



Acetogenic Aerobic Sequential Batch Reactors in Series Operation for Textile Wastewater Treatment

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Abstract

This paper reports on the efficacy of textile wastewater treatment using series operation of acetogenic sequential batch reactor followed by aerobic sequential batch polishing reactor. The experimental protocol was conducted using wastewater obtained from the equalization basin of a composite textile wastewater treatment plant. The experimental reactors were operated at the bench level under controlled conditions. The acetogenic reactor was maintained in a washout mode with daily shock aeration and the aerobic reactor was constantly aerated. Both acetogenic lead reactor and aerobic polishing reactor influent and effluent water were monitored for color, COD, BOD₅, TDS, and pH. The reactor HRT, TSS, F/M ratio, and temperature, were also monitored and controlled. The treatment train was operated till steady state operation was ensured and the data analyzed to determine the efficacy of the treatment system with respect to textile wastewater treatment. The results indicated that after a period of culture acclimation high rates of wastewater stabilization was achieved by the system. The color, BOD₅, COD, removal efficient were greater than 95%. The experimental program confirmed that acetogenic pretreatment followed by aerobic polishing is a viable option for treating textile processing wastewater.

Keywords: Textile wastewater, Acetogenic/Aerobic, Treatment

1 Introduction

The complexity of textile wastewater calls for treatment systems that are complex requiring multiple stages of treatment. The process flow train for textile wastewater treatment involves pH adjustment, colloidal solid and color removal by chemical addition and clarification, followed by degradation of soluble biochemical oxygen demand through extended aeration aerobic treatment (1). The soluble biochemical oxygen demand removal is the heart of the treatment process with hydraulic retention time higher than conventional aeration basin application in sewage treatment. Hydraulic retentive higher than thirteen hours is mandated by the Department of Environment (2). In actuality treatment systems are designed with hydraulic detention times from thirty to eighty hours. Although the combined physical chemical biological treatment system is the industry norm, the process is expensive to operate due to the requirement of chemicals in the chemically aided settling to remove color, and the high energy intensity of the extended aeration process to remove the soluble organics. This places an undue burden to resource challenged countries in developing economies. To make the textile industry more sustainable we have developed a process that is independent of chemicals and is also less energy intensive than the combined physical chemical biological process. This process is a two-step process, that involves acetogenic treatment requiring very little aeration as the first step followed by aerobic polishing.

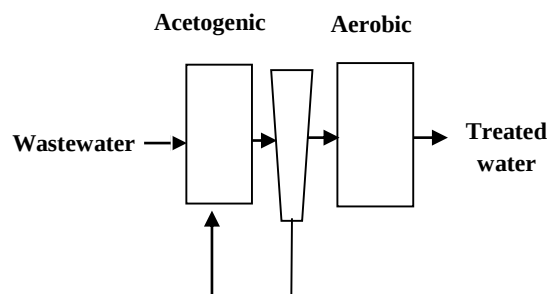


Figure 1: Schematic of the two stage process

In the proposed process the textile wastewater enters after screening directly to the acetogenic reactor where acetogenic microorganisms prevail. The acetogenic reactor has a hydraulic retention time (HRT) of four days with only a periodic shock aeration once per day instead of continuous aeration to maintain acetogenic operation. The reactor effluent is sent to a clarifier where the acetogenic biomass is recycled back to the acetogenic reactor periodically to prevent reactor washout. The effluent from the clarifier is polished in a continuously aerated aerobic reactor operated in a sequential batch mode. The reactor effluent is passed through a membrane ensuring that the polishing reactor mixed liquor suspended solids are kept in the reactor.

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The efficacy of the process was evaluated through a period of steady state operation ensuring high degree of wastewater stabilization defined by extent of chemical oxygen demand (COD), bio chemical oxygen demand (BOD₅), and color removal. The overall objective was to develop an energy efficient alternative to the conventional treatment process used for textile wastewater treatment that also does not require any chemicals for operation. This process will go a long way to make the textile processing more sustainable.

2 Materials and Methods

Raw wastewater: The test wastewater was collected from the wastewater equalization basin of one of the largest towel manufacturer in the world, Talha Terry Towel, in Gazipur, Bangladesh. The wastewater was a time proportioned sample collected over twenty-four hour of operation of the wastewater treatment plant.

Seed: Both the acetogenic and aerobic polishing reactor was seed with waste mixed liquid suspended solids from the wastewater treatment plant sludge thickener of the Talha Terry Towel.

Reactor Configuration: In the bench scale react setup the textile wastewater was fed directly to the acetogenic reactor where acetogenic microorganisms prevailed. The acetogenic reactor has a hydraulic retention time (HRT) of four days with only a periodic shock aeration once per day instead of continuous aeration to maintain acetogenic operation. The acetogenic reactor effluent was sent to a clarifier where the acetogenic biomass was recycled back to the acetogenic reactor periodically to prevent reactor washout. The effluent from the clarifier was polished in a continuously aerated aerobic reactor operated in a sequential batch mode with the effluent passed through a membrane ensuring that the mixed liquor is kept in the reactor. The treated effluent was analyzed on a daily basis for water quality parameters.

Anaerobic acetogenic reactor: The bench scale reactor was a glass vessel with a liquid volume of 1.0 L. The reactor content was completely mixed (Figure 2). The reactor was maintained at a (HRT) of 4.0 days. Every day 250 ml was wasted and 250 ml of the wastewater was fed to the reactor. The short HRT reflects an operation condition known as washout mode of operation that is the food to microorganism ration (F/M) increases with every day of operation. To further prevent methanogenic microorganisms from growing in the reactor in a daily basis, the reactor content is purged with air and raise the dissolved oxygen level in the reactor to 2.0 mg/L (3) (4) (5). Based on our prior experience in operating anaerobic acetogenic reactor that F/M ratio of greater than 1.0 causes reactor failure (6). To negate this the reactor waste MLSS recycled back to the acetogenic reactor periodically. The reactor pH, temperature and MLSS were monitored on a daily basis.

Aerobic Membrane Batch Reactor: The aerobic batch reactor had a liquid volume of 500 ml and was maintained in a waste feed mode on a daily basis (50 ml waste/feed volume). The reactor was continually aerated. The reactor effluent was passed through a membrane to separate the liquid from the biomass. The MLSS was not wasted for the duration of the testing program.

Analysis: The composite wastewater was analysed for COD, BOD₅, color, and TDS. The aerobic reactor effluent was centrifuged and the supernatant was saved on a daily basis and analysed for COD, BOD₅, and color for all days of operation as per standard methods (7). For spaced days of operation saved

effluent samples for the acetogenic reactor were sent for Furrier Transformation Inferred Spectrophotometric analysis (FT-IR).

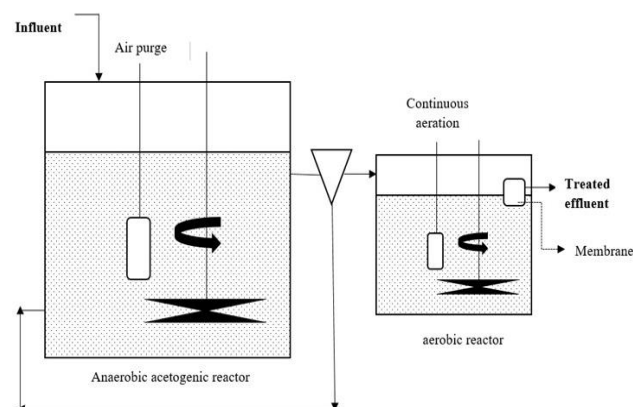


Figure 2: Acetogenic aerobic wastewater treatment used at the bench level

Specific oxygen consumption (SOUR): The oxygen utilization rate (OUR) was measured at day twenty by transferrin the aerobic culture to two 100 ml beakers. One reactor was fed 10 ml untreated textile wastewater and the other reactor was fed 10 ml of acetogenic reactor effluent. The surface of the liquid volume was covered with plastic foil to prevent oxygen transfer and the reactor dissolved oxygen was measured real time to determine the oxygen consumption for an hour to determine the OUR. The Specific oxygen consumption for both the wastewater were then determined by dividing the OUR by the reactor MLSS.

3 Results and Discussions

In line with biological treatment process to treat wastewater from industries this experimental program looked at textile processing wastewater treatment possibility using biological acetogenic process (6, 10, 11). The composite wastewater characteristic used in the study was a complex wastewater with high BOD₅ (3500 ± 114 mg/L), COD (5186 ± 138 mg/L), and color (3540 ± 353 ptco). The BOD/COD ratio of 0.67 makes the wastewater a good candidate for biological treatment and served as the challenge wastewater for the combined acetogenic aerobic polishing treatment process. The total dissolved solids and the total suspended solids of the test wastewater were 1963 ± 10 mg/L and 1783 ± 619 mg/L on an individual basis. The pH of the wastewater was 9.6 ± 0.26 .

The picture contrasting the color removal between the influent untreated wastewater and the treated water along with the biochemical oxygen demand (BOD₅) and the chemical oxygen demand (COD) removal trends for the combined process are shown in Figure 3a-c. From the onset the combined acetogenic aerobic process was able to treat the wastewater to a high degree of efficiency. Over the period of 20 days of operation the system consistently achieved complete removal of color as shown by the picture contrasting the influent blue color and clear treated water and greater than 95% removal efficiency of BOD₅, and COD for the twenty days of operation. Also the system did not require any period of acclimation prior to achieve the high degree of waste stabilization observed. The reason may be that the seed source was from the same wastewater treatment plant where the test wastewater was from and the culture is already acclimated to the wastewater. The microorganism present had the ability to produce

the enzymes for degradation of the wastewater. The quality of the treated water (Table 1) is within the regulatory standards of the Government of Bangladesh Standards for discharge into inland water bodies such as lakes and rivers of pH = 6-9, BOD₅ < 50 mg/L, COD < 200 mg/L, TSS = 150 mg/L, and color < 150 ptco (Environment, 2008). This emphatically emphasizes that the acetogenic pretreatment followed by aerobic polishing is a viable process of treating textile processing wastewater.

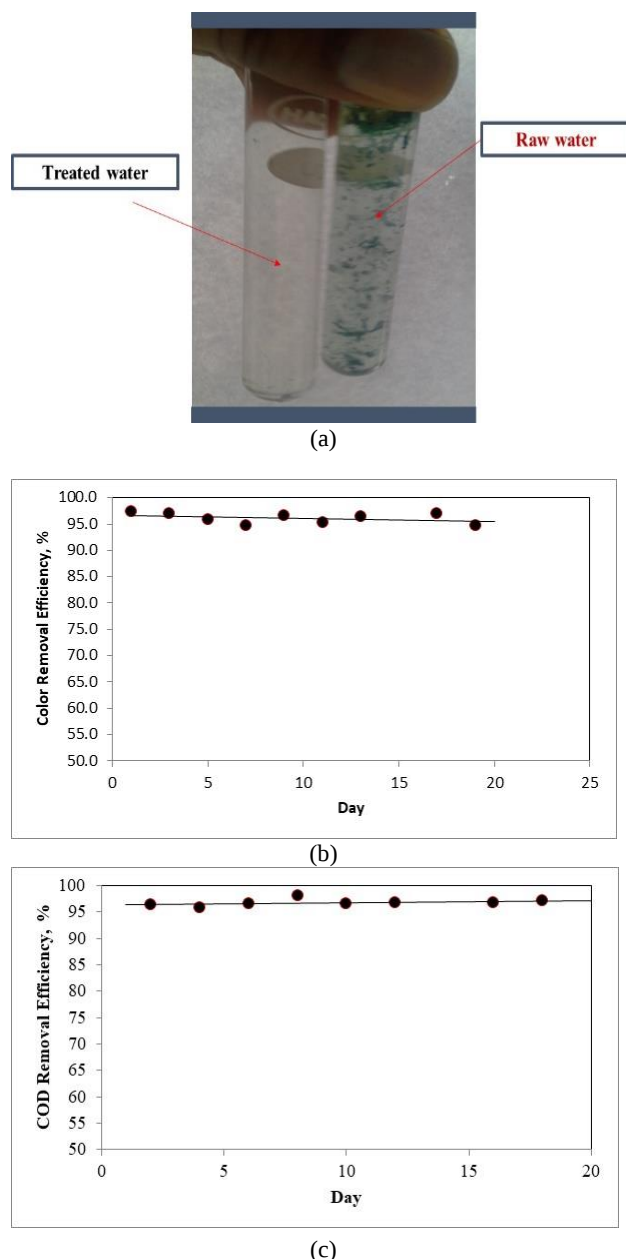


Figure 3: Acetogenic aerobic wastewater treatment (a) picture of color removal (b) percent biochemical oxygen demand (BOD₅) removal, and (c) percent chemical oxygen demand (COD) removal

The advantage of this process is that it is energy efficient due to the reduction of BOD loading to the aerobic polishing reactor for the acetogenic reactor removes BOD₅, does not require pH

adjustment for operation, or any color removal chemicals. FT-IR scan shows that in the acetogenic process complex aromatic compounds that is the chemical constituents of organic dyes get broken down.

Table 1: Characteristics of the treated discharge from the bench scale system

pH	BOD ₅ (mg/L)	COD (mg/L)	Color (ptco)	TSS (mg/L)
9.2 ± 0.10	17.5 ± 5.0	163 ± 10	193 ± 42	77 ± 16

The specific oxygen uptake rate (SOUR) for the acetogenic pretreated wastewater by the microorganisms in the aerobic polishing reactor (1.64 mg oxygen/g MLSS-hr). Was 32% less than that for the untreated influent test wastewater (2.40 mg oxygen/g MLSS-hr). Acetogenic pre-treatment of textile processing wastewater produces a net reduction of utilization that would correlate to less reactor aeration requirement and thus reduction in the energy required for aeration in the aeration basin. The acetogenic pretreatment produced an average COD reduction of the textile processing wastewater by 94% and at the energy requirement of 3.2 KWh per Kg of COD loading (8) to an aeration basin one can look at a net saving in energy of aeration by 15.74 KWh per meter cube of wastewater treated for this test case wastewater from a composite textile processing facility. The combination of acetogenic pretreatment followed by aerobic polishing is a viable energy efficient option of textile processing wastewater that meets the discharge criteria set by the government of Bangladesh and will go a long way if scaled up towards sustainable operation of textile processing facilities wastewater treatment systems.

4 Conclusion

The combined acetogenic aerobic polishing process is a viable process for treatment of textile processing wastewater with over 95% removal of BOD₅, COD, and color when it was applied at the bench level to a composite textile processing wastewater. This process is less energy intensive than extended aeration, did not require pH adjustment, and chemicals for color removal.

Ethical issue

Authors are aware of, and comply with, best practice in publication ethics specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests and compliance with policies on research ethics. Authors adhere to publication requirements that submitted work is original and has not been published elsewhere in any language.

Competing interests

The authors declare that there is no conflict of interest that would prejudice the impartiality of this scientific work.

Authors' contribution

All authors of this study have a complete contribution for data collection, data analyses. Manuscript writing was done by Nadim Reza Khandaker.

References

1. Khandaker NR, Talha AM. The new nexus and the need for understanding textile wastewater treatment. BUFT J. 2016;; p. 19–26.
2. Department of Forestry and Environment. Guide for Assessment of Effluent Treatment Plants. Dhaka:, Bangladesh Department of Forestry and Environment; 2008.
3. Fang HH, Liu H. Effect of pH on hydrogen production from glucose by a mixed culture. Biosource Research. 2002; 82(1): p. 87-93.
4. Fascetti E, D'Addario E, Todini O, Robertiello A. Photosynthetic hydrogen evolution with volatile organic acids derived from the fermentation of source selected municipal solid wastes. International Journal of Hydrogen Energy. 1998; 23(9): p. 753-760.
5. Huang Z, Ong SL, Ng HY. Submerged anaerobic membrane bioreactor for low-strength wastewater treatment: Effect of HRT and SRT on treatment performance and membrane fouling. Water Res. 2011;; p. 705-713.
6. Sarker MS, Rahman MM, Khandaker NR. Defining the kinetics of the novel application of anaerobic acetogenics for treating textile dyeing wastewater. Earth Syst. Environ. 2018 May; 4.
7. American Public Health Association. Standard Methods for Examination of Water and Wastewater, 17 edition. Washington D.C: American Public Health Association; 1989.
8. Plappally AK, Lienhard V. Energy requirements for water production, treatment, end use, reclamation, and disposal. Renew Sustain Energy Rev. 2012;; p. 4818–4848.
9. Khandaker NR, Young JC. Effect of culture acclimation on the kinetics of aldicarb insecticide degradation under methanogenic conditions. J Agric Food Chem. 2000; 48: p. 1411-1416.
10. Ali Arasteh Nodeh SA. Clean to Clean: Using Paper Waste to Produce Fermentable Sugar for Bioethanol Production. Journal of Environmental Treatment Techniques. 2017; 5(1).
11. Embrandiri A, Rupani PF, Woon LK, Jamaludin MH, Naim MA, Sun J, et al. Treatment of Dye Wastewater by Functionalization of Bentonite-Methylene Blue with Sodium Persulfate. Journal of Environmental Treatment Techniques. ; 7(2): p. 229-233.