Treatment of Pulp and Paper Effluent by Electro Coagulation

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ABSTRACT
The experiments were carried out in an electro coagulation reactor with aluminum as sacrificial electrodes. The influence of electrolysis time, current density, pH, NaCl concentration, rotational speed of the stirrer and electrode distance on reduction of color, COD and BOD were studied in detail. From the experimental results, 25mA/cm2 current density, pH of 7, 1 g/l NaCl, 100 rpm, 28 C temperature and 1.5 cm electrode distance were found to be optimum for maximum reduction of color, COD and BOD. The reduction of color, COD and BOD under the optimum condition were found to be 92%, 89% and 85% respectively. The electrode energy consumption was calculated and found to be varied from 103kWh/kg depending on the operating conditions. Under optimal operating condition such as 25mA/ cm2 current density, pH of 7, 1 g/l NaCl, 100 rpm, 28 C temperature and 1.5 cm electrode distance, The experimental results proved that the electro coagulation is a suitable method for treating pulp and paper plant effluents for reuse. 2013 Trade Science Inc. - INDIA

KEYWORDS: Aluminum electrodes; BOD; COD; Electro coagulation; Pulp and paper effluent.

INTRODUCTION
The Indian paper industries is the largest industry and more than 100 year old. Among world it ranks 20th paper producing country[1] .These industries dis- turbing the ecological balance of the environment by discharging a wide variety of wastewater.India was also the first country in the world to use bamboo as the ba- sis raw material for making paper due the limited forest resources other raw material like bagasse, straw, jute etc were identify and now extensively used waste pa- per is also being used for the paper making. Almost all variety of paper is produces using this material[4]. Waste generated by the pulp and paper industries carries very high BOD, COD, Toxic substances recalcitrant organics, pH, turbidity, high temperature and intense color. The coloring body present in the wastewater from pulp and paper industries is organic in nature and is com- prised of wood extractives, tannin resins, synthetic dyes, lignin and its degradation products formed by the ac- tion of chlorine on lignin[2]. The paper-making process requires large amount of water for the production pro- cesses (about 250-300 m3 per tones of paper) hence it is a water-intensive process. Consumption of water depends upon the raw material used in industrial pro- cesses. The natural raw material are used for the pro- cesses are wood, cellulose, vegetables, bagasses, rice husk, fibers and also waste-paper. This creates a high level of wastewater from processing[3]. The general char- acteristics of the pulp and paper industry effluent can be listed as: 1) high lignin content, 2) high absorbable organic halide concentration, 3) color, 4) low biode- gradability which is indicated by their high chemical oxygen demand to biochemical oxygen demand ratios, and 5) potential

toxicity problems. These effluents con- tain a number of compounds which are harmful to re- ceiving waters and are inhibitory or recalcitrant to bio- logical treatment. Conventional treatment processes like chemical pre-treatment[3], lagooning[4], and activated sludge treatment[5,6] are not adequate to meet the regu- latory effluent standards for being discharged into sew- ers. Therefore, the pulp and paper industry has to use tertiary stage to meet the effluent discharge standards. Several treatment methods are in use in large industries including physcio-chemical and biological process. The biological treatment is also not very effective in reduc- ing colour[7], although BOD and COD reduction has been found to be satisfactory. However, lignin and its derivatives show high stability to degradation[8,9]. Pri- mary treatment methods like physical, chemical and thermal prẽtreatment may be followed by anaerobic, aerobic and enzymatic treatment methods to remove the residual organics, which is largely degradable. Electro Coagulation can, however, be used as an ef- fective primary treatment method to remove much of the, colour, and COD (and BOD). This treatment will make the secondary treatment cost effective as well as efficient in the removal of BOD, COD and colour. The present paper deals with the COD, BOD and colour removal of pulp and paper industries effluent using alu- minum electrodes.

Physical and chemical processes are quite expen- sive and generate a considerable amount of sludge which itself needs further treatment[4,5]. The low biodegrad- ability index of pulp and paper effluent from bleaching process clearly shows that the biochemical method can- not be used[6,7]. Various treatment methods used for bleaching effluent reported in the literature are given in TABLE 1. In recent years, electrochemical technolo- gies such as electro coagulation, electro floatation and electro oxidation have been used for the treatment of pulp and paper effluent. Among these methods, electro coagulation emerges as one of the promising techniques due to its unique feature such as complete degradation of pollutants, less sludge generation and ease in opera- tion. Electrocoagulation is a complex and interdependent process where the generation of coagulants takes place in situ by dissolving sacrificial anode. From the literature it is found that most of the researchers suc- cessfully used electrocoagulation method for the treat- ment of black liquor from pulp and paper industries (TABLE 2). However, very limited works have been reported for the treatment of pulpbleachingeffluent using electrocoagulation method and hence in the present paper an attempt is made to study the influence of op-erating parameters such as time of electrolysis, current density, initial pH, electrolyte concentration, agitation speed and electrode distance on color,COD and BOD reduction and the fundamental and operating variables were optimized. The main objective of the paper is to analyze the physico-chemical characteristics of the ef-fluent and the influent of the effluent treatment plant of the paper mill. The world demand for paper has grown rapidly and was around 5-6% per year. The paper in- dustries have an larger investment and provide employ-ment to 2 lakh people. It is estimated that the capacity of the industries increases from 8.3 million tonnes in 2010 to 14 million tonnes in 2020[6]. In India the total production 70% is from hardwood and bamboo fibre, agro-waste and other 30% is from recycled material. For paper, paperboard and newsprint production, 550 industries in India use wastepaper as a raw material.

TABLE 1 : Characteristics of pulp and paper industry efflu- ent

Characteristics	Value
Chemical oxygen demand (COD) (mg/L)	7050
Biochemical oxygen demand	1350
Total Suspended Solids (mg/L)	1000
Conductivity (µmhos/cm)	54670
pH	9
Color	Dark brown

MATERIAL AND METHODS

Pulp and paper effluent used in this study was ob- tained from a Nepa limited located in Nepanagar Burhanpur District, Madhya Pradesh India The lab-scale batch experimental setup used for the electrochemical degradation studies is schematically shown in Figure 1. Experiments were carried out in a 1.4 L reactor made up of glass Electro coagulation treatment of both anionic and cationic species is possible byusing an alumi- num plates of thickness 3mm as the sacrificial electrode. The plates, if connected in series, have higher resistance. In a parallel arrangement, the electric current is divided between all the electrodes in relation to the resistance of the individual cell. Therefore, the electrode plates were arranged in parallel. There were four electrodes con- nected in a bipolar mode in the electrochemical reactor, each one with dimensions of 8 cm X 8.4 cmX.3cm. The total effective surface area of each electrode was 64cm2.The electrode plates were cleaned manually by abrasion with sandpaper, and theywere treated with 15% HCl for cleaning followed by washing with distilled wa- ter prior to their use. The electrodes were spaced 1.5cm apart (because <10 mm spacing between electrodes pre- vented movement of liquid adsorbate in the interstitial spaces of the electrodes thus, hindering/affecting removal efficiency). The anode and the cathode leads were con- nected to the respective terminals of DC power supply. The thickness of the plates was 3.00mm. Magnetic stir- rer was used to agitate the solution. At the end of the experiments, sample was filtered to remove sludge. The filtered liquid was used for color, BOD and COD analy- sis. The characteristics of effluent are analyzed using the following technique and are reported in TABLE 3.

Determination of color

The sample was centrifuged at 10,000rpm for 30 min to remove all the suspended matter. The pH of su- pernatant was adjusted to 7.6 by the addition of 2M NaOH and absorbance was measured at 465 nm. Color units (CUs) were determined from UV- vis spectropho- tometer.

Determination of biochemical oxygen demand

The 5-day BOD of sample was determined at 20 oC using standard dilution technique according to the American Public HealthAssociation (APHA)[23]. 300 ml of sample was taken in air tight BOD bottle and kept it in incubator for 5 days at 20 oC. Dissolved oxygen con- centration (DO) was measured initially and after 5 days of incubation. BOD was calculated from the difference between initial and final value of dissolved oxygen.

Chemical oxygen demand

COD was determined by the open reflux method according to APHA[23]. In this method, the sample was refluxed with potassium dichromate and sulfuric acid for 2 h and then titrated with ferrous ammonium sulfate and COD was calculated.

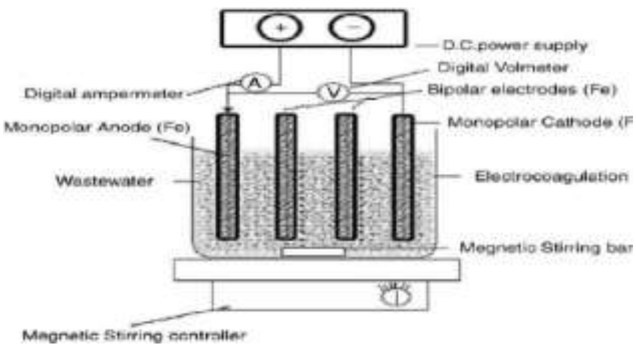

Figure 1 : Batch-scale EC reactor with bipolar electrodes in Parallel connection

RESULT AND DISCUSSION

Effect of current density

Many authors have worked on the effect of current density and find that current density has significance ef- fect on efficiency of electro coagulation process. The experiments were carried out by varying current den- sity and observation is shown in figure 2,figure 3,figure

4. The removal of color, COD, BOD was increased with increasing current density because of increase in the gas bubbles density with reduction in their size en- hances upwards flux resulting increased pollutant deg- radation and sludge floatation[25]. The removal of color, COD and BOD were increased with increasing current density. Optimum condition for the current density was observed at 25mA/cm2 current density for 60min of electro coagulation time. After 60min of electro coagulation not show anysignificant improvement on the per- centage of color, COD and BOD removal.

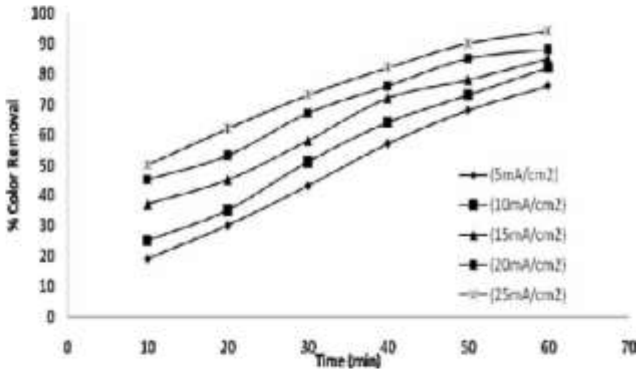

Figure 2 : Effect of current density on percentage color re- moval (rpm = 100, pH -7, temperature = 28oC, NaCl concen- tration = 1 g/l, electrode distanc e = 1.5 cm).

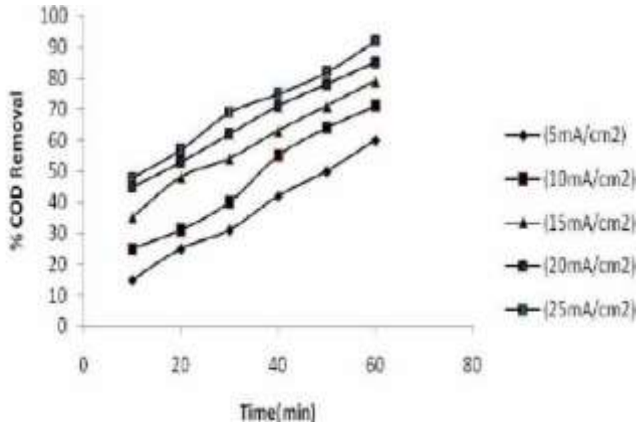

Figure 3 : Effect of current density on percentage COD re- moval (rpm = 100, pH 7, tem-perature = 28□C, NaCl = 1 g/l, electrode distance =1.5cm).

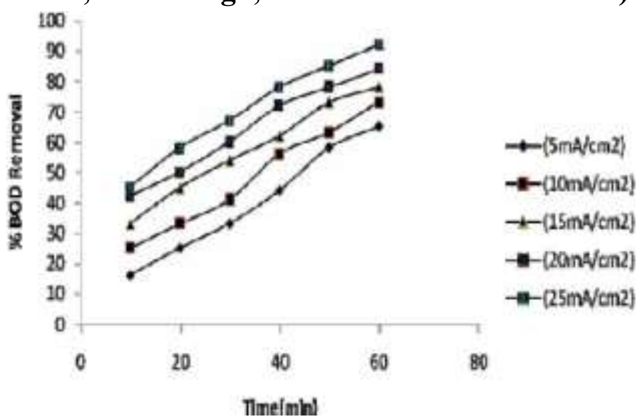

Figure 4 : Effect of current density on percentage BOD re- moval (rpm = 100, pH 7, temeperature 28□C,NaCl = 1 g/l, Electrode distance =1 .5 cm).

Effect of pH

pH is an important parameter for the electrocagulation process. Following are the reaction take place on aluminum sacrificial electrodes during the oxidation in acid and alkali medium[18].

For acid condition

$$Al \rightarrow Al^{3+} + 3e^-$$

$$Al^{3+} + 3H_2O \rightarrow Al(OH)_3 + 3H^+$$

For alkali condition

$$Al \rightarrow Al^{3+} + 3e^-$$

$$3H_2O + 3e^- \rightarrow (3/2)H_2(g) + 3OH^-$$

$$2Al + 6H_2O + 2OH^- \rightarrow 2Al(OH)_4^- + 3H_2$$

Since initially amorphous Al(OH)3 has large surface areas, which are beneficial for a quick adsorption of soluble organic compounds and entrapping of colloidal particles and hence more reduction of color, COD and BOD with increasing pH up to 7.further increasing in pH beyond 7 reduction of color, COD,BOD decreases because of Al(OH)4 which does not contribute to the reduction of color, COD and BOD[18].

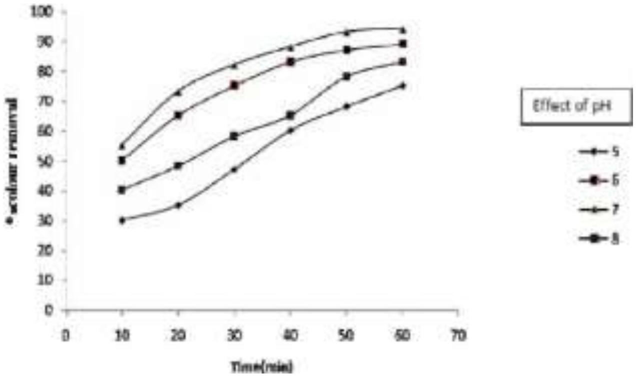

Figure 5 : Effect of pH on percentage color removal (rpm = 100, current density = 25 mA/cm2, temperature = 28□C, NaCl = 1 g/l, electrode distance = 1.5cm

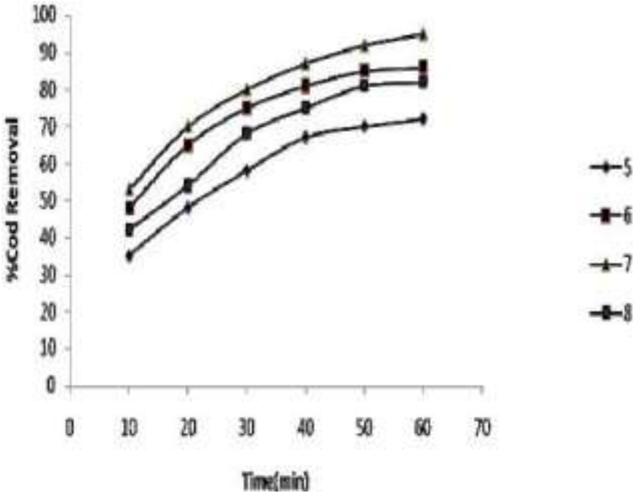

Figure 6 : Effect of pH on percentage COD removal (rpm = 100, current den-sity = 25 mA/cm2, temperature = 28□C, NaCl = 1 g/l, electrode distance = 1.5 cm)

Effect of rotational speed

The effect of rotational speed was observed by varying the rotational speed from 50 to 200 rpm it is found that with increasing in rotational speed from 50 to 200 rpm significantly increases the percentage re- duction of COD and BOD up to 100 rpm because of increases in intensity of turbulence with rotational speed and reduced the diffusion layer thickness of electrodes surface. Beyond the 100 rpm no significant increases in COD, BOD removal was observed because of com- plete mixing.

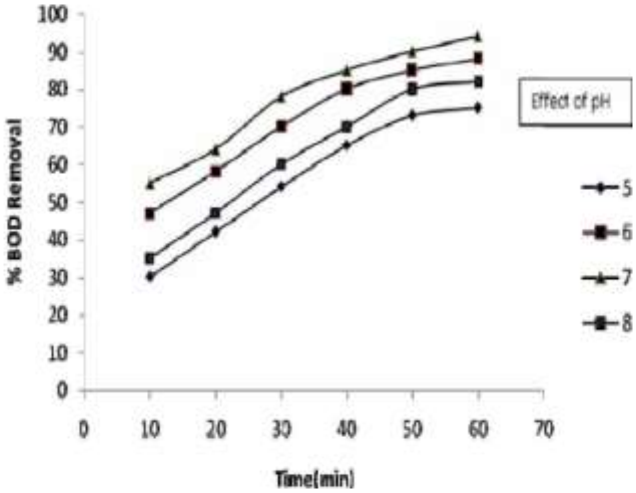

Figure 7 : Effect of pH on percentage BOD removal (rpm = 100, current density =25 mA/cm2, temperature = 28□C, NaCl = 1 g/l, electrode distance = 1.5 cm)

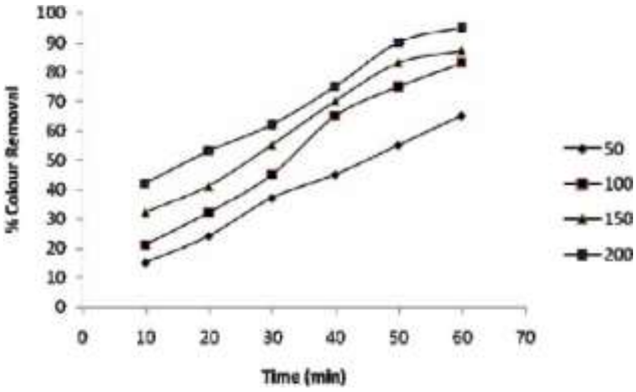

Figure 8 : Effect of rotational speed (rpm) on percentage color removal (pH 7, current density = 25 mA/cm2, tempera- ture = 28□C, NaCl = 1 g/l, electrode distance =1.5cm).

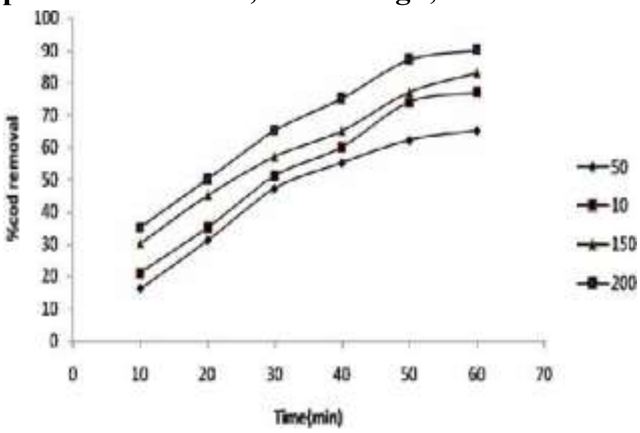

Figure 9 : Effect of rotational speed (rpm) on percentage COD removal (pH 7, current density = 25 mA/cm2, tempera- ture = 28□C, NaCl = 1 g/l, electrode distance =1.5cm).

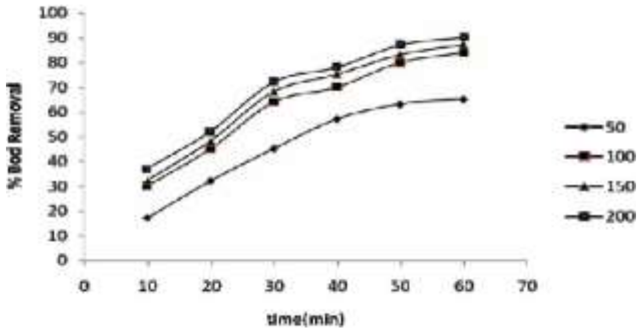

Figure 10 : Effect of rotational speed (rpm) on percentage BOD removal (pH 7, current density = 25 mA/cm2, tempera- ture = 28□C, NaCl = 1 g/l, electrode distance =1.5cm).

Effect of NaCl concentration

The effect of NaCl concentration on color removal efficiencyis given in Figure 12. Color removal increased from 86% to 99% as NaCl concentration increased from 0.5 to 2 g/l. When the chloride is present in the solution, the products of anodic discharge are Cl2 and OCl-. This OCl- acted as a strong oxidant agent to remove organic molecules. NaCl not onlyincreases the conductivity, but also contributes as strong oxidizing agents and hence color removal increases[15,26]. The presence of NaCl has a considerable effect on the per- centage COD and BOD.

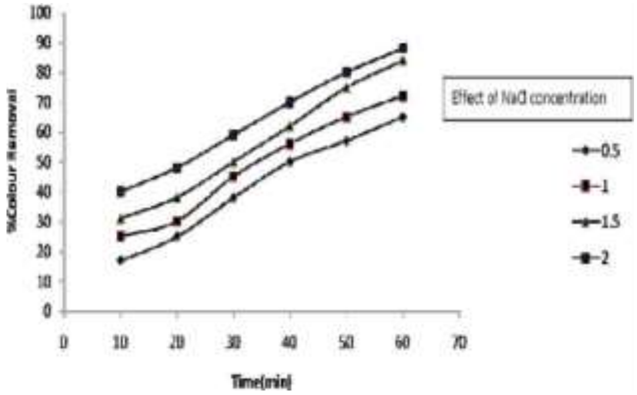

Figure 11 : Effect of NaCl concentration on percentage color removal (pH 7, current density = 25 mA/cm2, temperature = 28□C, rpm = 100, electrode distance = 1.5 cm).

Effect of electrode distance

Electrode distance has significant influence on the color, COD, BOD removal. It is observed that with increasing in electrode distance between 1.5 - 6cm The percentage removal of color, COD and BOD increases further increasing in electrode distance beyond 4.5 cm did not get any improvement on the percentage color, COD and BOD removal because the electric potential between the electrodes decrease while increasing elec- trode distance.

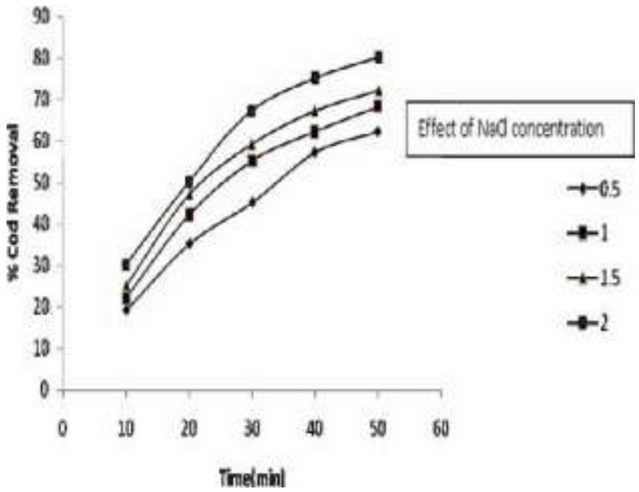

Figure 12 : Effect of NaCl concentration on percentage COD removal (pH 7, current density = 25 mA/cm2, temperature = 28□C, rpm = 100, electrode distance = 1.5 cm).

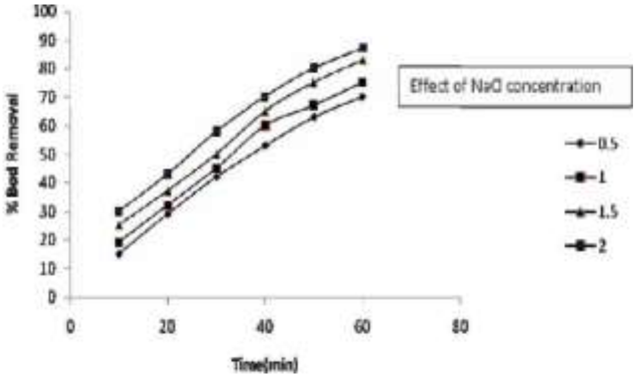

Figure 13 : Effect of NaCl concentration on percentage BOD removal (pH 7, current density = 25 mA/cm2, temperature = 28□C, rpm = 100, electrode distance = 1.5 cm).

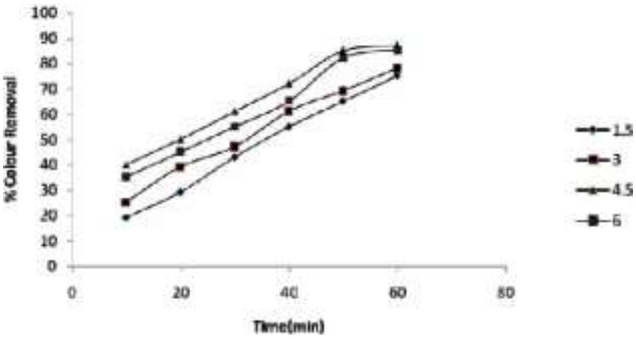

Figure 14 : Effect of electrode distance on percentage color removal (pH 7, current density = 25 mA/cm2, temperature = 28□C, rpm = 100, NaCl = 1 g/l).

Power consumption

To find out the power required per unit Color removal,BOD, COD removal, the data were evaluated

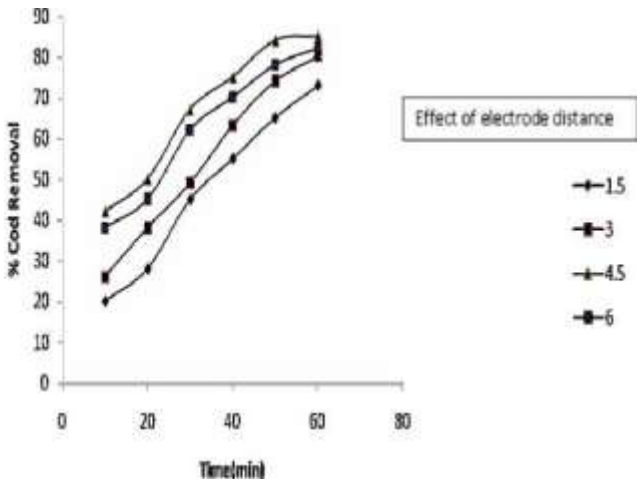

Figure 15 : Effect of electrode distance on percentage COD removal (pH 7, current density = 25 mA/cm2, temperature = 28□C, rpm = 100, NaCl = 1 g/l).

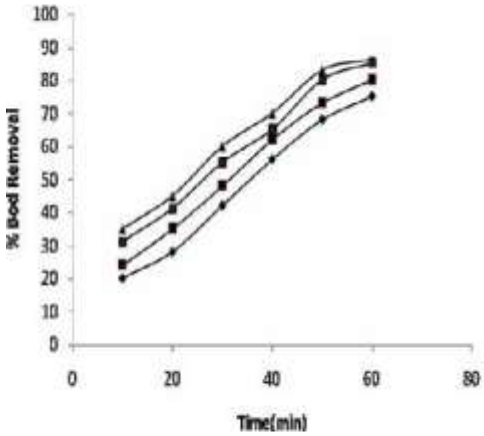

Figure 16 : Effect of electrode distance on percentage BOD removal (pH 7, current density = 25 mA/cm2, temperature = 28□C, rpm = 100, NaCl = 1 g/l).

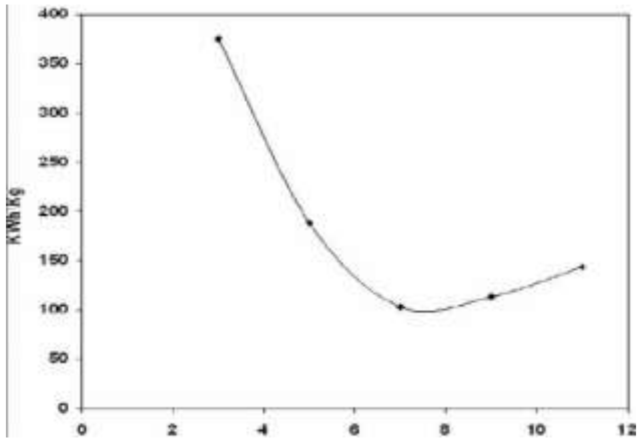

Figure 17 : Effect of pH on power consumption (pH 7, current density = 25 mA/cm2, temperature = 28□C, rpm = 100, NaCl = 1 g/l).

and presented in Figure 17. The power consumption per unit Color removal,BOD, COD removal were 103 kWh/kg at pH0 7 < 112.9 kWh/kg at pH0 9 < 143.24 kWh/kg at pH0 11 < 180 kWh/kg at pH05< 375 kWh/ kg at pH0 3. Thus, power consumption in COD re- moval point of view, EC at pH0 7 is better because it takes miminum power consumption than power con- sumption required at other Ph.

CONCLUSION

Electro Coagulation is a feasible process for the treatment of the pulp and paper industries effluent waste water, characterized by the high oil and greases con- tent, fluctuated COD, BOD and SS Concentrations. The Treatment of waste water usingaluminum electrodes was affected by the initial pH, the current density, elec- trodes distance, NaCl Concentration, rotational speed The results showed that optimum operating conditions were found to be an initial pH of 7, current density of 25mA/cm^2, rotational speed of 100 rpm, NaCl con- centration of 1 g/l and electrolysis time of 60min. This experimental study clearly showed that under the opti- mal conditions, about 92% color, 89% COD and 85% BOD were successfully removed. The decolorization, COD and BOD percentage removal were found to in- crease with the increase in sodium chloride concentra- tion, current density, impeller rotational speed. Power consumption was found to lowest at 7 pH. From the experimental result it is found that electro coagulation technique could be successfully used for the recovery of water from pulp and paper industries effluent for re- use.

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REFERENCES

1. P.Malaviya, V.S.Rathore; Seasonal variations in dif- ferent physico-chemical parameters of the efflu- ents of Century Pulp and Paper Mill,Lal
2. Kuan,Uttarakhand.‖, Journal of Environmental Bi- ology, **28(2)**, 219-224 **(2007)**.
3. N.M.Sakam; Industrial Effluent, origin character- istic, Effect Analysis and Treatment, Sakthi Publi- cation, India **(1987)**.
4. P.Holt, G.Barton, C.Mitchell; Electrocoagulation as wastewater treatment, The Third Annual Austra- lian Environmental Engineering Research Event. 23-26 November, Castlemaine, Victoria **(1999)**.
5. C.E.Dryden; Outline of chemical technology, Af- filiated East-West Press, **(1973)**.
6. D.W.Francis, P.A.Turner, J.T.Wearing; AOX re- duction of kraft bleach plant effluent by chemical pretreatment, Pilot-scale trials. Water Res., **31**, 2397 **(1997)**.
7. C.W.Bryant, G.L.Amy, B.C.Alleman; Lagoons, ponds, and aerobic digestion, J.Water Pollut.Control Fed., **60**, 828-831 **(1988)**.
8. J.A.Rintala, S.S.Lepisto; Anaerobic treatment of thermomechanical pulping whitewater at 35-70 oC. Water Res., **26**, 1297 **(1992)**.
9. A.Schnell, P.Steell, H.Melcer, J.H.Carey, P.V.Hodson; Enhanced biological treatment of bleached kraft mill effluent ñ I Removal of chlori- nated organic compound and toxicity. Water Res., **34**, 493 **(2000)**.
10. F.Cecen, W.Urban, R.Haberl; Biological and ad- vanced treatment of sulphate pulp bleaching efflu- ent. Water Sci.Technol., **26**, 435- 444 **(1992)**.
11. D.Liverniche, L.Jurasek, M.Desrochers, J.Dorica; Removal of colour from kraft mill wastewaters with cultures of white rot fungi and with immobilized mycelium of coriolus versicolor. J.Biotechnol & Bioen., **25**, 2055-2065 **(1983)**.
12. F.Archibald, L.Roy-Arcand; Photo degradation of high molecular weight kraft bleachery effluent or- ganochlorine and colour. Water Res., **29**, 661 **(1995)**.

13. N.Khan, F.Basheer, D.Singh, I.Farooqi; Treatment of paper and pulp mill wastewater by column type sequencing batch reactor|| Journal of Industrial ResearchTechnology, **1(1)**, 12-16 **(2011)**.
14. D.Pokhrel, T.Viraraghavan; Treatment of pulp and paper mill wastewater - a review, Sci.Total Environ., **333**, 37ñ58 **(2004)**.
15. K.S.Rajesh, M.Singaravel, P.Sankaralingam, S.Subramanian, S.V.Subrahmanyam; Color removal from pulp and paper mill effluent-methods and in- dustrial applicationsóa review, J.Indian Pulp Pa- per Tech.Assoc., **21(1)**, 143ñ148 **(2009)**.
16. G.Thompson, J.Swain, M.Kay, C.F.Forster; The treatment of pulp and paper mill effluent: a review, Bioresour.Technol., **77**, 275ñ286 **(2001)**.
17. T.Kreetachat, M.Damrongsri, V.Punsuwon, P.Vaithanomsat, C.Chiemchaisri, C.Chomsurin; Effects of ozonation process on lignin-derived com- pounds in pulp and paper mill effluents, J.Biochem.Eng., **35**, 365ñ370 **(2006)**.
18. P.Bajpai, A.Mehna, P.K.Bajpai; Decolorization of kraft bleach plant effluent with the white rot fungus Trametes versicolor, Process Biochem., **28**, 377ñ384 **(1993)**.
19. M.Kobya, O.T.Can, M.Bayramoglu; Treatment of textile wastewaters by electrocoagulation using iron and aluminum electrodes, J.Hazard.Mater. **B100**, 163ñ178 **(2003)**.
20. M.Zaied, N.Bellakhal; Electrocoagulation treatment of black liquor from paper industry, J.Hazard.Mater. **163**, 995ñ1000 **(2009)**.
21. A.E.Greenberg, J.J.Connors, D.Jenkins, M.A.Franson; Standard Methods for the Exami- nation of Water and Wastewater, 15th edition, American Public Health Association, Washington, DC, **(1995)**.
22. N.Adhoum, L.Monser, N.Bellakhal, J.E.Belgaied; Treatment of electroplating wastewater containing Cu2+, Zn2+ and Cr(VI) by electro-coagulation, J.Hazard.Mater. **B112**, 207ñ213 **(2004)**.
23. M.Kobya, O.T.Can, M.Bayramoglu; Treatment of textile wastewaters by electrocoagulation using iron and aluminum electrodes, J.Hazard.Mater., **B100**, 163ñ178 **(2003)**.
24. J.O.M.Bockris, B.E.Conway, E.Yeager, R.E.White, (Eds); Comprehensive Treatise of Electrochemistry, Plenum Press, NY, **2**, **(1981)**.
25. C.Phalakornkule, S.Polgumhang, W.Tongdaung; Performance of an electrocoagulation process in treating direct dye: batch and continuous upflow processes, in: World Academy of Science, Engineering and Technology, **57**, **(2009)**.
26. E.Yeager, J.O.M.Bockris, B.E.Conway, S.Sarangapani, (Eds.); Comprehensive Treatise of Electrochemistry, Plenum Press, NY, **6**, **(1983)**.