first time to pre-treat reactive dye textile processing waste water to reduce loading to conventional aerobic treatment thereby saving energy required in conventional extended aeration process conventionally used for textile wastewater treatment. The concept of acetogenic pre-treatment has been applied to high strength easily biodegradable wastewaters such as food waste [6-8], but was never applied to complex moderate strength wastewaters. In this experimental program at the bench level have developed a treatment train that incorporates acetogenic pre-treatment with aerobic polishing and microfiltration. We looked at the efficacy of the system and also reported on the energy savings potential of the newly developed treatment system when compared to conventional extended aeration aerobic treatment system to treat reactive dyeing wastewater from a Terry Towel processing facility.

2. Problem identification and basic principle

The basic principle reported in this paper is the development of a treatment train to treat textile dyeing wastewater using anaerobic acetogenic pre-treatment to reduce substantially the loading to the aerobic basin then coupling that to aerobic polishing and micro filtration to produce a treatment system which is more energy efficient to the standard extended aerobic treatment system for textile wastewater treatment. The treatment train used in the program is outlined in Figure 1 below.

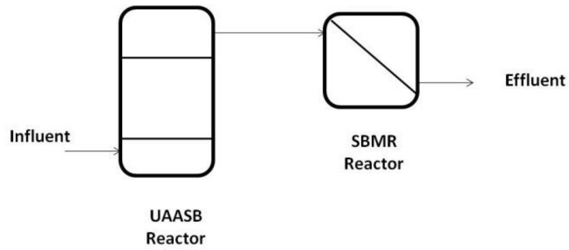

Fig. 1 Schematic flow diagram of the proposed, modified treatment train for wastewater treatment from textile processing facilities. UAASB stands for up-flow anaerobic acetogenic sludge blanket reactor and SBMR stands for sequential batch membrane reactor.

The experimental program conducted and reported in this experimental program was designed to assess the effectiveness of a treatment train combining anaerobic acetogenic pre-treatment with aerobic polishing and microfiltration. The test case wastewater was from a Terry Towel Textile Manufacturing Plant at Gazipur, Dhaka, Bangladesh. Noman Terry Towel Mills is the largest terry towel manufacturer in Bangladesh.

3. Methodology

This treatment system envisioned and conducted in the bench level at the laboratory should serve as the envisioned treatment train in real life application. Central to the testing program is the operation of a treatment train at the bench level consisting of an anaerobic acetogenic reactor, followed by an aerobic polishing reactor and a microfiltration membrane filtration system. Raw wastewater is fed to the anaerobic acetogenic reactor for pre-treatment, the treated effluent from the anaerobic acetogenic reactor is fed to the aerobic polishing reactor, and the effluent from the polishing reactor is the filtered through the micro/macro-filtration unit and is the final treated effluent.

The anaerobic acetogenic reactor used in this experimental program was a two liter glass vessel with a one liter liquid volume. The content of the reaction vessel is continuously stirred by means of a magnetic stirrer. The reactor was seeded with sludge from an extended aeration aerobic treatment system treating textile processing facility. The reactor was operated in a semi-continuous batch operation with daily waste feeding once per day with the waste feed volume of 250 ml (1/HRT). The reactor was operated at a HRT of 4 day reflecting a washout condition to enhance acetogenisis and limit methanogenesis. Periodic reseeding was done using sludge from the polishing reactor to prevent complete washout of the acetogenic reactor. Further, provisions were built in the reactor to periodically purge the reactor with air to limit methanogenisis. The reactor was purged once on a daily basis by bringing the dissolved oxygen concentrations to 2.0 mg/L to shock kill the methanogens [6-8].

The reactor was maintained at mesophilic temperature (25-40 ^{o}C). The reactor operating parameters such as temperature, total suspended solids, pH, volatile fatty acids, soluble chemical oxygen demand, and colour was monitored on a daily basis.

To ensure culture acclimation the reactor was operated till ninety five percent volume turnover or for three HRT's. Kinetic studies were once the cultures were acclimated and the details of procedure and modeling of the kinetic studies have already been reported [9-12].

The aerobic polishing reactor used in this experimental program was a one liter glass vessel with a 500ml liquid volume. The content of the reaction vessel is continuously stirred by means of a magnetic stirrer. The reactor was seeded with sludge from an extended aeration aerobic treatment system treating textile processing facility. The reactor was operated in a semi-continuous batch operation with daily waste feeding once per day with the waste feed volume of 150 ml (30 % of reactor liquid volume). The reactor operation reflected the design and operation of a conventional sequential batch reactor applied in industrial wastewater treatment as a polishing unit. The reactor was constantly aerated using a fine bubble diffuser and the dissolved oxygen concentration at all times was maintained greater than 2.0 mg/L assuring complete aerated condition.

The reactor was maintained at mesophilic temperature (25-40 ^{o}C). The reactor operating parameters such as temperature, total suspended solids, pH, and dissolved oxygen was monitored daily, soluble chemical oxygen demand and colour was monitored on a daily basis after microfiltration.

The microfiltration unit consisted of a 0.45micron cellulose acetate filter that is commonly used in water filtration. The water flow through the micro filter was by gravity.

The sampling and analysis procedures are outlined in depth elsewhere[8-11].

4. Results and discussions

This experimental program was conducted using a twenty four hour time proportioned composite wastewater sample that was collected from the equalization basin of the terry towel textile manufacturing plant was characterized and reported as mean ± Standard deviation (refer to Table 1). The existing wastewater treatment facility uses extended aeration with a HRT of 60 hrs as its treatment system. The current wastewater generation at Noman Terry Towel is around 6000 m^3 per day with an expected anticipated increase to 10,000 m^3 per day over the next five years the current measured BOD_5 of 2170 mg/L the loading to the aeration basin would be 13, 000 Kg/day. Thus the energy requirement for aeration at 4.0 kWh/Kg-d BOD_5 for fine bubble diffusers for the existing plant is estimated at 52, 000 kWh/day (2.1 mega watt).Thus anaerobic acetogenic pre-treatment would be an attractive option to save energy for the establishment.

Table 1. Characteristics of the wastewater.

Parameter	Value
TSS (mg/L)	1783± 619
TDS (mg/L)	1963 ± 10
pH	9.6 ± 0.3
Colour (ptco)	3540 ± 353
COD (mg/L)	5186 ± 138
BOD_5 (mg/L)	2170 ± 120

The acetogenic reactor was operated for more than three HRT (12 days) to ensure attainment of steady state operation. The anaerobic acetogenic reactor upon steady state operation was able to reduce the chemical oxygen demand (COD) by 96.5 % (Figure 2) and reduce the colour in the wastewater by 96.8 % (Figure 3). There was no need for pH adjustment in the operation of the anaerobic acetogenic reactor (Figure 4). The pH was adjusted by the acetic acid produced by the acetogenic degradation process.

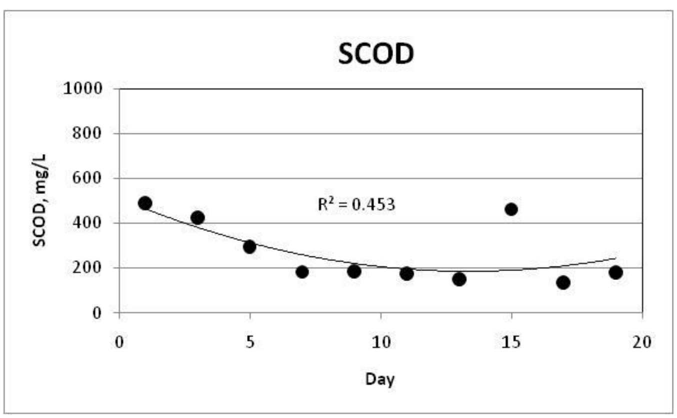

Fig. 2 Reactor effluent soluble chemical oxygen demand SCOD of master culture semi continuous batch anaerobic acetogenic reactor.

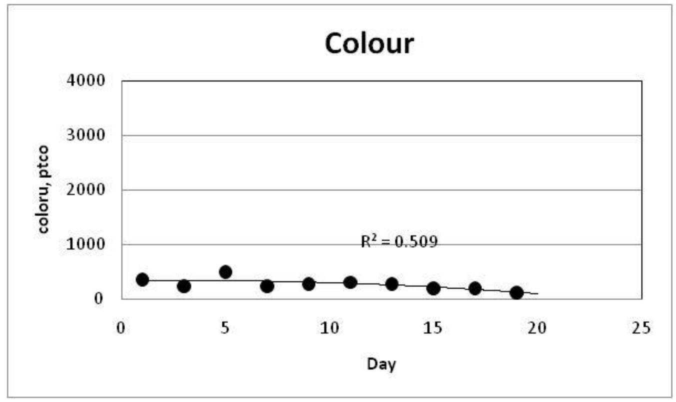

Fig. 3Reactor effluent colour of master culture semi continuous batch anaerobic acetogenic reactor.

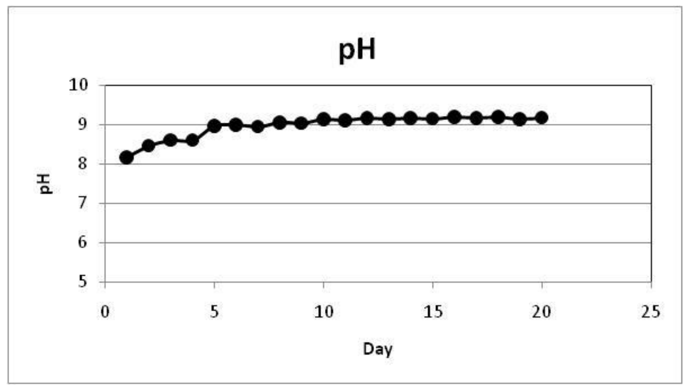

Fig. 4Reactor effluent pH of master culture semi-continuous batch anaerobic acetogenic reactor.

The aerobic polishing reactor was operated as a sequential batch reactor with the waste feed volume of 30 percent of the reactor liquid volume. The reactor operating average mixed liquor suspended solids was 2057 mg/L, at an operating temperature of 28.05 ± 0.53. The reactor operating pH was 9.22 ± 0.11. The reactor mixed liquor suspended solids were filtered through a microfiltration system and the filtrate is considered as the final treated effluent. The final effluent quality after treatment which included anaerobic acetogenic pre-treatment followed by aerobic polishing and microfiltration is listed in Table 2. Of the parameters monitored in the experimental program, the proposed treatment train produced a wastewater that can be safely discharged within the regulatory standard of the government of Bangladesh for discharge to inland water bodies with respect to the critical parameters of concern of COD, BOD_5, and TDS. The only parameter that is borderline is the pH which slightly exceeds the limit but can easily be remedied with slight pH adjustment before discharge. Of concern was the volatile fatty acid produced in the anaerobic acetogenic reactor and whether it would be released to the environment. The aerobic polishing totally removed the acetic acid from the wastewater and thus producing a benign safe wastewater. Although there are no standards for colour in discharge water it is highly desirable for colour in water affects adversely the aquatic environment by limiting light penetration, this treatment process has successfully removed colour from the wastewater from the high value of 3540 ptco to 139 ptco. In essence the colour was completely removed from the wastewater. The proof of success of the colour removal is the picture showing the blue dyeing wastewater and the clear treated wastewater held next to each other in Figure 5.

Table 2. Characteristics of the treated effluent after anaerobic acetogenic pre-treatment and aerobic polishing.

Parameter	National Standards	Effluent Water Quality
TSS (mg/L)	100	67 ± 619
VFA (mg/L)	No limit	0
pH	6.5 – 9	9.22 ± 0.11
Colour (ptco)	No limit	139 ± 42
COD (mg/L)	200	163 ± 10
BOD_5 (mg/L)	50	<50
TDS (mg/L)	636 ± 88	2100

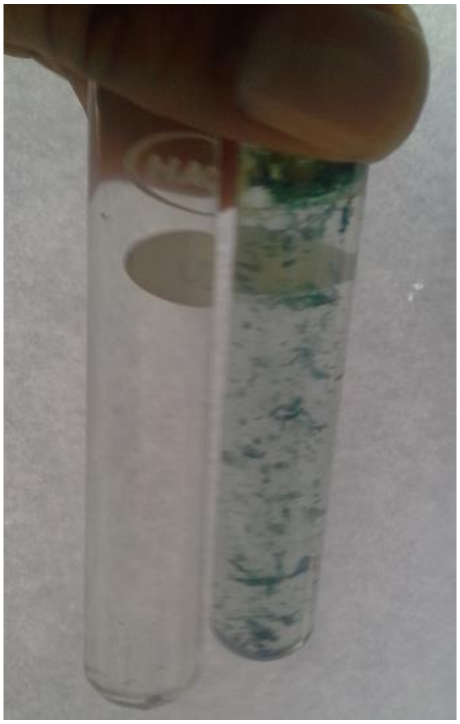

Fig. 5Picture of raw wastewater against treated effluent clearly showing visually the success of the treatment process.

At the current wastewater generation and loading of be 13, 000 Kg/day at Noman Terry Towel the energy requirement for aeration at 4.0 kWh/Kg-d BOD_5 for fine bubble diffusers for the existing plant is estimated at 52, 000 kWh/day (2.1 mega watt).Thus anaerobic acetogenic pre-treatment would reduce the loading to the aeration basin by 96.5 % or 12,500 Kg/day.Thus this would mean an aeration energy savings of 50,000 kWh/day or roughly 2.0 megawatts of power saving. The total power generation of Noman Terry Towell is 8.0 megawatts. Thus acetogenic pretreatment of the wastewater would reduce the energy consumption by the establishment by 25%. Energy saving is energy generation and the 25% reduction in energy consumption would make this amount of energy available for other beneficial production purposes. The establishment of concern is limited by energy production capacity in their future expansion plans and introducing the pretreatment option would provide them with the energy capacity without incurringadditional cost of operation. A win win situation in terms of energy needs and sustainable operation.

5. Conclusions

The pre-treatment of anaerobic acetogenic followed by aerobic polishing using membrane reactor has been shown to be successful in treating textile processing wastewater and breaking down complex organics with high degree of COD and colour removal efficiency and also saving substantial amount of energy. The treated effluent complies with the regulatory limits set by the Government of Bangladesh. The benefits of this co-treatment as a sustainable solution will be even more felt once, it is implemented, to replace the stand-alone aerobic treatment, in the textile wet processing plants across the country.

Abbreviations

BOD_5=Biochemical Oxygen Demand, mg/L
COD=Chemical Oxygen Demand, mg/L
TSS=Total Suspended Solids, mg/L
TDS=Total Dissolved Solids, mg/L

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