Optimization of COD Removal from Pulp and Paper Mill Effluent using Electrooxidation

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Abstract

Available treatment methods for pulp and paper industries waste effluent include biological treatment, adsorption, chemical precipitation, which are of high cost of the treatment and suitable for small and medium scale industries. Among the available methods, the chemical precipitation method is commonly used, which requires addition of chemical coagulants and generates more sludge compared to electrooxidation. The electrochemical method of organic matter destruction is a suitable alternative for the treatment of pulp and paper mill effluent, which combines the benefit of electrooxidation and electrocoagulation, capable of removing fine particles as a result of coagulation and electric field. The objective of the study is to evaluate the potential of electrooxidation for organic matter destruction from the pulp and paper mill effluent under various operating conditions such as pH, voltage, reaction time, and to optimize the operating conditions to maximize COD removal using response surface modelling. The wastewater for this study was collected from a pulp and paper mill located in Odisha, with wastewater collected from the outlet of the wastewater discharge before entering the treatment plant, and stored under 2^0 C to prevent its degradation. The results obtained from this study concluded 73.48% COD removal under optimum conditions (pH=9, V=11.2 V, RT=60 min) however, under experimental conditions, COD removal of 72.90% was observed. This batch monopolar electrooxidation system is efficient to remove COD from pulp and paper mill wastewater, and further studies are required on a continuous reactor to scale up the COD removal by electrooxidation.

Keywords: Biological Treatment, Electrooxidation, *Electrocoagulation, Chemical Precipitation, Sludge*

1. Introduction:

The pulp and paper industry is one of the country's most important industries used for the recycling and production of paper products. This industry consumes a lot of water, ranging from 76 to 227 m^3 per tonne of paper product produced, resulting in the generation of a lot of wastewaters. However, the amount of pulp produced accounts for up to 45% of the raw material by weight (Mahesh et al., 2006). This is the primary reason for the high biochemical oxygen demand (BOD), chemical oxygen demand (COD), and suspended solids (SS) content in the effluent.

Available treatment methods for pulp and paper industries' waste effluent include biological treatment, adsorption, chemical precipitation (Buzzini & Pires, 2002). The high cost of installation of the treatment plant and the recurring cost inhibits the effluent treatment by the small and medium scale industries. Among the available methods, the chemical precipitation method is commonly used. However, this method requires addition of chemical coagulants and generates more sludge compared to electrooxidation (Sengupta et al., 2015). The electrochemical method of organic matter destruction is a suitable alternative for the treatment of pulp and paper mill effluent. This process combines the benefit of electrooxidation and electrocoagulation(Pouet & Grasmick, 1995). In this method, the coagulants are produced from the anode and form metal hydroxides. This method is capable of removing fine particles as a result of coagulation and electric field.

2. Objectives:

The Objectives of the present study are as under:

1. To evaluate the potential of electrooxidation for organic matter destruction from the pulp and paper mill effluent under various operating conditions (pH, voltage, reaction time).
2. To optimize the operating conditions to maximize COD removal using response surface modelling.

3. Material and Methods

The Materials and Methods adopted for the experimental study are described as follows:

3.1 Wastewater Sampling

The wastewater for this study was collected from a pulp and paper mill located in Odisha. The wastewater was collected from the outlet of the wastewater discharge before entering the treatment plant. The wastewater was sampled for a week to check the consistency of its different parameters. The wastewater was stored under 2^0 C to prevent its degradation.

3.2 Experimental Setup

The laboratory setup for the electrocoagulation process is depicted in figure 1. Experiments were carried out in a borosilicate container with an effective volume of 1L. Monopolar electrode configuration with 2 electrodes with dimensions of 5cm (width) × 6 cm (length) × 0.1 cm (thickness) were used for this experiment. The active surface area for this electrode configuration is 30 cm^2. Electrode spacing was kept constant at 1.5 cm. As a power source for this study, a digital DC power with variable voltage was used. The schematic of the experimental setup is shown in Fig (1). Experiments were carried out at ambient temperatures.

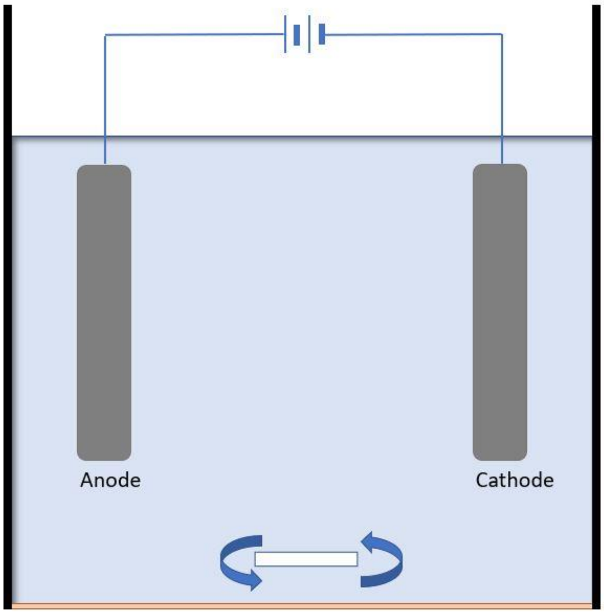

Figure 1: Schematic of Experimental Setup

Initial characterization of the effluent was carried out in triplicate. Determination of pH, conductivity, chemical oxygen demand (COD), Biochemical oxygen demand (BOD), total suspended solids (TSS), and chlorine concentration were carried out according to standard methods. COD was measured using closed reflux (titrimetric method). COD results show that the outlet of the wastewater falls under medium-strength wastewater. The initial characterization data is shown in table 1. The optimization process was carried out for COD removal. Samples were collected after the treatment for COD analysis.

The COD removal efficiency was calculated using the following equation (1)

$$Removal\ Efficiency = \frac{C_i - C_f}{C_i} \times 100$$

Where C_i and C_f are the initial and final concentrations of COD.

Table 1. Initial characterization of pulp and paper mill effluent

Parameter	Unit	Value
pH	-	7.1 $\pm$ 0.5
Color	-	Dark Brown
COD	Mg/L	1100 $\pm$ 50
BOD	Mg/L	300 $\pm$ 32
TSS	Mg/L	1012 $\pm$ 85

3.3 Experimental Design and Model Development

Independent Process Variable affecting COD removal is optimized using the response surface methodology. Run parameters for this study were obtained using the Minitab (version 19). The factors for this study are the initial pH, Voltage (V), and reaction time (RT). In this study central composite was used for the experimental design with levels (-1.68, -1,0,1,1.68). The experimental design for 3 factors and 6 central points involves 20 experimental runs. All the experimental runs were conducted in duplicates.

4. Results and Discussion:

4.1 Statistical Analysis

Twenty experimental runs were conducted in duplicates according to the central composite design for modelling COD removal from pulp and paper mill effluent. Analysis of variance (ANOVA) results revealed that 6 out of 9 model terms were significant. Among them, pH was the most significant factor affecting COD removal in the electrooxidation process. V^2 among quadratic terms and interaction of pH and RT are the significant terms affecting the process.

Here R^2 predicted value indicates the predictability of the model for a given operating condition. In this study predicted R^2 value was found to be 0.85 which signifies higher reliability of the quadratic model (Makwana & Ahammed, 2017). Nonsignificant model terms were removed for a better fit of the experimental data to the quadratic model. The quadratic equation for COD removal was obtained as equation 1.

$$
\begin{aligned}
COD\ Removal\ Efficiency(\%) &= 64.97 + 10.723pH + 2.256V + 2.799RT - 2.255pH^2 \\
&\quad - 8.382RT^2 - 2.79pH.RT
\end{aligned}
\tag{1}
$$

The relationship between the independent variables and response variables was explained using the factorial plots and contour plots. Low COD removal efficiency was observed at a low initial pH and gradually increased with increasing pH. The COD removal efficiency was found to be increasing with increasing voltage until 11V. Further increases in voltage lead to a decrease in COD removal efficiency. For retention time, removal efficiency increases with increasing retention time varying between 30 min to 60 min.

4.2 Optimization

Single response optimization was carried out using Minitab software to optimize the levels of the independent variables to achieve maximum COD removal. Optimum conditions for COD removal was obtained at a pH of 9, a voltage of 11.2 V, and a retention time of 60 min. At optimum conditions, the quadratic model predicted a removal efficiency of 73.48 %. Confirmatory runs were carried out to validate the model. Under experimental conditions, COD removal of 72.90% was observed.

5. Conclusion

The results obtained from this study concluded 73.48% COD removal under optimum conditions (pH=9, V=11.2 V, RT=60 min) however, under experimental conditions, COD removal of 72.90% was observed. This batch monopolar electrooxidation system is efficient to remove COD from pulp and paper mill wastewater. More study is required on a continuous reactor to scale up the COD removal by electrooxidation.

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