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Effect of Current Density on Removal of COD from Sugar Mill Wastewater using SS and Al Electrodes.

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Abstract— **This paper deals with the electrochemical degradation of sugarcane based sugar mill waste water (SMW). The studies on removal of COD of SMW were investigated by using two liter capacity electrolytic batch reactor. Effect of current density on the performance of two electrodes viz. stainless steel and aluminium has been reported in the study. The study was performed by passing 1.67 and 3 amp current through above electrodes. Applied voltage, COD removal efficiency as a function of current density for SS and Al electrodes are observed. Likewise optimal current density as a function of surface area to volume was observed. From this study it is found that CD of 25 A/m2 providing a maximum COD removal of 54.55% having SA/V ratio of 0.06 m2/m3 with ET=20 min was consider appropriate treatment condition with aluminium electrode.**

Keywords— **Sugar mill waste water, electrochemical treatment, Electrodes, Current density, COD**

Introduction

The sugar industry has played a vital role in both agriculture and industrial development. About 7.4 % of the rural populations are involved in the cultivation of sugarcane.

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The industry provides employment to over 0.5 million skilled and unskilled workers (Solomon, 2005). Sugar industry has also diversified into by-products and has established large number of distilleries, organic chemical plants, paper and board factories and power co-generation plant. The off-season fodder from cane tops and leaves is an important energy source for cattle. With such extensive and wide ranging socio-economic activities, the sugar industry has occupied an important place in the Indian economy. Waste water from sugar mills with its high BOD and COD rapidly depletes available oxygen supply when discharged into water bodies endangering fish and other aquatic life and also creates septic conditions, generating foul smelling hydrogen sulphide, which in turn can precipitate iron and any dissolve salts, turning the water black and highly toxic for aquatic life.

Suspended solids reduce light penetration capability and, as a result, plant production in the receiving water body is diminishing by increasing turbidity that can also clog fish gills. The Dissolved Solids (TDS) refers to all dissolved materials present in the water. Combined sugar mill effluents generally do not have a TDS measure high enough to have an adverse environmental impact. Discharge of water with high TDS level would have adverse impact on aquatic life, render the receiving water unfit for drinking, reduce crop yield if used for irrigation, and exacerbate corrosion in water system and pipe. Highly colour water, besides being aesthetically unpleasing, limits light penetration, reducing production of phytoplankton and, by association, zooplankton, fish and dissolved oxygen supply.

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During the electrochemical process the degradation / pollutant removal takes place by two mechanisms, namely electro oxidation and electro coagulation. In recent years, electrochemical degradation has been found to be very effective in treating various types of industrial wastewater. There are various applications of this technology e.g. treatment of electroplating wastewater for the removal of various heavy metals (Adhoum et al., 2004), news paper waste water (Fox and Noike, 2004), paper and pulp mill wastewater (Ganjidoust et al., 1997; Mahesh et al. 2006a, b), treatment of poultry slaughterhouse waste water (Kobya et al. 2005).

Reactors used for energy conversion and electrochemical synthesis are different from those used in the destruction of contaminants/pollutants present in water or wastewaters. Therefore, it is important to select (or design) an ECR for a specific use. There are two types of reactors which can be used for the treatment of wastewater in electrocoagulation method. One is Batch reactor and second is continuous reactor. Adequate attention must be paid to the form of the electrode, its geometry, together with the need for cell division or a thin electrolyte gap. The form of the reactants/pollutants/contaminants and products and the mode of operation (batch and continuous) are also important design factors. Environmental regulatory authorities generally prescribe the maximum limit on waste water generation which is discharged either into water bodies/sewers or on to land. When the treatment methods entails high cost and/or the standards not achievable by using existing treatment technologies, fresh water is used to dilute the treated waste water so as to meet the discharge standards. In many situations, reduction in water usage, plant-wise waste water segregation and their treatment using advanced techniques are recommended.

The present paper reports about the electrochemical treatment of sugar mill waste water. The various types of electrodes can be used for the treatment of sugar mill wastewater. The paper also deals with the comparative study of various electrode materials viz. steel, iron, copper and aluminium.

MATERIAL AND METHOD

Characterization of Wastewater

The wastewater used in this study was collected from the sugarcane based sugar mill Devhada, Tah. Mohadi, Dist- Bhandara (M.S.). The waste water is yellow–green in color. The characteristics of waste water are shown in Table 1.

Table 1 Characteristics of waste water from a sugar mill.

Parameter	Concentration
BOD	1420 mg/l
COD	3300 mg/l
pH	5-7
Temperature	25 to 35^{0}C
Total dissolved solids	2000 mg/l

Experimental Setup

The efficiency of electrolytic plate was studied using different electrode materials. The pH of wastewater is maintained 4 to 5 before start of experiment. The COD of the solution was determined by using an open reflux system as per standard method.

The laboratory based experimental setup was used for the electrochemical treatment of sugar mill wastewater. The dimensional Characteristics of the experimental setup and the electrical assembly are shown in Table 2.

Table 2: Dimensional Characteristics of the experimental setup

Electrode	
Material (anode and cathode)	Stainless steel (SS), Aluminium (Al)
Shape	Rectangular Plate
Size	90mm x 110mm

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Thickness	1.5 mm
Plate arrangement	Parallel
Effective electrode surface area (sq.mm)	9900
Reactor Characteristic	
Make	Plexiglas
Reactor type	Batch mode
Dimension	146mm x 94mm x146mm
Volume	2 liter
Electrode gap	10 mm
Stirrer mechanism	Magnetic bar
Power supply	Direct current (DC)
Voltage range (V)	0-32
Current range (A)	0-3

RESULT AND DISCUSSION

The current density (CD) being a surrogate parameter is found to influence the treatment efficiency of the electrochemical degradation processes (Chen et al., 2000; Den and Huang, 2005). Therefore, the applied CD was varied to examine its effect on the COD for a 4, 6 and 8 plate configuration of Stainless steel and aluminium electrodes in parallel arrangement. In electrolysis, the cell voltage increases with increasing CD. A linear relationship between the applied voltage and the CD is shown in Figure 1. As can be seen, an increase in CD from 10.44 to 25 A/m^2 for SS causes an increase in the applied voltage from 6.2 to 10.5 V. Similarly, for Aluminium electrode, an increase in current density from 18.75 to 37.5 A/m^2 causes an increase in voltage from 13 to 19.1 V.

The influence of CD on the treatment efficiency of the electrochemical process was observed by several investigators (Lin and Peng, 1994). It is apparent that the COD removal improves steadily with an increase in CD and tends to peak out at around a particular CD value (Lin and Lin, 1998). This optimal value can cut down the investment and operational cost. Operating CD is critical in a batch ECR as it is the only parameter which can be directly controlled.

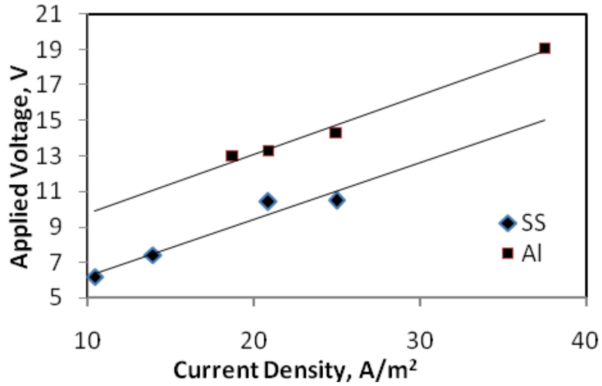

Figure 1 Applied voltage as a function of Current Density.

At higher CDs the hydroxide ion concentration on the surface of the cathode increases and a part of the OH- are carried away by diffusion or electric migration in to the bulk of the solution. In practical applications, it is necessary to limit the operating CD to reduce excessive evolution of oxygen and other negative aspects such as heat generation. The selection of an appropriate CD depends on other operating parameters such as pH0, wastewater character, conductivity, temperature, SA/V ratio and the flow rate as well (Mahesh et.al 2006). Too large a CD would result in a significant decrease in the current efficiency (CE). Also at too large applied current, the electrical energy gets used up in heating the cell solution/aqueous mixture. At higher CDs the hydroxide ion concentration on the surface of the cathode increases and a part of the OH- are carried away by diffusion or electric migration in to the bulk of the solution.

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Figure 2 presents the COD removal efficiency as a function of applied CD for SS and Al Electrodes. The residual COD of the solution determined after the EC process reaches an apparent steady state condition, normally after 20-30 min of operation. At 13.92 A/m^2, 37.21% COD removal for a SS electrode is observed; at 25.0 A/m^2, 54.55% COD removal for a Aluminium electrode is observed. Above these values of CD, the COD removal efficiency tends to decrease.

Based on the experimental observations, aluminium electrode configuration at a current density 25 A/m^2 with 54.55% COD removal efficiency was considered optimal.

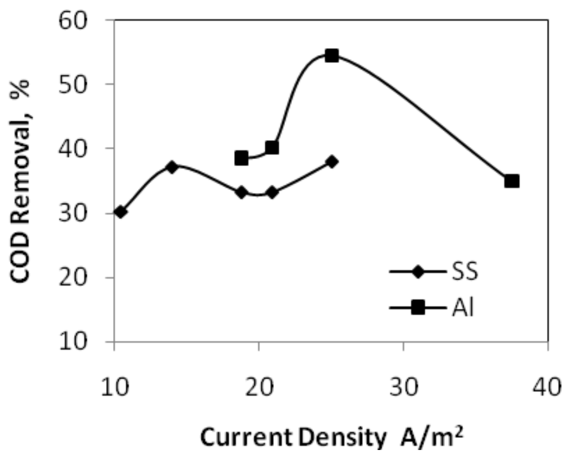

Figure 2: COD removal at different current densities

This decrease in performance may be attributed to the increase in the size of the emanating bubbles which resulted in quick floatation of the particles, thus lowering the COD removal efficiency. The small-sized bubbles possess and provide a larger total surface area to coalesce with the metals released to form hydroxides and remain in the solution for a long time. These small sized bubbles are available for the attachment of particles and the formation of denser and larger flocs in the aqueous stream resulting in a better separation. At high CD (above the limiting CD), only a fraction of the applied current, which is equal to the limiting current, is used for the combustion and the rest for the side reaction for oxygen evolution (Mollah et. al 2004).

Figure 3 demonstrates a decrease in the optimum CD as the scale-up parameter SA/V increases. The increase in the anode area, (ie. increase of the SA/V parameter) induces a decrease in the necessary EC time (ET) for a given CD. A CD of 25 A/m^2 providing a maximum COD removal of 54.55% having an SA/V ratio of 0.06 m^2 /m^3 with ET = 20 min, was considered an appropriate treatment condition with aluminum electrode.

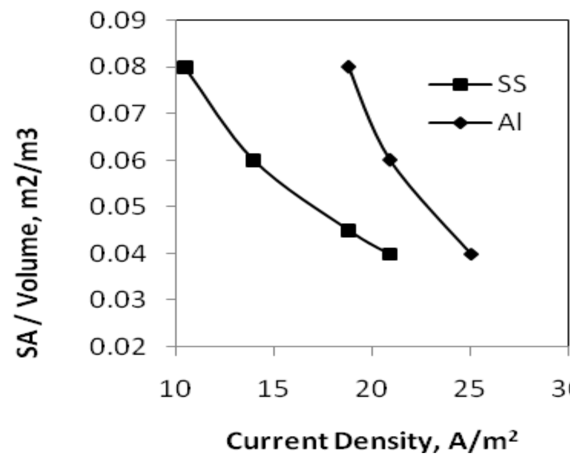

Figure 3: Optimum Current Density as a function of SA/V

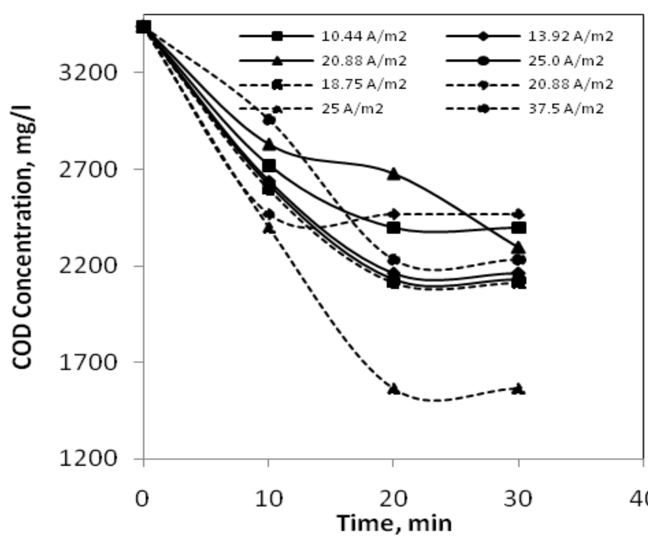

Figure 4: Time-course of COD and colour at different Current Densities

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COD concentration was observed at 10, 20 and 30 min at various CD is observed in figure 4. A graph of 10.44, 13.92, 20.88 and 25 A/m2 was observed for SS electrodes and 18.72, 20.88, 25 and 37.5 A/m^2 was observed for Al electrodes. From this Al electrode with CD of 25 A/m^2 and ET=20 min was observed to be optimal.

CONCLUSION

From the present study the following conclusions can be drawn:

- The current density (CD) materials of electrode have significant effect on the removal of COD from sugar mill wastewater.
- Maximum COD removal in the present study was found to be about 54.55 % by using Aluminium electrode with CD is 25 A/m2 and ET=20 min.
- Aluminium electrodes was found to be more efficient than stainless steel electrodes.
- It can be concluded that the Electrocoagulation process can be adopted for the removal of COD from sugarcane based sugar mill wastewater.

References

1. Adhoum, N.; Monser, L.; Bellakhal, N.' Belgaid E.J. Treatment of electroplating waste water containing Cu2+, Zn2+ and Cr (VI) by electrocoagulation. J. Hazard. Mater. 2004. B112, 207.

2. Chen G, Chen X, Yai C P.L. Electrocoagulation and electroflotation of restaurant waste water, ASCE J Environ Eng. Div 2000 126,858

3. Den W Hang C Electrocoagulation for removal of silica nano particales from chemical – mechanical- plant organization waste. Collids surf A 2005 254,81

4. Fox, M.; Noike, T. Wet oxidation pretreatment for the increase in anaerobic biodegradability of newspaper waste. Bioresour. Teclmol. 2004. 91, 273.

5. Ganjidoust, H.; Tatsumi, K.; Yamagishi, T.; Gholial, R.N. Effect of synthetic and natural coagulant on lignin removal from pulp and paper mill wastewater. Water Sci. Technol. 1997, 35, 291.

6. Kobya, M.; Senturk, E.; Bayramoglu, M. Treatment of poultry slaughterhouse waste water by electrocoagulation. J. Harzad, Mater, 2005, in press.

7. Lin, S.H.; Lin, Mahesh S. B. Prasad, I.D.Mall and I.M. Mishra, Electrochemical Degradation of pulp and paper will wastewater Part I cod and color removal, Ind.Eng.Chem. Res.2006a.

8. Lin S.H. Peng, CF Treatment of txtile waste water by electrochemical method, Water Rs 1994 25,277

9. Lin S.H. Lin C.S. Reclamation of waste effluent from a chemical fibre plant Desalination 1998 120,185

10. Mahesh S. B. Prasad, I.D.Mall and I.M. Mishra, Electrochemical Degradation of pulp and paper will wastewater Part I COD and color removal, Ind. Eng Chem Res.2006b.

11. M. Saleqzzaman, S.M. Tariql islam, A. Tasnuva et.al. Environmental Impact of sugar industry – A case study on kushtia sugar mills in Bangladesh. i.innov.dev.stratagy 2(3):31-35 (November 2008)

12. Mollah, M.Y. A.; Pathak, S.R.; Patil, P.K.; Vayuvegula, M.; Agarwal, T.S.; Gomes, J.A.G.; Kesmez, M.; Cocke, D.L. Treatment of orange II azo-dye by electrocoagulation (EC) technique in a continuous flow cell using sacrificial iron electrodes. J. Hazard, Master. 2004 B109, 165.

13. Sanjay K. Solomon, Environment pollution and its management in sugar Industry in India : An Appraisal, Sugar Tech 7(1)(2005):77-81