SETTLING AND FILTERABILITY STUDIES OF ELECTROCHEMICALLY TREATED PULP AND PAPER MILL WASTEWATER FOR REMOVAL OF COD AND SVI CONTROL

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ABSTRACT:

This paper deals with the removal of COD, settling and filterability aspects of pulp and paper mill wastewater using batch electrochemical coagulation (ECC) with SA/V of 33.33 m^2/m^3. Stainless steel (SS304) and Copper (99.99% purity) plates are used as electrodes for removal of COD and TDS. For SS electrodes, 50% and 62% COD removal was observed at an applied cell voltage of 16 V and 20 V respectively and Cu electrodes showed 36% and 43% COD removal after ECC treatment at an applied cell voltage of 16 V and 20 V respectively. For Cu electrodes SVI values 376 mL/g and 431 mL/g were obtained and for SS electrodes SVI values 296 mL/g and 322 mL/g were obtained after ECC treatment at applied cell voltage of 16 V and 20 V respectively.

Keywords: Paper mill wastewater, ECC, Settleability, Filterability, Sludge Volume Index.

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1. Introduction

Paper mill wastewater contains generally large quantities of solids (total solids and Total Dissolved Solids) along with considerable amount of Color and COD. Pulp and paper mills generate large amounts of wastewater in their manufacturing processes. Pollutants are produced during the wood debarking, digesting, pulp washing, pulp bleaching and papermaking processes (Mahesh et al., 2006 a Part-I). Effluents often contain high amounts of toxic chemicals which originate from raw materials such as resin acids and tannins, or are produced during the manufacturing processes, such as chlorinated organic compounds. These pollutants cause long-term toxic effects on animal life, such as respiratory stress, toxicity, mutagenicity and genotoxicity (Vepsalainen et al., 2011).

Irfan et al., 2013 reported 76% COD, 95% TSS and 95% colour removal with coagulation–flocculation process. Sridhar et al., 2011 carried out in an electrocoagulation using aluminum as sacrificial electrodes and reported 94%, 90% and 87% reduction of color, COD and BOD respectively at 15 mA/cm^2 current density. Parama Kalyani et al., 2009 carried out coupling electro-coagulation with sequential batch reactor (SBR) and reported maximum color removal efficiency of 92% and 84% and COD reduction of 95% and 89% for mild steel and aluminum electrode respectively. Khansorthong et al., 2009 reported 97% of color and 77% COD removal under batch EC treatment and 91% and 77% color and COD removal respectively in continuous EC treatment with iron electrodes. Soloman et al., 2009 reported 55% COD removal and 87% color removal with batch ECC carried out with mild steel electrodes. Wang et al., 2007 carried out electrochemical oxidation of pulp and paper making wastewater assisted by transition metal (Co, Cu) modified kaolin in a 200 ml electrolytic batch reactor with graphite plate as electrodes and reported 96.7 % COD removal. Zodi et al., 2009 treated paper mill wastewater with batch ECC using Fe and Al electrodes and reported COD removal of 32 % with Al and 68 % with Fe electrodes respectively and also reported SVI values of 207 and 310 mL/g with Al electrodes at 100 and 150 A/m^2 current density respectively and SVI value of 81 and 91 mL/g with Al electrodes at 100 and 150 A/m^2 current density respectively. Mahesh et al., 2006 treated black liquor from pulp and paper industry using Fe electrodes and reported 80% COD removal and SVI values for the initial system pH$_o$, 5, 7, 9, 11 were found to be 269, 312, 154, 133 respectively.

Many researchers have reported treatment of paper mill wastewater using Fe and Al electrodes and very limited work is reported for ECC using Cu and SS electrodes as also settling and filterability aspects. Therefore, in the present research, post ECC settling and filterability studies of paper mill wastewater for pre-optimized operating conditions of SA/V of 33.33 m^2/m^3 using SS and Cu electrodes was carried out considering COD and TDS as target parameters for removal in batch ECC mode in a bipolar array.

2. Materials and Methods

Raw wastewater samples were collected from the South India Paper Mill effluent treatment plant located in Mysore, Karnataka, India. The collected raw wastewater sample was stored in preservator and was thoroughly mixed and brought to room temperature, before drawing 1.5 L liquid for every batch ECC test run. The characteristics of wastewater analyzed as per Standard methods APHA, 2010 are presented in Table 1.

Table 1: Physico-Chemical characteristics of Pulp and Paper mill wastewater

Sl.No	Parameter	Value
1	Color	Brown
2	Temperature (^oC)	28
3	pH	6.01 - 6.62
4	COD (mg/L)	2659 - 2974
5	BOD (mg/L)	763 - 974
6	Chlorides (mg/L)	120 - 122
7	Conductivity (µS/cm)	2002 - 2053
8	Total Alkalinity (mg/L)	120 - 140
9	TS (mg/L)	3356 - 3714
10	TDS (mg/L)	2564 - 2946

Batch ECC treatment was carried out using four small sized SS and Cu sheets as electrodes to obtain a SA/V of 33.33 m^2/m^3. The resultant slurry obtained from batch EC treatment is used was for settling and filterability studies.

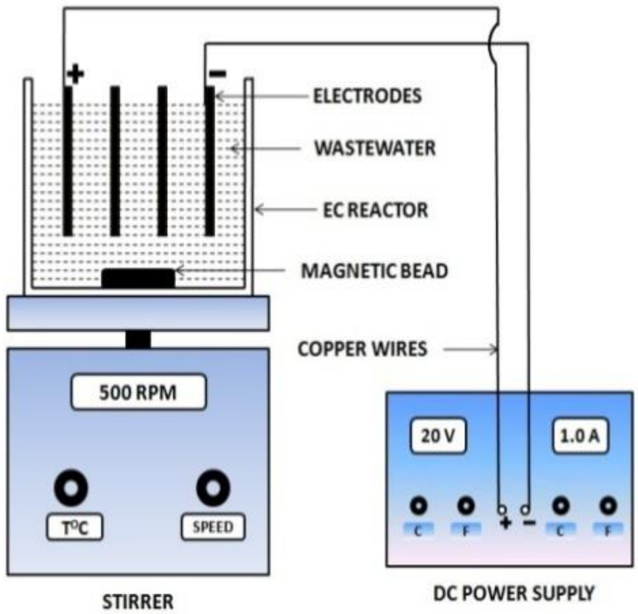

Figure 1: Batch ECC set-up

Figure 1 shows the laboratory set-up of batch ECC treatment. The EC reactor made of Plexiglass with an effective holding capacity of 1.5 L was used in the batch ECC studies Stainless steel (SS304) and Copper (99.99% purity) plates were used as sacrificial electrodes. The distance between the electrodes were maintained at 1 cm and the end electrodes were connected to DC power supply unit through copper lead wires. The electrolysis time was predetermined for a constant treatment time of 60 min for each run for different applied cell voltages of 16 V and 20 V. The wastewater sample was poured into the EC reactor placed on a magnetic stirrer and gentle inductive stirring was done at 500 rpm. The EC reactor was cleaned and the electrodes were washed thoroughly before and after each experiment using water with 15 % HCl solution followed by distilled water to dislodge the deposition of layer formed on the electrodes.

After EC treatment, the mixture was homogenized and poured into a settling column as per APHA, 2010. The height of solid-liquid interface (murky or clear) was recorded at regular intervals upto 30 min duration. The filterability of sludge was tested using a gravimetric filter paper having a pore size of 11 μm (grade I) supported over a ceramic buechner funnel having 73 mm internal diameter (filter area: 49.854 cm^2). The slurry was filled into the Buechner funnel and the filtrate was collected in thin cylinder is recorded at regular time intervals. SVI were calculated as per APHA standard methods, 2010.

$$SVI = \frac{\text{settled sludge volume (mL/L) x 1000}}{\text{suspended solids (mg/L)}}$$

3. Results and Discussion

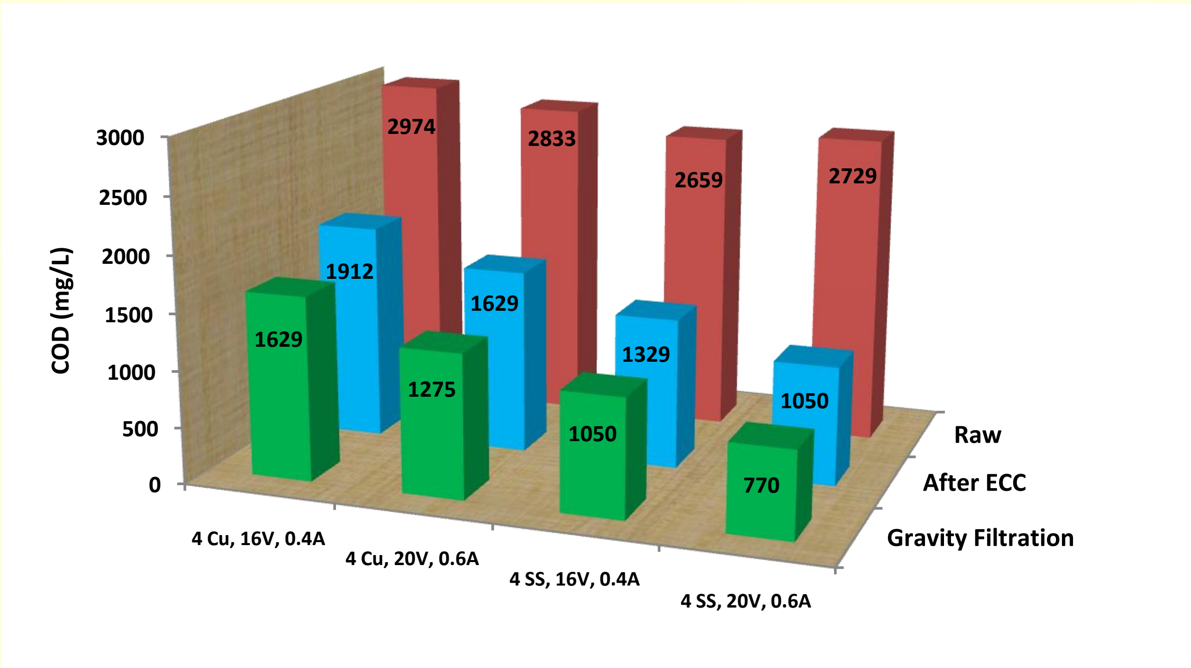

Figure 2: COD reduction as a function of applied cell voltage for SS and Cu electrodes.

Figure 2 shows the COD removal at applied cell voltages of 16 V and 20 V for SS and Cu electrodes for raw wastewater, post ECC supernatant and after gravity filtration. For Cu electrodes, COD removal of 36% and 15% was observed after ECC treatment and after gravity filtration respectively at an applied cell voltage of 16 V and COD removal 43% and 22 % were observed after ECC treatment and after gravity filtration respectively at an applied cell voltage of 20 V.

For SS electrodes, 50% and 21% COD was removed after ECC treatment and after gravity filtration respectively at an applied cell voltage of 16 V and COD removal 62% and 27 % were observed after ECC treatment and after gravity filtration respectively at an applied cell voltage of 20 V.

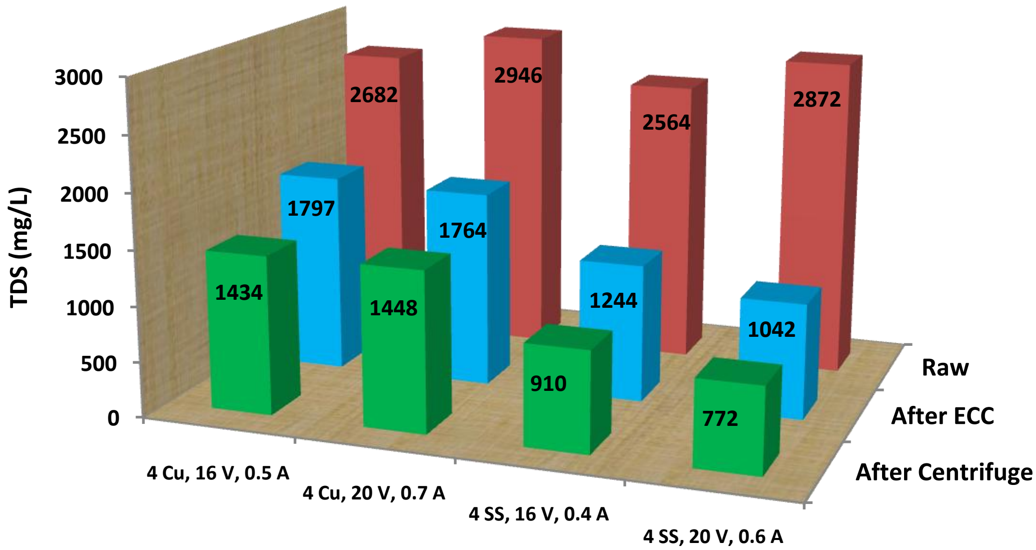

Figure 3: TDS reduction as a function of applied cell voltage for SS and Cu electrodes.

Figure 3 shows the TDS removal at applied cell voltages of 16 V and 20 V for SS and Cu electrodes for raw wastewater, post ECC supernatant and after centrifuging at 2500 rpm for 10 min duration. For Cu electrodes, TDS removal of 33% and 20% was observed after ECC treatment and after centrifuge respectively at an applied cell voltage of 16 V; 40% and 18% TDS removal were observed after ECC treatment and after centrifuge respectively at an applied cell voltage of 20 V.

For SS electrodes, 50% and 21% TDS was removed after ECC treatment and after gravity filtration respectively at an applied cell voltage of 16 V. 62% and 27 % TDS removal were observed after ECC treatment and after centrifuge respectively at an applied cell voltage of 20 V.

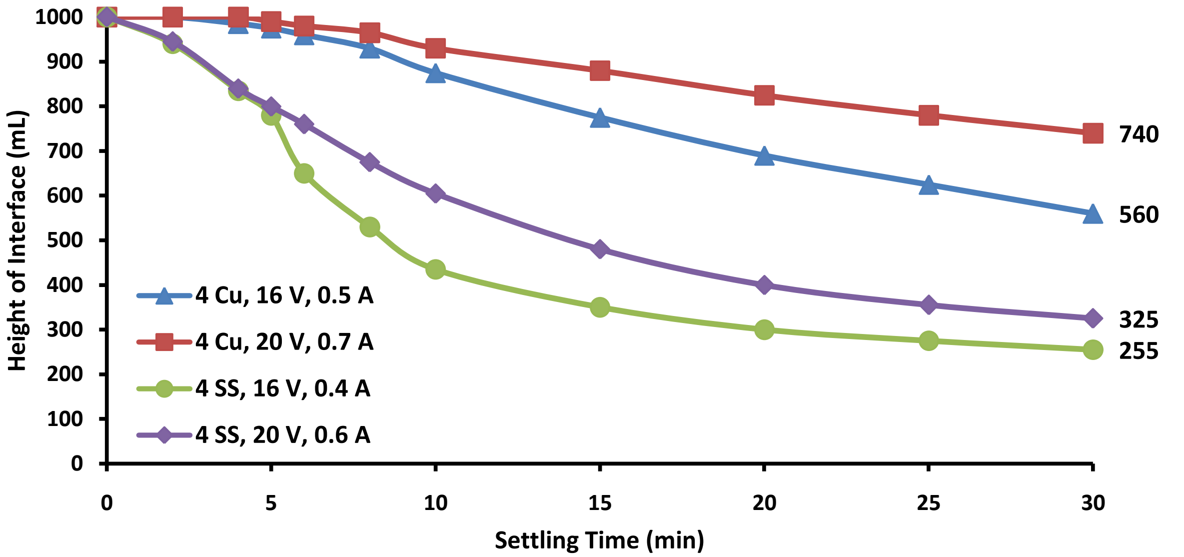

Figure 4: Settleability of sludge as a function of applied cell voltage for SS and Cu electrodes.

Figure 4 shows the settleability of ECC treated slurry at applied cell voltage of 16 V and 20 V for Cu and SS electrodes. For Cu electrodes 560 mL and 740 mL sludge volume was obtained after ECC treatment at applied cell voltage of 16 V and 20 V respectively and 255 mL and 325 mL sludge volume was obtained after ECC treatment at applied cell voltage of 16 V and 20 V respectively for SS electrodes. Murky interface was seen at initial 10 min settling time for SS electrodes and upto 15 min for Cu electrodes during settling tests. For Cu electrodes, Centrifugal settleability Index (CSI) values 125 and 121 were observed at applied cell voltage of 16 V and 20 V respectively and for SS electrodes CSI values 137 and 136 were obtained at applied cell voltage of 16 V and 20 V respectively after centrifuging at 2500 rpm for 10 min duration.

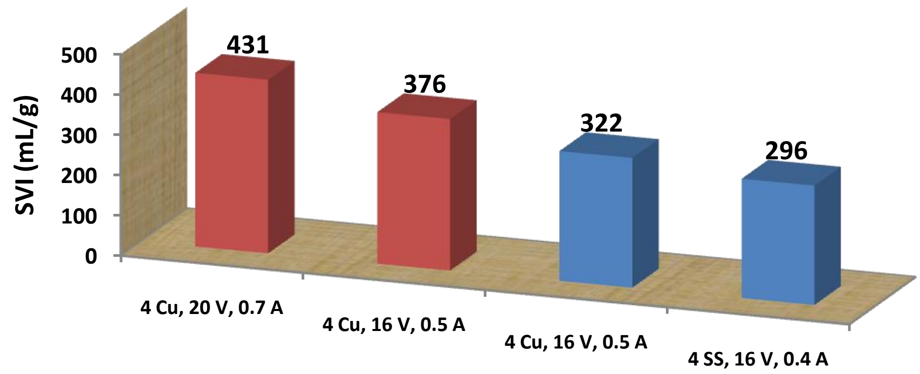

Figure 5: SVI values as a function of applied cell voltage for SS and Cu electrodes.

Figure 5 shows the SVI values of ECC treated slurry at applied cell voltage of 16 V and 20 V for Cu and SS electrodes. For Cu electrodes, SVI values 376 mL/g and 431 mL/g were obtained after ECC treatment at applied cell voltage of 16 V and 20 V respectively and for SS electrodes, SVI values 296 mL/g and 322 mL/g were obtained after ECC treatment at applied cell voltage of 16 V and 20 V respectively.

The settleability properties of wastewater treated with SS electrodes were better compared to Cu electrodes. The high SVI values of Cu electrodes may be due to the fact that the sludge formed by Cu electrodes was light and fluffy and the foam formed during the EC treatment by Cu electrodes and increase in the current density allowed larger floc sizes and reduced their density and hence hindered their settleability. The sludge formed by SS electrodes was heavy enough to produce a compact layer. When the current density was increased, the sludge floc size increased, and after settling the sludge layer became thinner and more compact (Zodi et al., 2011). At high current densities, the extent of electrode dissolution increases, resulting in a greater amount of suspended solids after EC treatment. The rate of bubble-generation increases and the bubble size decreases with increasing current density. Hydrogen bubbles adsorb more easily onto the particles and the settling velocity decreases (Zodi et al., 2009).

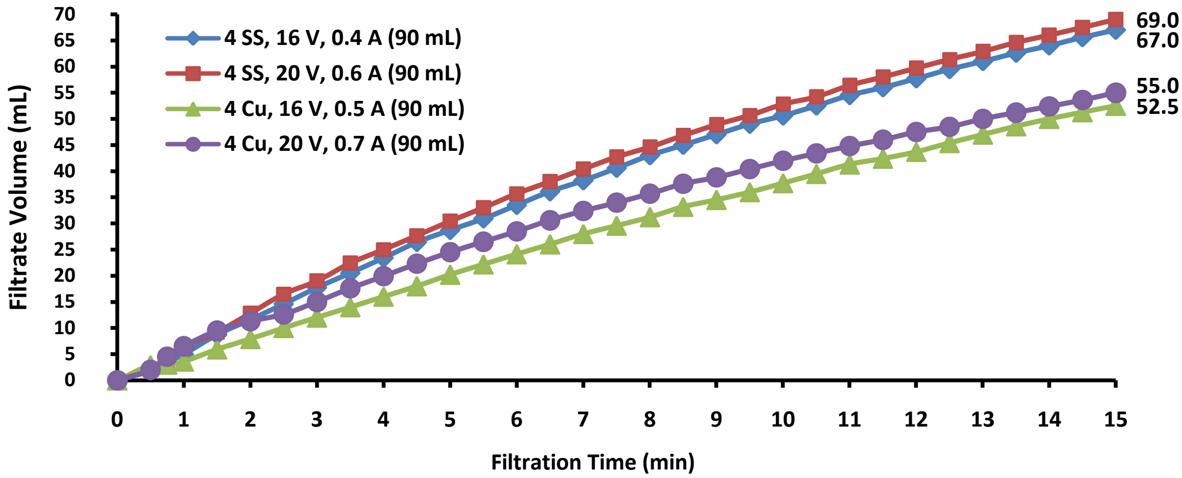

Figure 6: Filterability of EC treated sludge as a function of applied cell voltage for SS and Cu electrodes.

Figure 6 shows the filterability of ECC treated slurry at applied cell voltage of 16 V and 20 V for Cu and SS electrodes. For Cu electrodes filtrate volume 52.5 mL and 55 mL were obtained after ECC treatment at applied cell voltage of 16 V and 20 V respectively after 15 mins filtration duration, buechner funnel filled 2/3 volume. For SS electrodes, filtrate volume 67 mL and 69 mL were obtained after ECC treatment at applied cell voltage of 16 V and 20 V respectively 15 mins filtration duration, buechner funnel filled 2/3 volume. Filtration was good with Cu electrodes and better with SS electrodes. Small increment in filtrate volume was observed when the applied cell voltage was increased from 16 V to 20 V.

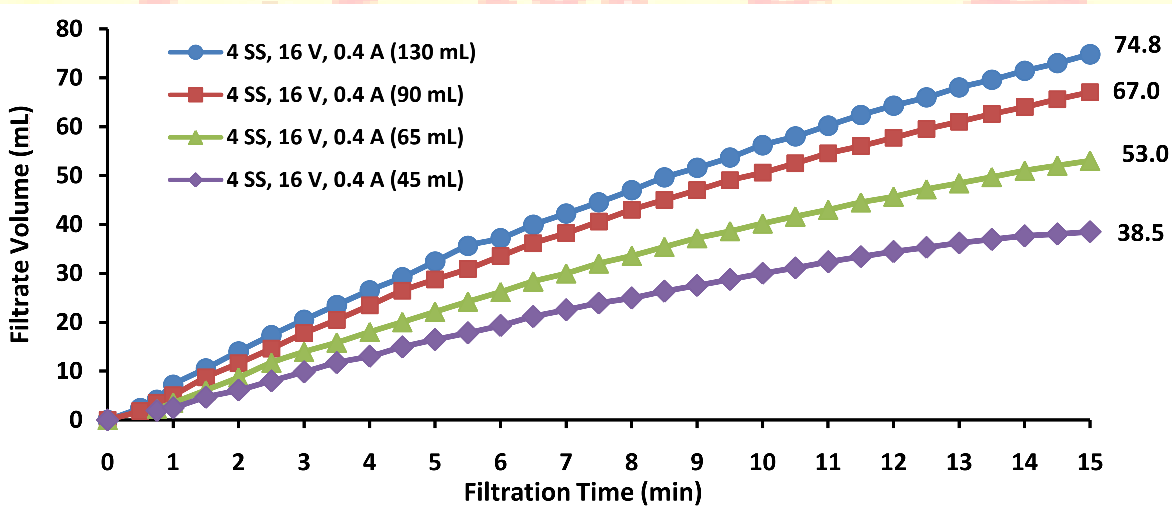

Figure 7: Gravity filtration with Buechner funnel as a function of volume for SS electrode.

Figure 7 shows the gravity filtration with Buechner funnel as a function of volume for SS electrode. Increase in the head above the filter media improves the filtration process. This is because of increase in pressure above the filter medium caused by the increase in volume above the filter bed.

4. Conclusion

In this paper, post ECC settling and filterability studies of paper mill wastewater for pre-optimized operating conditions of SA/V of 33.33 m^2/m^3 using SS and Cu electrodes was carried out considering COD and TDS as target parameters for removal in batch ECC mode in a bipolar array. Increase in COD and TDS removal efficiency was observed as the applied cell voltage increased from 16V to 20V for Cu and SS electrodes. SS electrodes showed better COD and TDS removal efficiency than Cu electrodes. Less sludge volume was obtained with SS electrodes than Cu electrodes. The SVI values obtained from SS electrodes were better when compared to Cu electrodes. For Cu electrodes, SVI values 376 mL/g and 431 mL/g were obtained after ECC treatment at applied cell voltage of 16 V and 20 V respectively and for SS electrodes, SVI values 296 mL/g and 322 mL/g were obtained after ECC treatment at applied cell voltage of 16 V and 20 V respectively. For Cu electrodes, Centrifugal settleability Index (CSI) values 125 and 121 were observed at applied cell voltage of 16 V and 20 V respectively and for SS electrodes CSI values 137 and 136 were obtained at applied cell voltage of 16 V and 20 V respectively after centrifuging at 2500 rpm for 10 min duration. Improvement in COD and TDS removal efficiency were observed when the voltage was increased from 16 V to 20 V with both SS and Cu electrodes.

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References

[1] APHA Standard methods for the examination of water and wastewater, 16th edition, 2010.

[2] Irfan M, Butt T, Imtiaz N, Abbas N, Khan R A, Shafique A, 2013, The removal of COD, TSS and colour of black liquor by coagulation–flocculation process at optimized pH, settling and dosing rate, Arabian Journal of Chemistry, pp 1-12.

[3] Khansorthong S, Hunsom M, 2009, Remediation of wastewater from pulp and paper mill industry by the electrochemical technique, Chemical Engineering Journal 151, pp 228–234.

[4] Mahesh S, Prasad B, Mall ID, Mishra IM, 2006 "a", Electrochemical degradation of pulp and paper mill wastewater. Part 1. COD and color removal, Industrial and Engineering Chemistry Research, 45, pp 2830-2839.

[5] Mahesh S, Prasad B, Mall I D, Mishra I M, 2006 "b", Electrochemical degradation of pulp and paper mill wastewater. Part 2. Characterization and analysis of sludge. Industrial and Engineering Chemistry Research, 45, pp 5766-5774.

[6] Parama Kalyani K S, Balasubramanian N, Srinivasakannan C, 2009, Decolorization and COD reduction of paper industrial effluent using electro-coagulation, Chemical Engineering Journal, 151, pp 97–104.

[7] Soloman P A, Ahmed Basha C, Velan M, Balasubramanian N, Marimuthu P, 2009, Augmentation of biodegradability of pulp and paper industry wastewater by electrochemical pre-treatment and optimization by RSM, Separation and Purification Technology, 69, pp 109–117.

[8] Sridhar R, Sivakumar V, Prince Immanuel V, Prakash Maran J, 2011, Treatment of pulp and paper industry bleaching effluent by electrocoagulant process, Journal of Hazardous Materials, 186, pp 1495–1502.

[9] Vepsalainen M, Kivisaari H, Pulliainen M, Oikari A, Sillanpaa M, 2011, Separation and Purification Technology, 81, pp 141–150.

[10] Wang B, Gu L, Ma H, 2007, Electrochemical oxidation of pulp and paper making wastewater assisted by transition metal modified kaolin, Journal of Hazardous Materials 143, pp 198–205.

[11] Zodi S, Louvet J N, Michon C, Potier O, Pons M N, Lapicque F, Leclerc J P, 2011, Electrocoagulation as a tertiary treatment for paper mill wastewater: Removal of non-

biodegradable organic pollution and arsenic, Separation and Purification Technology, 81, pp 62–68.

[12] Zodi S, Potier O, Lapicque F, Leclerc J P, 2009, Treatment of the textile wastewaters by electrocoagulation: Effect of operating parameters on the sludge settling characteristics, Separation and Purification Technology, 69, pp 29–36.