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Treatment of paper industry effluent using electrochemical method

K. Senthilkumar*, P. Akilamudhan
Dept. of Chemical Engineering, Erode Sengunthar Engineering College, Thudupathi, Erode-638057, Tamilnadu.
***Corresponding author: E-Mail: uksen2003@gmail.com**

ABSTRACT

Various conventional methods of treating paper mill effluent include physical, chemical and biological methods, which are less efficiency in treating effluent. In the present work an attempt has been made to study to treat paper industry effluent using an electrochemical method. In the present work, the influence of different parameters such as current density, amount of supporting electrolyte, flow rate of electrolyte and effluent volumes were conducted. The experimental results indicated that the rate of reduction of Chemical Oxygen Demand (COD) of the effluent increased with increase in supporting electrolyte and current density whereas Chemical Oxygen Demand (COD) diminished with an increase in reservoir volume and flow rate of electrolyte.

KEY WORDS: paper industry effluent treatment, electrochemical method, supporting electrode.

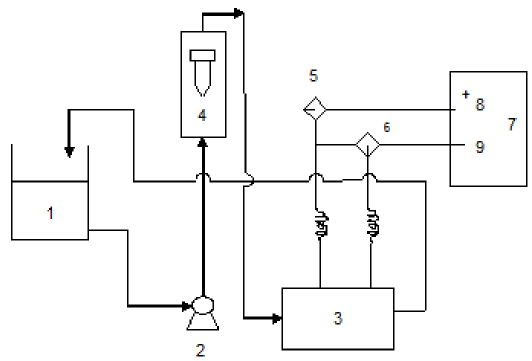
1. INRODUCTION

Pollution implies the introduction of extraneous substance into the environment either directly or indirectly which may be in the solid, liquid, or gaseous states. The pulp industry is one of the largest polluters in discharging a variety of pollutants in gas, liquid and solid wastes into the environment. It is the major pollution of water bodies, because huge amount of wastewater are generated per metric ton of paper. Since the pulp produced corresponds to only about 40-50% of the original wood's weight, the effluents are greatly loaded with organic substances. These effluents cause major harm to receiving areas if discharged untreated since they have a high suspended solids, fatty acids, chemical oxygen demand (COD), biochemical oxygen demand (BOD), phenol compounds, chlorinated compounds, tannins, lignin and its derivatives. The methods which can be conveniently employed for treatment of effluent are primary treatment such as sedimentation, coagulation, floatation, flocculation and secondary treatment methods. These are conventional treatment methods, and may not be economically viable for small and medium scale pulp and paper industries and these processes are not only costly to install but also hard to sustain and run at the expected level of efficiency.

A review of previous work have been undertaken in order to achieve a organized and appropriate procedure for accomplishing the main plan of the present investigation. During the review of the published material it was found that great weightage had been done by treating various industrial effluents using electrochemical methods. In electrochemical processes, hypochlorite has been formed and it was a powerful oxidizing and bleaching agent. The advantages of electrochemical methods are high efficiency of conversion, reuse of treated water is possible. To overcome these demerits of the existing treatment process, in the present work an effort has made to study the treatment of paper mill effluent by using electrochemical method.

2. EXPERIMENTAL SETUP AND PROCEDURE

The electrochemical reactor cell made up of both stainless steel mesh as anode and as cathode under galvonostatic process. The sizes of the electrodes were 0.06 m x 0.06 m. The schematic of the experimental setup is shown in the Figure 1. The effluent was mixed with known amount of supporting electrolyte (sodium chloride) and pumped from the reservoir to the reactor cell which was in rectangular form. The effluent of known volume for example 1 litre was taken in the reservoir tank. The treated effluent in the reactor cell was recirculated to the reservoir. For every reservoir volume the experiment was repeatedly conducted for various flow rates of effluent. The samples during recirculation were collected for each one hour, kept at acidic conditions and were subjected to COD analysis. COD of the treated samples was measured by open reflux method. The temperature of the recirculating electrolyte also measured. The experiments were carried out for various flow rates, current densities, and supporting electrolyte concentration for the various reservoir volumes. The effects of electrolysis time, current densities, NaCl amount and effluent volume were selected as parameters.



1.Reservoir,
2. Pump
3. Electrochemical reactor
4. Flow meter
5. Ammeter
6. Voltmeter
7. Power supply
8. Anode
9. Cathode

Fig.1.The schematic of the experimental setup

3. RESULTS AND DISCUSSIONS

3.1. Influence of sodium chloride (NaCl) concentration: Experiments were performed with various NaCl concentrations and the other parameters like current density, flow rate, P^H, effluent volume were kept constant. The increasing concentration of NaCl increases the rate of reduction of colour and COD of the effluent, as shown in Table.1. The experimental results revealed that the optimum conditions of NaCl was found as 3 gpl. Increasing sodium chloride concentration it suppresses chlorine hydrolysis therefore increasing the concentration of unhydrolysis chlorine in the effluent may reacts with lignin producing water soluble electrolignins and easily oxidizable chlorolignins.

3.2. Influence of current density: The current density was changed within the limits of 0.5 A/dm^2 to 2.5 A/dm^2 and the other parameters were kept constant. From the observed experimental data, it is evident that the COD reduction depends on the current density, as reported in the available literature. It is observed that increase in current density increases the removal of COD of the effluent. Then the reservoir volume of effluent was increased and the other conditions were same. The experimental results revealed that if the effluent reservoir volume was increased, then the small decrease in percentage of the COD reduction was observed, as shown in Table 2.

Table.1. Effect of NaCl on COD removal

Oxidant amount/g l^{-1}	COD/ ppm		% reduction of COD
	Initial	Final	
Nil	2350	1660	29.3
1.0	2350	1520	35.3
2.0	2350	1415	39.8
3.0	2350	1275	45.7
4.0	2350	1200	48.9

Table.2. Influence of Current Density

Current density/ A dm^{-2}	COD/ ppm		% reduction of COD
	Initial	Final	
0.5	2350	1700	27.6
1.0	2350	1610	31.4
1.5	2350	1430	39.1
2.0	2350	1175	50.0
2.5	2350	960	59.12

3.3. Influence of flow rate on COD removal: The flow rates of the recirculating electrolyte were changed from 5 to 40 LPH in different ranges. The other conditions kept constant. From the experimental results (Table 3) indicated that if the flow rate of the recirculating effluent is increased, there is decrease in the percentage of COD reduction.

Table.3. Influence of Flow rates on COD removal

Flow rate/ LPH	COD/ ppm		% reduction of COD
	Initial	Final	
5	2350	920	60.8
10	2350	1130	51.9
20	2350	1480	37.0
30	2350	1580	32.7
40	2350	1720	26.80

3.4. Electrochemical Reactor Modeling: The Pseudo steady state is based on the idea of no accumulation of the intermediate in the reactor helps to obtain the rate of the reaction in the batch reactor with electrolytic recirculation. Under steady state conditions, it can be assumed that the reactor is ideal CSTER and the performance equation can be written as

$$\tau_R = \frac{V_R}{Q} = \frac{C - C'}{-r} \qquad (1)$$

Where, -r = the rate of disappearance of organic pollutants

The rate of disappearance of organic pollutants is directly proportional to concentration of organic pollutants 'C' and the pseudo first order kinetic equation is given by

$$-r = KaC \qquad (2)$$

Where, -r = rate of disappearance of organic pollutants in the reactor, K = Electrochemical reaction rate constant, cm sec^{-1}, V_R = Active volume of reactor, litre, Q = Volumetric flow rate of electrolyte, LPH, τ_R = spare time for the reactor (V_R/Q), hour, C' = concentration of organic pollutants in leaving stream of reactor, ppm, C = concentration of organic pollutants in entering stream of reactor, ppm, a = Specific electrode area (A / V_R), dm^2.

The equations (1) and (2) can be written as

$$\frac{C'}{C} = \frac{1}{1 + KA/Q} \qquad (3)$$

For batch reactor with electrolytic recirculation reactor system, the mass balance can be written as,

$$V\ \frac{dC}{dt} = Q(C - C') \qquad (4)$$

From the above equations, we get

$$\ln\ C/Co = -KA/Q(1 + KA/Q)t/\tau \qquad (5)$$

By plotting the above equation (5), which gives a straight line and slope value (rate constant). Here, Co is initial concentration of organic pollutants in the reservoir, C is the concentration of organic pollutants at time 't' in the reservoir, Q is volumetric flow rate, V is the volume of the reservoir and τ is space time for the reservoir

3.5. Influence of various parameters on electrochemical reaction rate constant: By using the experimental results, the rate constant values were determined for different supporting electrolyte concentration, different current densities, different flow rates and for different reservoir volumes. The Table.4 shows that the variation of electrochemical reaction rate constant with respect to various current density and electrolyte reservoir volume for the constant flow rate. The experimental results shows that the rate constant was decreased when reservoir volumes increased and if the flow rate of recirculation electrolyte increases, the rate constants are decreased.

Table.4. Influence of various parameters on rate constant

Current density/ A dm^{-2}	Rate constant, $kx10^3$ / cm s^{-1}		
	1 litre	1.5 litres	2 litres
0.5	0.47	0.465	0.454
1	0.48	0.469	0.449
1.5	0.486	0.452	0.44
2	0.539	0.518	0.491
2.5	0.56	0.524	0.512

4. CONCLUSION

In the present study, the experimental results revealed that the increasing concentration of NaCl and current density increases the rate of reduction of COD. If the flow rate of the effluent is increased, then decrease in the percentage of COD reduction was observed. Finally, it was concluded that the electrochemical method of treating industrial effluent is a good method with environmental friendly and not producing any secondary pollutant.

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