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Application of Acetogenic Reactor for Textile Dyeing Wastewater Treatment in the Context of Bangladesh

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Abstract

Grameen Shakti has been extremely successful in introducing biogas production to rural Bangladesh using micro-financing. Unfortunately the application is limited to anaerobic degradation to solids waste such as cow manure and poultry waste to generate biogas. The application of anaerobic biotransformation to industrial wastewater treatment is well established in more developed economies. To further optimize anaerobic biotransformation the recent research thrust worldwide has been to limit the generation of green house gases and stabilize industrial wastewater by developing acetogenic anaerobic reactors. To date the application of acetogenic reactors has been limited to easily degradable wastes with no work done to apply acetogenic reactors to treat complex wastewaters. The concept of acetogenic reactors to treat textile dyeing wastewater is novel. In the research program, the concept of acetogenic biotransformation was applied successfully to actual textile dyeing wastewater to address the pressing need to treat the wastewaters generated from the about five thousand textile dyeing industries around greater Dhaka city in Bangladesh in an energy efficient and sustainable way. Under controlled conditions we have successfully applied the concept of acetogenic reactor to remove color and chemical oxygen demand from an operational textile dyeing wastewater processing blue denim fabric. We will be reporting on the characterization of the wastewater and the kinetics of the bio-transformation reaction involved in the application of acetogenic reactor to treat Textile Dyeing Wastewater. It is hoped that our novel discovery will ensure proper wastewater treatment from textile dyeing industries in Bangladesh in an energy efficient and sustainable manner.

Key words: Textile dyeing wastewater, treatment, acetogenic reactor, energy efficient.

1. Introduction

Grameen Shakti a concern of Nobel Prize winning Grameen Bank has been extremely successful in introducing biogas production to rural Bangladesh using micro-financing. Unfortunately the application is limited to anaerobic degradation to solids waste such as cow manure and poultry waste to generate biogas [1]. The application of anaerobic biotransformation to industrial wastewater treatment is well established in more developed economies. To further optimize anaerobic biotransformation the recent research thrust worldwide has been to limit the generation of green house gases and stabilize industrial wastewater by developing acetogenic anaerobic reactors. To date the application of acetogenic reactors has been limited to easily degradable wastes [2, 3, 4] with limited work done in the application of acetogenic reactors to treat complex industrial wastewaters. The concept of acetogenic reactors to treat textile dyeing wastewater is novel. In the research program, the concept of acetogenic biotransformation was applied successfully to actual textile dyeing wastewater to address the pressing need to treat the wastewaters generated from the about five thousand textile dyeing industries around greater Dhaka city in Bangladesh in an energy efficient and sustainable way [5]. The present choice of treatment calling for extended aeration (constant aeration keeping the dissolved oxygen level at 2.0 mg/L in the aeration basin with a hydraulic retention time of more than twenty four hours) is energy intensive and not sustainable in the context of a least developed country economy such as Bangladesh. This is leading to non compliance and dumping of untreated textile dyeing wastewater into the water bodies, polluting the rivers and wetlands of Bangladesh and also contaminating the aquifers [5]. In contrast acetogenic treatment of the textile dyeing wastewater only requires short burst of aeration one time to raise the dissolved oxygen level to 2.0 mg/L once a day to shock the system to prevent the growth of methane generating microorganisms in the reactor. The greatly reduced aeration requirement in acetogenic reactor has the potential to be a

more sustainable option in the context of a least developed country such as Bangladesh.

2. Problem identification and basic principle

The specific objective of our research is to apply the concept of short hydraulic and solids retention time to the design and operation of acetogenic anaerobic sludge blanket reactors [2,3] to pre-treat complex textile dyeing wastewater. Under controlled conditions using bench scale reactors kinetics of chroma, and COD removal will be defined using existing models defining complex substrate removable under acetogenic condition [6]. Kinetics models will be used for defining the kinetics of textile dyeing wastewater stabilization using acetogenic reactor. The end product/outcome of the research program is the development of a novel anaerobic reactor to pre-treat textile dyeing wastewater with defined kinetic model using the concept of short hydraulic detention time for acetogenic operation optimizing for color, BOD and COD removal in an energy efficient and carbon neutral way .

3. Methodology

An experimental program has already been conducted under controlled conditions using bench scale continuously stirred tank reactors to optimize for hydrogen generation by limiting the process of hydrogenotrophic methanogenesis. Central to the protocol was the operation of a master culture reactor under controlled conditions. The reactor was maintained under waste feed mode with a hydraulic retention time and hydraulic retention time of four days. A Multi-Level protocol for assessing the fate and effect of organic chemicals in anaerobic reactions based on US Environmental Protection Agency (EPA) Project R814488, was followed to assess the kinetics of degradation of easily degradable food waste as substrate optimized for hydrogen generation thereby limiting the emission of green house gases and yet produce waste stabilization and hydrogen generation [7-12]. Central to the experimental protocol was the operation of the master culture reactor at a fixed HRT/loading and temperature of 35^{o}C. The master culture reactor volume was 1.0 L. The reactor was operated in a semi-continues batch operation with a regime of daily waste and feeding. The reactor pH, temperature was monitored real time by using data acquisition systems, the reactor SCOD, TSS were monitored on a daily basis using standard methods [7, 8]. Cultures were transferred from the master culture reactor to small reactors to conduct batch kinetics studies. The batch reactors were serum bottle reactors continuously steered and maintained at constant temperature. The reactor content composition with respect to COD, TSS, colour, and total fatty acid (TFA) was monitored at preset timed intervals.

The data generated from the batch kinetics experimental program was used to define the kinetics of COD transformation for the using the using the generalized rate equation expressing first order transformation of substrate given in Equation (1) below:

$$COD_t = COD_0 \times e^{-kT} \qquad (1)$$

The experimental data for the batch kinetics experiment was fitted to equation by using Math Lab software.

4. Results and discussions

The result of the experimental program showed that acclimated acetogenic culture maintained under controlled condition optimized for acetogenic operation was able to degrade a composite sample of a textile dyeing wastewater obtained from a factory where fabrics are dyed using blue reactive dye to produce blue denim. The characteristics of the wastewater is summarize in the table below (refer to Table 1).

Table 1: Wastewater characterization of a twenty four hour composite sample obtained from a reactive dyeing facility equalization basin.

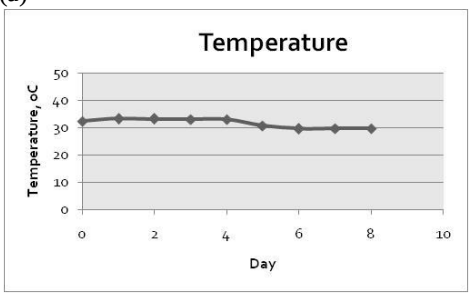
Sample Location	TSS (mg/L)	pH	Colour (ptco)	TDS (mg/L)	COD (mg/L)	BOD_5 (mg/L)
Equalization Basin	144	8.6	660	2470	371	228

Operation of the Master Culture Reactor showed that the cultures required a period of operation to acclimate to the wastewater and once steady state operation was achieved the reactor was operating with a high degree of waste stabilization efficiency producing treated water within the limits of the Government of Bangladesh discharge criteria for effluent discharge to natural waterways under acetogenic conditions. The reactor operational data monitored are summarized in Figurers 1a through Figure 1f. Of note is the COD removal efficiency of ninety five, and also the acetogenic reactors ability to breakdown chroma with the color removal efficiency of 74%. The acetogenic reactor was also able to operate without need of pH adjustment which is attractive in a resource challenged environment as Bangladesh. The acetogenic operation was verified by increase in the reactor effluent total fatty acid concentration indicating that there was a buildup of acetogenic bacteria as reactor steady state was achieved. Acetogenic operation limits the generation of green house gas methane and optimizes for hydrogen generation as the terminal metabolite a greener alternative.

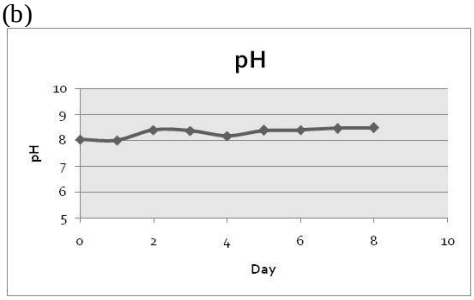
The batch kinetics of the COD degradation with time was defined by a first order model $COD_t = COD_o \times e^{-kt}$, (goodness of fit between observed and modeled data (r^2) of 0.84 (refer to Figure 2), where: COD_t= Chemical oxygen demand at any time (t); COD_t= Chemical oxygen demand at time zero (t=0);

k = first order rate constant; and t = time. The value of the first order rate constant "k "for the degradation of the textile dyeing wastewater was 0.047 hr^{-1} (95% confidence bound; 0.030, 0.064). This indicates that first order kinetics predicts the microbial degradation of textile dyeing wastewater from a blue denim dyeing operation and as such first order models can be used to design acetogenic reactors for textile dyeing wastewater treatment.

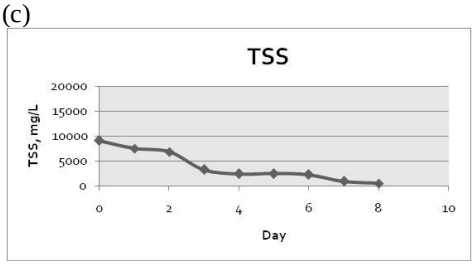
(a)



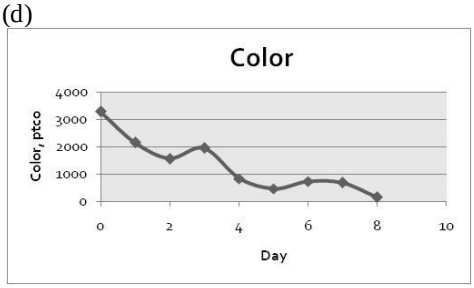
(b)



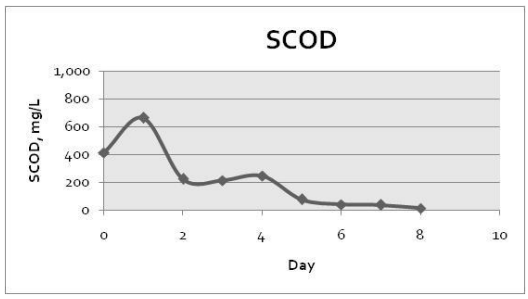
(c)



(d)



(e)



(f)

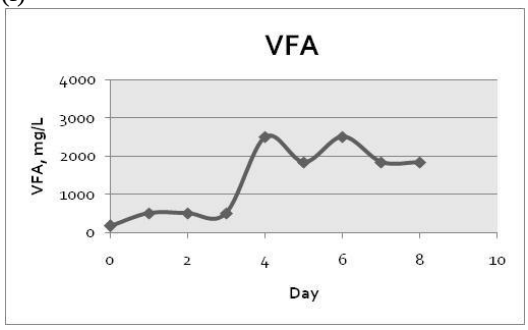


Figure 1. Operational Data of Master Culture Semi Continuous Batch Acetogenic Reactor. (a) Operating Temperature, (b) Operating pH, (c) Total Suspended Solids (TSS), (d) Color, (e) Soluble Chemical Oxygen Demand (COD), and (f) Volatile Fatty Acids (VFA) expressed as Total Acetic Acid.

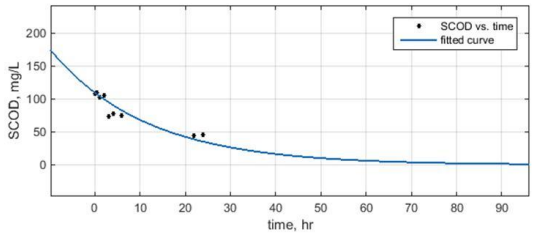


Figure 2. Batch Kinetics of Textile Dyeing Wastewater COD Removal with Time. Modeled and observed Data.

The experimental program showed that anaerobic reactor optimized for acetogenic operation can successfully treat textile dyeing wastewater. This will be a viable sustainable alternative to industry norm extended aeration treatment of textile dyeing wastewater with aeration basin detention times greater than twenty four hours. The energy required by the blowers in extended aeration is an operational constrain in a developing country such as Bangladesh. The nominal aeration requirement of the acetogenic reactor will go a long way to ensure proper wastewater treatment from textile dyeing industries in Bangladesh in an energy efficient and sustainable manner.

5. Conclusions

In this program for the first time the concept of acetogenic biotransformation was applied successfully to actual textile dyeing wastewater. This will go a long way to address the pressing need to treat the wastewaters generated from the textile dyeing industries in Bangladesh in an energy efficient and sustainable greener manner.

Abbreviations

BOD5 = Biochemical Oxygen Demand, mg/L
COD = Chemical Oxygen Demand, mg/L
TSS = Total Suspended Solids, mg/L
TDS = Total Dissolved Solids, mg/L
k = First Order Rate Constant, hr^{-1}
T = Time, hr

References

[1] Khandaker, N., Rashid, S. (2010).Affordable renewable energy: How microfinancing powers rural Bangladesk". The Journal of Polecy Engagement. 2(6), 20-22.

[2] Faseetti, E., Daddario, E., Todini, O., Robertiello, A.(1998).A photosynthetic Hydrogen Evolution with Volatile Organic Acids Derived from the Fermentation of Source Selected Municipal Solid Wastes." Int J. Hydrogen Energy, 13(9), 753-60.

[3] Fang, H.H.P., Liu, H. (2002). Effect of pH on Hydrogen Production from Glucose by a Mixed Culture. Bioresour Technol, 82(2), 87-93.

[4] Ferchichi, M., Crabbe, E., Gil, G., Hintz, W., Almadidy, A. (2005). Influence of Initial pH on Hydrogen Production from Cheese Whey. J .Biotechnol., 120, 402-9.

[5] Islam, M. M., Mahmud, K., Faruk, O.,Billah, M. S. (2011). Textile Dyeing Industries in Bangladesh for Sustainable Development. International journal of Environmental Science and Development, 428-436.

[6] Andrews, J. F. (1968). Modeling of Biological Treatment Processes, Biotechnology and Bioengineering, 10, 707-723.

[7] Standard Methods for the Examination of Water and Wastewater. (1989), 17th Edition. American Public Health Association, Washington, D. C.

[8] Standard Methods for the Examination of Water and Wastewater. (1988), Supplement to the 16th Edition. American Public Health Association, Washington, D.C.

[9] Tabak, H. H., Desai, S. and Govind, R. (1989). "The Determination of Biodegradability and Biodegradation Kinetics of Organic Pollutant Compounds with the Use of Electrolytic Respirometry," Proc. 1989 Research Symp.: Remedial Action, Treatment, and Disposal of Hazardous Wastes, Cincinnati, OH.

[10] U.S. Environmental Protection Agency, (1986). "Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act: Technical Amendments and Notice of Availability of Information, Federal Register, 40 CFR Part 136.

[11] Young,J.C and Tabak, H. H. (1991). Multi-Level Protocol for Assessing the Fate and Effect of Toxic organic Chemicals in Anaerobic Reactions, Final Report EPA Project R814488, Civil Engr. Dept., Univ. of Arkansas, Fayetteville, AR.

[12] Young, J. C., Kuss, M. L. and Nelson, M., (1991). Use of Anaerobic Respirorneters for Measuring Gas Production in Toxicity and Treatability Tests, Proc. 84th Annual Meeting of the Air and Waste Management Association, Vancouver, B.C., Canada.

Commonwealth Energy and Sustainable Development Network (CESD-Net)

CESD-Net is a major global initiative in energy and sustainable development. The objective of network is to promote energy and sustainable development in commonwealth countries.
Focussing on Multidisciplinary Research, Promoting Future Low Carbon Innovations, Transferring Knowledge and Stimulating Networking among Stakeholders to Ensure the UK Achieves World Leading Status in Energy and Sustainable Development. https://www.weentech.co.uk/cesd-net/

The 1st International Conference on Energy, Environment and Economics (ICEEE 2016) was held at Heriot-Watt University, Edinburgh, EH14 4AS, UK, 16-18 August 2016. ICEEE2016 focused on energy, environment and economics of energy systems and their applications. More than fifty eight delegates from 31 countries with diverse expertise ranging from energy economics, solar thermal, water engineering, automotive, energy, economics and policy, sustainable development, bio fuels, Nano technologies, climate change, life cycle analysis etc. made conference true to its name and completely international. During conference total 51 oral presentations and six posters were shared between delegates. The presentations showed the depth and breadth of research across different research areas ranging from diverse background. ICEEE2016 aimed:

- To identify and share experiences, challenges and technical expertise on how to tackle growing energy use and greenhouse gas emissions and how to promote sustainability and economical, cost effective energy efficiency measures.

In total 11 technical sessions and two invited talks both from academia and industry provided insight into the recent development on the proposed theme of the conference. Preparation, organisation and delivery of the conference started from July 2015 and further co-ordinated by vibrant team of Conference Centre, Heriot Watt University. Conference organisers would like to acknowledge support from the sponsors particularly World Scientific Publication ltd and its team members for the delivery of the conference. Organisers are also thankful to all reviewers who contributed during peer review process and their contributions are well appreciated. At the end and during vote of thanks following awards have been announced and we would like to congratulate all well deserving delegates.

- Best Paper –Academia: Amela Ajanovic, EEG, TU Vienna, Austria
- Best Paper – Student : Christian Jenne,University of Duisburg-Essen, Germany
- Best Poster – Student: Yoann Guinard, University of New South Wales, Sydney, Australia
- Best Poster – Academia: E. Salleh, Universiti Kebangsaan Malaysia, Malaysia
- Active Participation Award - Yoann Guinard, University of New South Wales, Sydney, Australia

At the end we would like to extend our gratitude to all of you for your participation and hopefully welcome you again during ICEEE2017.

Editors:
Dr. Singh is Senior Scientist at Indian Agricultural Research Institute, New Delhi, India. Her area of expertise are bio energy and bio fuels, environmental engineering, carbon accounting and renewable energy integration for rural development.
Dr. Kumar is visiting faculty at Prince of Songkla University, Thailand. He have 16 years of research and teaching experience in the field of solar energy, drying and energy efficiency.

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