STUDY OF THE ELECTROCHEMICAL PROCESS FOR DISTILLERY WASTEWATER TREATMENT

B.M. Krishna*, Usha N. Murthy[1], B. Manoj Kumar and K.S. Lokesh[2]

1. Department of Civil Engineering, UVCE, Bangalore University, JB campus, Bangalore, (INDIA)
2. Department of Environmental Engineering, S. J. College of Engineering, Mysore, (INDIA)

Received Febraury 04, 2010 *Accepted August 30, 2010*

ABSTRACT

In this work the electrochemical (EC) process is used as a pretreatment step for the treatment of distillery wastewater using iron plates as electrodes in a batch EC reactor. The maximum COD removal of 56% was achieved at a current density of 0.10 A cm^{-2} with 140 min of electrolysis time at wastewater pH of 3. The BOD to COD ratio increased from 0.15 to 0.52 indicating improvement in wastewater biodegradability. The maximum anodic efficiency observed was 2.68 kg COD $h^{-1}A^{-1}m^{-2}$ with a corresponding energy consumption of 0.71 kWh kg^{-1} COD.

Key Words : Electrochemical process, Iron electrode, Pretreatment, Distillery, Wastewater

INTRODUCTION

Distilleries are very large agro-based chemical industry in India where ethyl alcohol is produced by fermentation of cane sugar molasses. The fermentation broth containing 6-8% alcohol by volume is distilled to recover alcohol. The distilleries generate 12-17 m^3 of wastewater per m^3 of alcohol produced. A distillery industry discharges approximately 100-1000 m^3/day wastewater depending on the size of the process[1]. Alcohol is separated by distillation and the residual liquor is discharged as effluent. This effluent is called as 'spent wash', which is characterized by highly acidic, high BOD and COD, high recalcitrant organics with dark in color.[2,3]

Of the various treatment methods for distillery wastewater, anaerobic digestion has gained wide acceptability due to methane recovery in the anaerobic step of the treatment. It is reported that anaerobic treatment results in 60-85% of the BOD reduction, but still substantial amount of recalcitrant organic pollutants are left behind which requires post treatment.[4] Considerable research work has been carried out in the past to evaluate alternate options for abating the pollution potential of predigested distillery effluent. They include physicochemi-

* Author for correspondence

cal method[5] and biological methods such as bioremediation.[6-7]

Electrochemical treatment has attracted great attention in treating industrial wastewater because of the versatility and its environmental compatibility. Electrochemical treatment is widely used to treat different industrial effluxents with varying degree of treatment and with different experimental conditions.[8-9]

The present study focuses on the pretreatment of distillery wastewater collected from the existing anaerobic lagoon of existing treatment plant for COD removal and improvement of BOD to COD ratio. The operating parameters affecting the electrochemical degradation such as electrolysis duration, pH and current density are evaluated during this study.

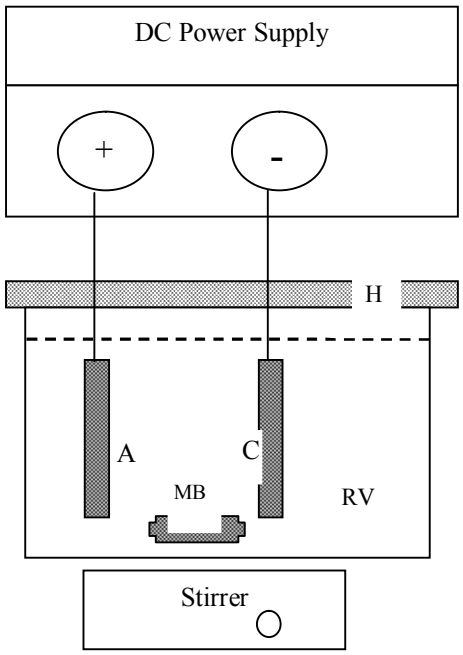
MATERIAL AND METHODS

Wastewater

For this study, wastewater was collected from the anaerobic lagoon of distillery effluent treatment plant. The wastewater was analyzed for various parameters and is characterized by high COD in the range of 42240-46440 mg/L, BOD of 6757-8600 mg/L, chlorides ranging from 6300-7200 mg/L and pH varying between 7.7-7.95, which indicates that the wastewater contains high amount of organics. The initial (BOD/COD) ratio was found to be very low in the range of 0.159 to 0.185, which suggests that there is a presence of recalcitrant nature of organics in the wastewater.

Electrochemical reactor setup

A plexi-glass laboratory scale batch reactor of working volume 1.5 litres was used for electrochemical oxidation experiments. The aluminum plates of size 5 cm x 5 cm was used as both anode and cathode electrode which were placed at a fixed distance of 2 cm apart. The experimental setup is shown in **Fig. 1**. A direct current power supply unit was used for current supply. The samples were collected at regular time interval and were analyzed for various parameters. All the analytical procedures followed the standard methods for examination of water and wastewater.[10]



A-Anode, C- Cathode, RV- Reactor Vessel, H- Head plate, MB-Magnetic Bit,

Fig. 1: Schematic diagram of electrochemical reactor setup

Electrolysis experiments

Initially batch studies were conducted at the existing pH of the distillery wastewater to find the optimum electrolysis duration at which maximum COD removal takes place. At the optimum electrolysis duration, further experimental runs were conducted at varying pH of 3, 5, 7 and 9. The optimum pH which

resulted in maximum COD removal was fixed up for further experiments with varying current densities. Thus all the experimental conditions such as duration of electrolysis, pH and current density with optimized values have drawn on the basis of maximum percentage COD removal.

RESULTS AND DISCUSSION

Effect of electrolysis duration

The initial set of experiments was conducted at the existing wastewater pH of 7.95. It is seen from **Fig. 2**, that the rate of COD reduce-tion is gradual up to 140 min and later on approaches constant value and start decreasing. The maximum COD reduction of 27.2% was achieved in 140 minutes of electrolysis duration which is considered as optimum. The decrease in COD removal at later stage might be due to the exhaustion of hypochlorite and free chlorine generation in-situ in the reactor. It can also be observed that BOD to COD ratio increased from 0.18 to 0.46 at 140 minutes, suggesting increase in biodegradability with an increase in elec-trolysis duration.

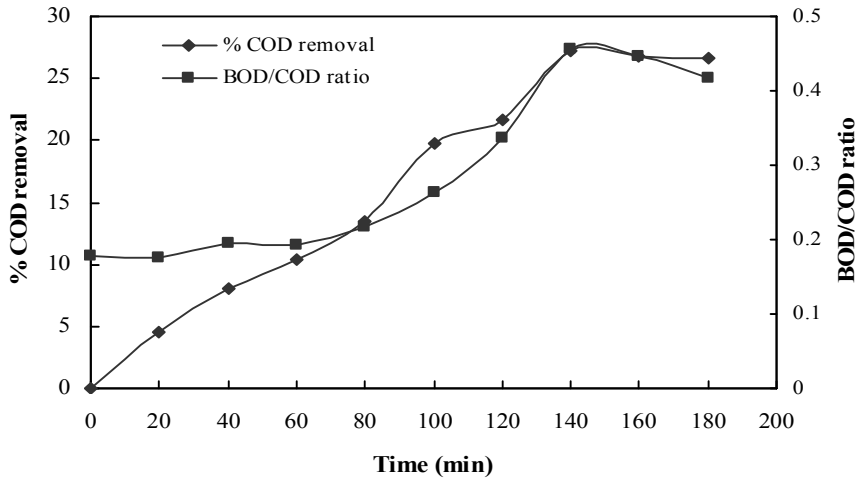


Fig. 2: Variation of COD removal efficiency and BOD /COD ratio as a function of electrolysis duration

Effect of pH

To examine the effect of pH, individual experiments were conducted at different wastewater pH of 3, 5, 7 and 9. The electrolysis duration was fixed at 140 minutes. The pH of wastewater was adjusted by adding sodium hydroxide or sulfuric acid to get the desired pH throughout each run. **Fig. 3** reveals that the maximum COD reduction of 52% was observed at wastewater pH of 3 and minimum COD reduction of 29.7% was observed at pH 9. This shows that acidic condition is more favorable for the treatment of distillery wastewater. The BOD to COD ratio exhibited an analogous optimum increase from 0.19 to 0.49 at pH 3 as shown in **Fig. 4**. It is observed that the COD removal and BOD to COD ratio decrease with increase in wastewater pH is probably due to the decreased production of chlorine/ hypo-chlorite at higher pH condition.[11]

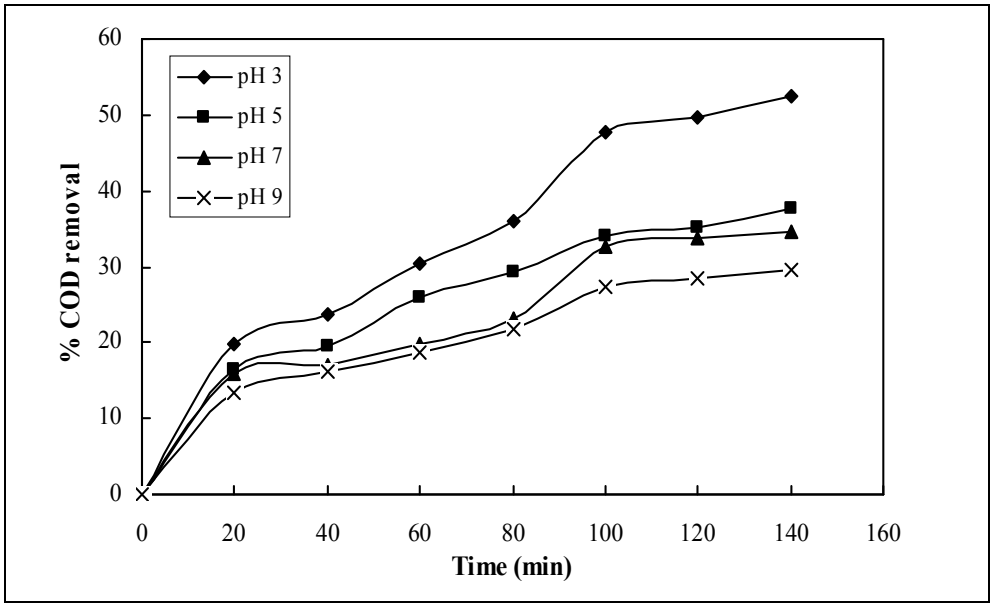


Fig. 3 : Effect of pH on COD removal

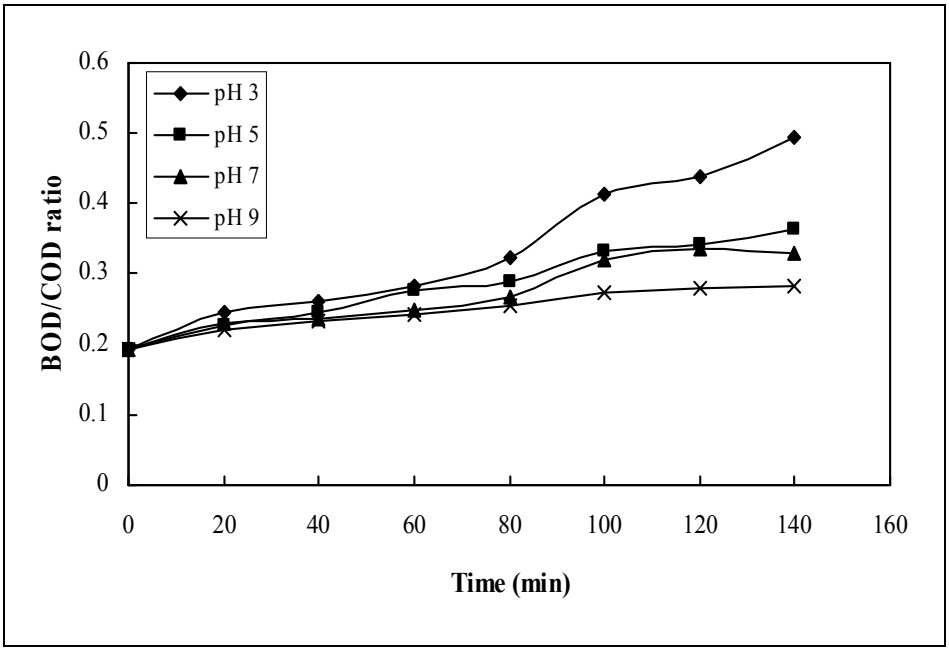


Fig. 4 : Effect of pH on BOD/COD ratio

Effect of current density

To study the effect of varying current density on COD reduction and to know the improvement of BOD to COD ratio, experiments were carried out at 0.02, 0.04, 0.06, 0.08, 0.10 and 0.12 A cm^{-2} with a constant pH of 3 for 140 minutes. The experimental results of COD removal and BOD to COD ratio are shown in **Fig. 5** and **Fig. 6** respectively. **Fig. 5** shows that the maximum COD removal of 56% was observed at an applied current density of 0.10 A cm^{-2}. For initial 70 minutes the COD removal was rapid and later on it was gradual. **Fig. 6** shows that there was increase in BOD to COD ratio from 0.15 to 0.52 at current density of 0.10 A cm^{-2}. Increasing current density led to the increase in COD reduction following Faraday's law[12] because of the increased production of chlorine/ hypochlorite at higher current densities.

Energy consumption and anodic efficiency

The specific electrical energy consumption is defined as the amount of electrical energy consumed per unit mass of organic load and was calculated in terms of kilo Watt hour per kg of COD removed (kWh kg^{-1}COD). The anodic efficiency of electrochemical treatment has been calculated in terms of kg COD removed per hour per ampere per square meter area of electrode (kg COD $h^{-1}A^{-1}m^{-2}$). This study was conducted at the wastewater pH of 3 and the current applied was 0.5, 1, 1.5, 2, 2.5 and 3 A. The maximum anodic efficiency of 2.68 kg COD $h^{-1}A^{-1}$ m^{-2} was observed at applied current of 2.5 A (0.10 A cm^{-2}) with energy consumption of 0.71 kWh kg^{-1} COD removal. The energy consumption increased by 2.6 times

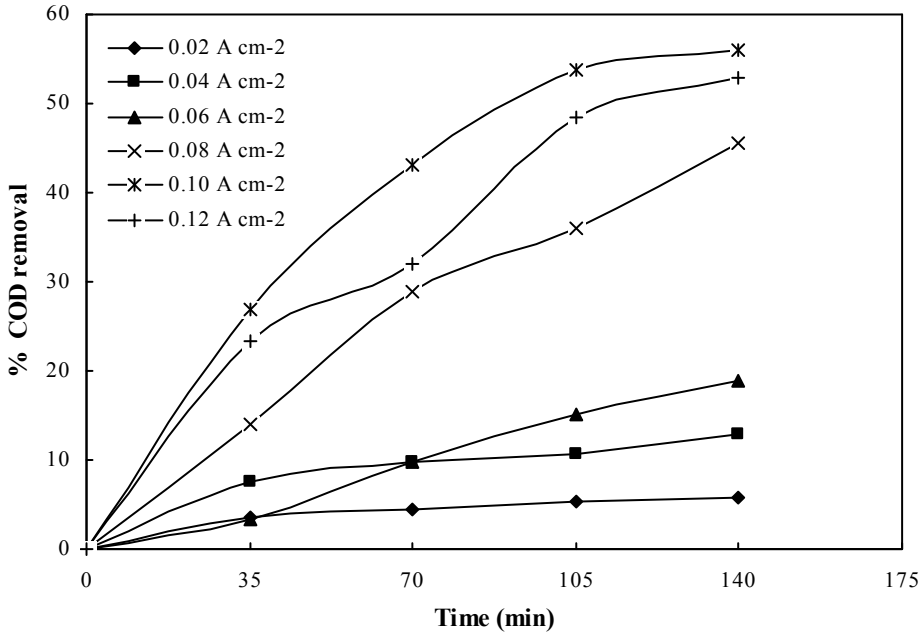


Fig. 5 : Effect of current density on COD removal at wastewater pH 3

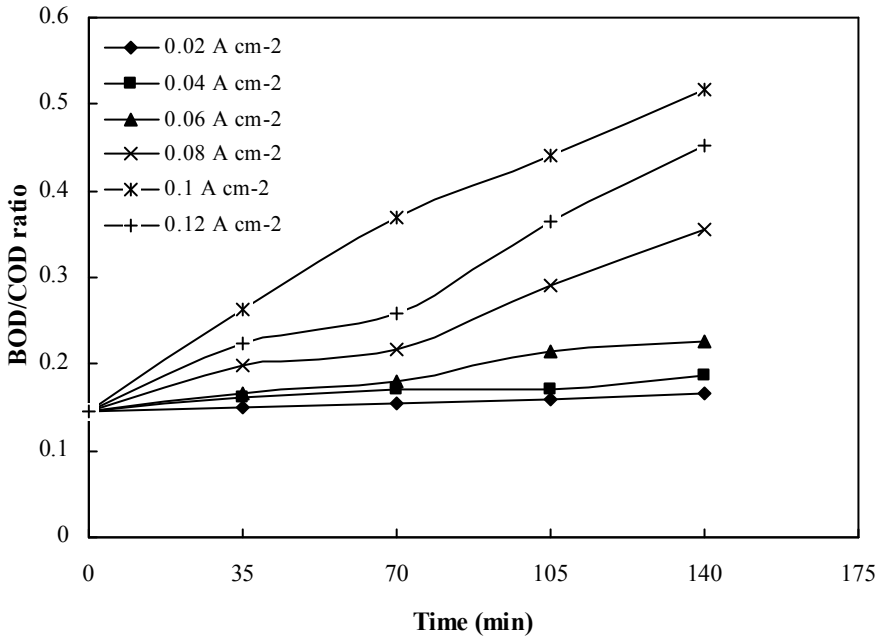


Fig. 6 : Effect of current density on BOD/COD ratio at wastewater pH 3

with increase in current from 2.5 A to 3 A. Under similar conditions, the anodic efficiency at 2.5 A is 1.3 times more than that at a current of 3 A. This is in comparison with the studies made by Deshpande et al.[13] It is evident that increase in current density has actually resulted in decrease in anodic efficiency and increase in energy consumption.

CONCLUSION

Based on the above discussion, the efficiency of Iron electrode in terms of COD removal has been found to be dependent on pH and current density. The maximum COD removal was 56% at 140 minutes electrolysis time, at a current density of 0.10 A cm^{-2} and wastewater pH of 3. BOD to COD ratio increase from 0.15-0.52 was observed indicating an improvement in the bio-degradability of wastewater. The maximum anodic efficiency of 2.68 kg COD $h^{-1}A^{-1}m^{-2}$ was observed with an energy consumption of 0.71 $kWhkg^{-1}$ COD removed. Although all organic contaminants of wastewater were significantly reduced during the study, still COD and BOD values were found to be high, indicating that one step treatment by electrochemical process was not sufficient and further need for a follow up treatment using appropriate methods is required to meet the statutory limits of effluent disposal standards.

ACKNOWLEDGEMENT

The authors sincerely wish to thank Dr. T. P. Halappa Gowda, Professor (Retd.), for his valuable suggestions and guidance. Authors also wish to thank Dr. B. G. Sangameshwara, Principal, Dr. Syed Shakeeb Ur-Rehman,

Dean, VTU Belgaum and Vice-principal and Dr. H. S. Ramesh, Professor and Head, Env.Engg.Dept., Sri Jayachamarajendra College of Engineering, Mysore, Karnataka, for extending laboratory facilities to carry out this research work.

REFERENCES

1. Chaudhari P.K., Mishra I.M. and Srichand, Effluent treatment for alcohol distillery : Catalytic thermal pretreatment (Catalytic thermolysis) with energy recovery, *Chem. Engg. J.,* ***136***, 14-24, **(2008).**
2. Takur C.K., Srivatsava V.C. and Mall I.D., Electrochemical treatment of distillery wastewater : Parametric and residual disposal study, *Chem. Engg. J.,* **148**, 496-505, **(2009).**
3. Baskar G., Deeptha V. T. and Rahaman A., Root zone technology for compus waste water treatment, *J. Environ. Res. Develop.,* **3**(3), 695-705, **(2009).**
4. Pathade G.R., Studies on the Bench level Aerobic Biological Treatment of Anaerobically Digested Distillery Waste using Developed Mixed Microbial Seed Culture, *J. Environ. Protec.*, **21**(2), 114-121, **(2000).**
5. Dikshit A.K. and Chakraborty D., A Techno-economic feasibility study on removal of persistent colour and COD from anaerobically digested distillery effluent : A case study from India, *Clean Tech. Environ. Pol.,* **8**(4), 273-285, **(2006).**
6. Maiorella B.L., Blanch H.W. and Wilkie G.R., Distillery effluent treatment and byproduct recovery, *Processes Biochem,* **18**, 5-8, **(1983).**
7. Mondal P.K. and Ahmed R., Aplication of acid treated water nut activated Carbon for removal of Malachite – green from industrial waste water by column operation, *J. Environ. Res. Develop.,* **3**(3), 807-816, **(2009).**
8. Garg V.K. and Guptha R., Bioremediation of anaerobically digested post-methanation distillery spentwash, *Indian J. Chem. Techno*, **9**, 491-495, **(2002).**
9. Salina B., Krishnakumar S., Saravanan A. and Natarajan S. K., Microbial and enzyme dynamics in distillery spentwash treated soil, *Research J. agri. and Biol. Sci.,* **1**(2), 166-169, **(2005).**
10. American Public Health Association, *Standard Methods for Examination of Water and Wastewater*, **Twentieth Edition**, APHA, AWWA, Washington D.C., **(1998).**
11. Rajkumar D., Song B.J. and Kim J.G., Electrochemical degradation of reactive blue 19 in chloride medium for the treatment of textile Dyeing wastewater with identification of intermediate compounds, *J. Dyes Pigm.*, **72**, 1-7, **(2007).**
12. Prentice G., *Electrochemical Engineering Principles, Prentice-Hall,* Singapore, **(1991).**
13. Deshpande A., Lokesh K.S., Bejankiwar R.S. and Gowda T.P.H., Electrochemical oxidation of Pharmaceutical effluent using cast Iron electrode, *J. Environ. Sci. Engg.*, **47**(1), 21-24, **(2005).**

● ● ● ● ●

Save Earth. We have no where else to go!