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Electrochemical Treatment Of Rice Grain Based Distillery Effluent Using Iron Electrode

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Abstract: In the present study, electrochemical treatment process was conducted to treat rice grain based distillery biodigester effluent (BDE). The process was performed using iron plates as electrode. The effect of pH (3.5-9.5) on the COD and color reduction was investigated. At the current density (j) of 99.3 A/m^2 and electrode gap 1.5 cm and pH 8 the chemical oxygen demand (COD) and color removal efficiency were maximum with 83% COD reduction and 69% color reduction. The organic removal efficiency was strongly depended on initial pH (pH_i). At the pH 8 electrode consumption was 25.3 mg/dm^3 while energy consumption was 29.8 Wh/dm^3 of treated BDE.

Keywords: biodigester effluent, chemical oxygen demand, color reduction, anode consumption, energy consumption.

Introduction

In India sugar cane molasses is main raw material to produce ethanol. Since large amount of rice is produced, therefore, rice grain is also being used as a raw material in the place of sugar cane molasses. The molasses based distillery produce high organic loaded wastewater in comparison to rice grain based distillery. So its treatment of rice grain based distillery effluent is easy.

Ethanol is produced by fermentation of raw material in fermentation broth. The liquor, after fermentation contains around 6-15% alcohal, which is separated from the series of distillation column as a top product and the hot liquid coming out from the bottom is a waste material. This hot liquid is commonly known as spent wash (SW). The SW is dark brown in color and having high COD = 30-50 kg/m^3 and BOD = 7-11 kg/m^3. Due to biodegradable in nature, it is first treated by anaerobic biodigestion, which reduces 60-70% COD and 70-80% BOD of SW. The anaerobic biologically treated effluent known as biodigester effluent (BDE). The BDE still contains high COD (10-15 kg/m^3) and BOD (1.5-2.5 kg/m^3) and is dark brown in color. According to the central pollution control board (CPCB) of India the treated wastewater should have discharge quality (COD< 0.1 kg/m^3, BOD< 0.03 kg/m^3) to discharge in surface waters and (COD< 0.3 kg/m^3, BOD< 0.1 kg/m^3) to discharge in sewers[1]. Therefore, comprehensive strategy is required for maintaining desired standard of the effluents.

Physicochemical treatments are very effective process to treat BDE. Various method like coagulation[2,3], thermolysis with catalyst and without catalyst[4], Wet oxidation[5] and adsorption process has been well reported to treat distillery effluent. Electrocoagulation as a treatment method is more effective as compare to traditional coagulation/flocculation method due to less sludge generation and better color and COD removal efficiency. Prasad and Shrivastava[6] achieved maximum 83.31% color and 39.66% COD reduction, where ruthenium oxide coated titanium mesh acted as anode and stainless steel as cathode. Thakur et al reported 61.6% COD reduction and 98.4% color reduction with the iron electrode[7].

The aim of this study is to find suitable treatment condition for EC process. The process was performed at various pH, keeping constant current density(j) and constant electrode gap (g). The energy consumption and electrode loss have been also evaluated at different pH.

Experimental Section

Effluent and its characterization

The BDE used in the present study was obtained from Chhattisgarh Distillery Pvt. Ltd. Kumhari, Chhattisgarh. Iron plate was used as electrode. Reactor was made up of perspex glass. The effluent was characterized for various parameters namely COD, color, total solids, total dissolved solids, total suspended solid reduced carbohydrate, sulphate, chloride, etc., as per standard method of analysis[8]. The main characteristic of the BDE used for the present study is given in Table 1.

Experimental methods

The lab-scale batch experimental setup was used for the EC studied. The 1.4 dm^3 BDE was taken in a 1.5 dm^3 EC reactor. The pH of BDE was maintained using H_2SO_4 (2 M) and NaOH (2 M) solution. Four electrodes of SS-302 plates 1.5 cm thickness were used for the experiment. All electrodes were rectangular in shape. The area of electrodes dipped into the effluent (BDE) was 7 cm × 7.2 cm. Therefore, total effective surface area of each electrode was 50.4 cm^2. A 1.5 cm gap was provided between the bottom of the electrodes and the bottom of the reactor for proper stirring. The gap between two electrodes in EC reactor was 1.5 cm. Magnetic stirrer was used for continuous mixing of BDE sample. The electrodes were cleaned with 10% diluted HCl solution before each run. Following each run, the electrodes were cleaned with distilled water and dried at room temperature. After this it was reused for the next experiment. The current density was maintained constant by means of a digital direct current (D.C.) power supply (0–30 V, 0–5 A). At the end of the experiments, sample was filtered with Wattman (42 size) filter paper to remove sludge. The filtered liquid was used for analysis of parameters (COD and color).

Results and Discussion

The BDE of rice grain based distillery contains high organic load (COD and BOD material). The COD and BOD of BDE are due to presence of various organics such as melonidian, protein, colloidal particles etc. They are responsible to produce negative charge which takes part in electrochemical process. Fe^{3+} ions released from anode, when potential is applied through external DC power surface across the electrode, which gets attached to the negative ions of BDE, causing small colloids to convert into the heavy flocks. When electro generated Fe cations are librated in solution it hydrolyses to form monomeric and polymeric species: $Fe(OH)^+$, Fe OH^{2+}, $Fe_2(OH)_2{}^{4+}$, Fe $(OH)_4{}^{5+}$, Fe $(OH)_2{}^0$(s) and Fe $(OH)_4{}^-$, etc[9] . The general equation is

$$xM^{3+} + yH_2O = M_x(OH)_y{}^{(3x-y)+} + yH^+ \quad \text{……..} (1)$$

The colloidal particles have net negative charges, which gets entrapped in amorphous ions hydroxides and gets neutralized. The neutralized mass as well as $Fe(OH)_3$ formed, promote to sweep flocculation.

Table 1: Typical composition of biodigester effluent

Parameters	Biodigester effluent
COD	13800
TDS	46245
TSS	40000
TS	86245
Reduced carbohydrate	416
Protein	185
Chlorine	124
Phosphate	.05
Total hardness	9000
Sulphate	4920
pH	7.8
Color	Blakish brown
Absorbence at wavelength = 475nm	0.932
Color (PCU)	450

Effect of pH

pH of the solution has been found to highly influence in the EC treatment process. The effect of pH in the range of 3.5-9.5 was studied at constant current density (j=99.3 A/m^2) and electrode gap (g=1.5 cm). The effect of electrolysis time on COD and color reduction was also observed and the results are presented in Fig.1 (a) and (b). It can be seen that 65%, 66%, 68%, 70% and 63% COD reduction is obtained at pH; 3.5, 5, 6.5, 8 and 9.5 respectively in 20 minute which increases to 78 %, 79 %, 80 %, 83 % and 73 % in 120 minutes. The color reductions of 31 %, 34 %, 36 %, 42 % and 30 % is obtained at pH; 3.5, 5, 6.5, 8 and 9.5 respectively in 20 minute which enhance to 47 %, 52 %, 58 %, 69 % and 48 %. It is clear that pH 8 provides best result during EC treatment. The 83% COD reduction and 69% color reduction is achieved in 120 minutes. Since the BDE have pH 8, thus, no pH adjustment is needed for treatment.

For the optimum design of EC treatment, energy consumption has also been evaluated. It was determinated with the help of following equation[10].

Energy consumption (Wh/dm^3) =

$$\frac{VIt}{Treated\ volume\ (dm^3)} \quad (2)$$

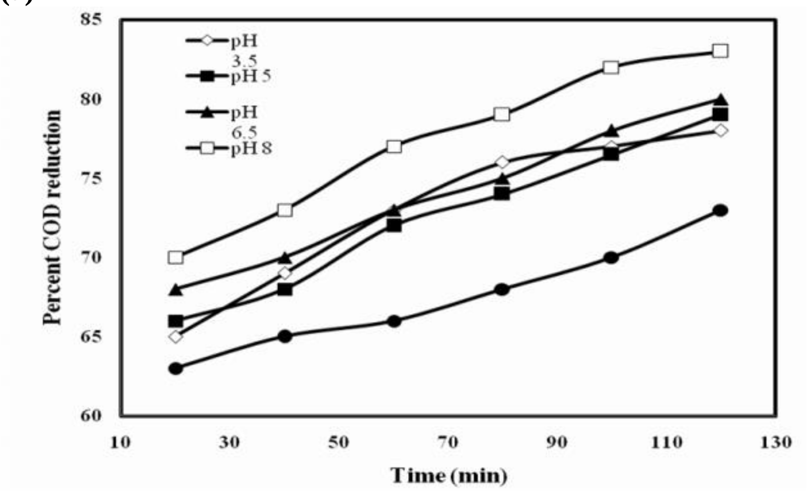
Where V is the cell voltage in volt, I is the current in ampere (A) and t is the electrolysis time (h). The electrical energy consumption during the EC of BDE was determined at different pH (3.5-9.5) current density j = 99.3 A/m^2, electrode gap (g) = 15 mm, treatment time (t_R 120 min and stirring speed = 120 rpm. The results are shown in Fig.2. It was observed that energy consumption increases with increase in pH. The energy consumption of 22.3, 25.2, 27, 29.8 and 32.1 Wh/dm^3 BDE are noted at pH 3.5, 5, 6.5, 8 and 9.5 respectively.

The anode consumption at different pH was also calculated. Two anodes and two cathodes were used in the experiment. The values are shown in Fig.3 at similar operating condition and pH 3.5, 5, 6.5, 8 and 9.5**.** At these pH anode consumes to 23.2, 14.8, 38.2, 25.3 and 309 mg per dm^3 of treated BDE.

Conclusions

EC process with iron as sacrificial electrode had given good results to treat BDE of a rice grain-based distillery. The COD reduction of 78 %, 79 %, 80 %, 83 % and 73 % and color reduction of 47 %, 52 %, 58 %, 69 % and 48 % were obtained at the pH 3.5, 5, 6.5, 8 and 9.5 respectively and at current density 99.3 A/m^2. At the pH 3.5, 5, 6.5, 8 and 9.5 the 22.3, 25.2, 27, 29.8 and 32.1 kWh energy have consumed for per dm^3 treatment of BDE. The weight losses of electrodes obtained at pH 3.5, 5, 6.5, 8 and 9.5 are 23.2, 14.8, 38.2, 25.3 and 309 mg per dm^3 BDE treatment.COD and color was not completely removed by EC process. Thus, the treatment of BDE by EC followed by membrane separation will be good combination to achieve zero discharge.

(a)



(b)

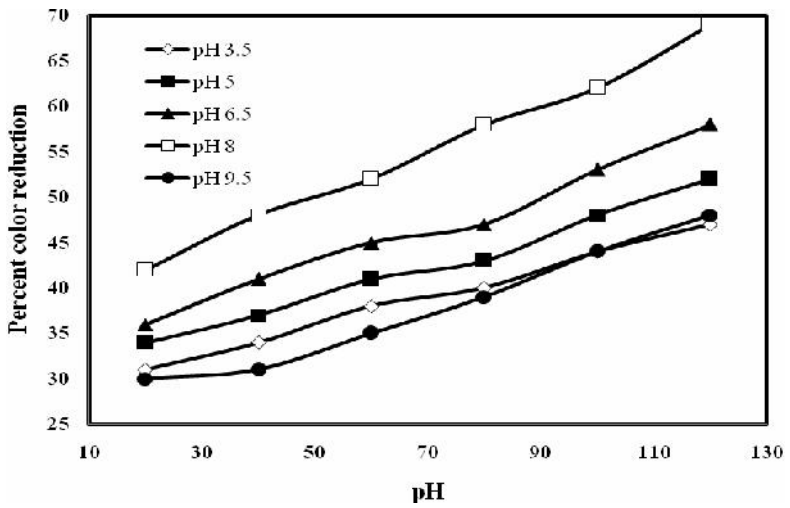


Figure 1. Effect of pH on (a) percentage COD removal (b) color removal (rpm=130, current density 99.3 A/m^2, electrode distance=1.5 cm, COD_i=13600 mg/dm^3)

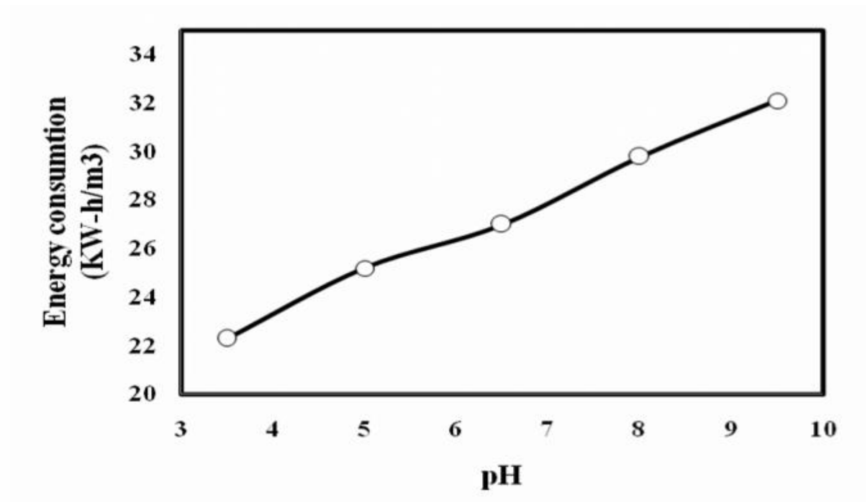


Figure 2. Effect of pH on anode consumption (rpm=120, electrode gap 1.5 cm, electrolysis time 120 min, current density 99.3 A/m^2)

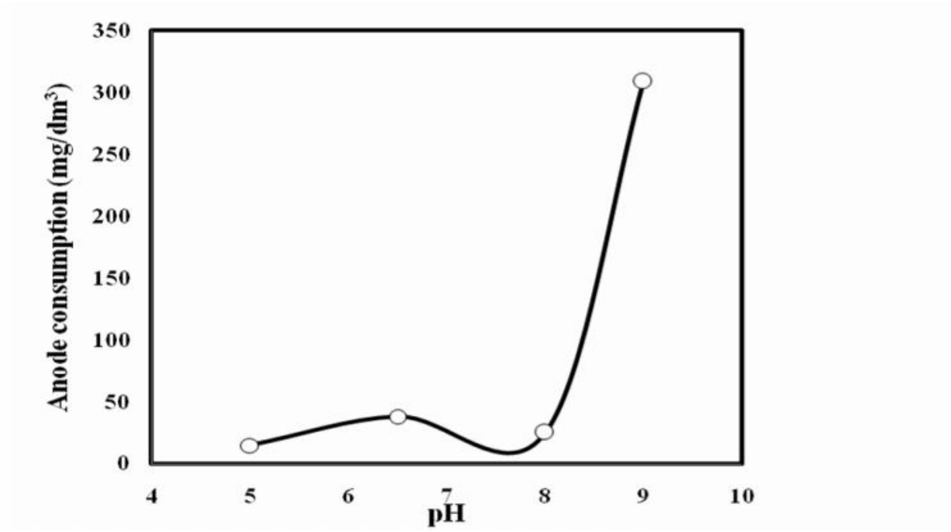


Figure 3. Effect of pH on electrode energy consumption (current density 99.3 A/m^2, electrode gap 1.5 cm and electrolysis time 120 min)

References

1. CPCB, Pollution Control Acts, rules and Notifications Issued There Under, Central Pollution Control Board,Delhi, India, 2006.
2. Chaudhari P.K. Mishra, I.M. Chand, S. "Decolorization and removal of chemical oxygen demand (COD) with energy recovery: Treatment of biodigester effluent of a molasses- based alcohol distillery using inorganic coagulants", Colloids Surf. A: Physicochem. Eng.Aspects 296 pp. 238–247 (2007).
3. Prasad, R.K. "Color removal from distillery spent wash through coagulation using moringa oleifera seeds: Use of optimum response surface methodology", J. Hazard. Mater. 165 pp. 804–811 (2009).
4. Chaudhari, P.K. Singh, R. Mishra, I.M. Chand, S. "Kinetics of catalytic treatment (Catalytic Thermolysis) of distillery wastewater and Bio-digester effluent of alcohol production plant at atmospheric pressure", Int. J. Chem. Reactor Eng., 8 pp. 1-22 (2010).
5. Belkacemi, K. Larachi, F. Hamoudi, S. Sayari, A."Catalytic wet oxidation of high strength alcohol-distillery liquors". Appl. Catal. A: General, 199 pp.199-209 (2000).
6. Prasad, R.K. and Srivastava, S.N. "Electrochemical degradation of distillery spent wash using catalytic anode:Factorial design of experiments", Chem. Eng. J. 146 pp.22–29 (2009).
7. Thakur, C. Srivastava, V.C. Mall, I.D. "Electrochemicaltreatment of a distillery wastewater: Parametric and residue disposal study", Chem. Engg. J. 148 pp. 496– 505 (2009).
8. APHA, in: L. Clesceri, A.E. Greenberg, R.R. Trussell (Eds.), Standard Methods for Water and Waste Water Examination, 17th ed., New York, 1989.
9. Ching, H.W. Tanaka, T.S. Limelech, M.E. "Dynamics of coagulation of kaolin particles with ferric chloride", Water Res. 28(3) pp.559-569 (1994).
10. Kumar, M. Infant, F. Ponselvan, A. Malviya, J.R. Srivastava,V.C. Mall, I.D."Treatment of bio-digester effluent by electrocoagulation using iron electrodes", J. Hazard. Mater. 165 pp.345–352 (2009).

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