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# Turbidity and BOD removal of a paper recycling mill effluent by electro-coagulation technique

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ABSTRACT

The purpose of this work was to provide an alternative to effluent treatment of an OCC paper recycling mill by electro-coagulation technique. The experiments carried out to find the optimum conditions for turbidity and biological oxygen demand (BOD) reduction of the effluent at four levels of electrolysis time (10, 20, 30 and 60 min), three initial suspension pH levels (3, 7.5 and 10), by two constant voltage of 9.0 and 12.0. The results indicated that electro-coagulation is an effective technique for treatment of paper recycling mill effluent. At optimum conditions, more than 99.7% of turbidity and 96.1% of BOD were effectively removed.

*Keywords:* Electro-coagulation; Paper recycling; Effluents; Turbidity; BOD

## 1. Introduction

In terms of chemical composition, pulp and paper mills effluents are still not completely understood. This naturally causes difficulty in making a proper assessment of the effects of such effluents and to choose the most appropriate methods of treatment. Effluent loadings depend on the raw materials and production process [1].

Paper industry consumes a high quantity of water resulting in large amounts of wastewater generation and environmental problems [2]. Part of the high volume of water returned to recycling system at the mill but the other part flows out of the process that contains high organic matter, suspended solids (mainly fibers), dark color, biological oxygen demand (BOD) and chemical oxygen demand (COD) [3–6].

Effluent color may increase water temperature and decrease photosynthesis, both of which probably lead to a decreased concentration of dissolved oxygen. The wastewater color is primarily due to lignin and its derivatives, which rejection of this effluent in nature without any treatment is responsible of serious damage for the environment and constitutes a threat for human health [7].

Paper recycling industry is one of the rapidly developing industries in Iran due to insufficient forest resources in the country. Although, waste paper recycling from environmentally point of view is attractive but the recycling process have some effluent which are significant contributors of pollutant to the environment.

Since pulp and paper industry discharges varieties of pollutants, the treatment methods also vary such as, physicochemical treatment, biological treatment, fungal treatment and integrated treatment processes [19].

Although these methods are available but however, there are several problems with them, for example, activated sludge produces sludge with very variable settlement properties, it is sensitive to shock loading and toxicity, and its capacity to remove poorly biodegradable toxic substances is limit [2]. Color removal is a significant problem for the industry; traditional biological treatments are ineffective [8] and many unconventional approaches are inefficient and expensive.

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Most color-removal techniques are uneconomical to mill operations and chemical precipitation release chemicals materials to the environment [9].

In recent years, electro-coagulation (EC) was a simple, efficient and economical method that has been reported to successfully treat of different kinds of wastewaters in commercial level. The characteristics of electro-coagulation are simple equipment and easy operation, brief reactive retention period, decreased or negligible equipment for adding chemicals and decreased amount of sludge [10]. In comparison with traditional flocculation and coagulation, electro-coagulation has, in theory, the advantage of removing even small colloidal particles; they have a larger probability of being coagulated because of the electric field that sets them in motion. Addition of excessive amount of coagulants can be avoided, due to their direct generation by electro-oxidation of a sacrificial anode [11].

Although electro-coagulation is an effective method of treatment for pulp and paper effluent, but less research has been studied regarding a paper recycling mill effluent.

In this paper, effects of several experimental parameters such as voltage, electrolysis time and effluent pH of an OCC paper recycling mill on the turbidity and BOD removal efficiency was investigated by using the electro-coagulation batch method.

### *1.1. Description of electro-coagulation process*

Electro-coagulation is a complex and interdependent process. The most widely used electrode materials in this process are aluminum and iron, sometimes steel [12]. The metal ions generation takes place at the anode; hydrogen gas is released from the cathode. The hydrogen gas would also help to float the flocculated particles out of the water. In the case of aluminum, main reactions in anode and cathode are:

$$\text{Anode: } Al(s) \rightarrow Al^{3+}(aq) + 3e^- \quad (1)$$

$$\text{Cathode: } 3H_2O(l) + 3e^- \rightarrow \frac{3}{2}H_2(g) + 3OH^-(aq) \quad (2)$$

$Al^{3+}$ and $OH^-$ ions generated by electrode reactions (1) and (2) react to form various monomeric species such as $Al(OH)^{2+}$, $Al(OH)_2^+$, $Al_2(OH)_2^{4+}$, $Al(OH)_4^-$, and polymeric species such as $Al_6(OH)_{15}^{3+}$, $Al_7(OH)_{17}^{4+}$, $Al_8(OH)_{20}^{4+}$, $Al_{13}O_4(OH)_{24}^{7+}$, $Al_{13}(OH)_{34}^{5+}$, which transform finally into $Al(OH)_3$ (s) according to complex precipitation kinetics [3,13,14].

$$Al^{3+}(aq) + 3H_2O(l) \rightarrow Al(OH)_3(s) + 3H^+(aq) \quad (3)$$

$Al(OH)_3$ (s) have large surface areas, which are beneficial for a rapid adsorption of soluble organic compounds and trapping of colloidal particles. Finally, these flocks are removed easily from aqueous medium by sedimentation or $H_2$ flotation [15,16].

## 2. Materials and methods

### *2.1. Effluent characteristics*

The effluent samples used in this study were collected from Afrang Mill, an OCC paper recycling mill in the north of Iran near of sea Caspian. Its initial characteristics measured (Table 1) and stored in obscurity at 4 °C to further experiments.

### *2.2. Analytical procedure*

The turbidity was measured by turbiditimeter (IR TB 100) and BOD tests were carried out in accordance with Standard Methods for the Examination of Water and Wastewater [17] by (BOD meter Oxidirect, Aqualitic, lovibond, Germany).

The experiments were carried out in a batch mode at a constant temperature of 25 °C at 200 rpm stirring speed. In each run, 300 cm$^3$ of effluent was poured into an electrolytic cell with the aluminum electrodes dipped into the sample solution up to an active surface area of 80 cm$^2$. The electrode distance between anode and cathode was maintained constant of 1 cm during electrolysis. Direct current was supplied by a DC-regulated voltage source and two constant voltages of 9.0 and 12.0 were applied. Four different level of electrolysis times (10, 20, 30 and 60 min) at three level of suspension pH (adjusted at 3, 7.5 and 10) were investigated. The turbidity and BOD removal efficiencies after electro-coagulation treatment were calculated by the following eq. [14].

$$CR(\%) = \frac{C_0 - C}{C_0} \times 100 \quad (4)$$

Table 1
Wastewater characteristics before treatment

| Parameters | Concentration |
|---|---|
| pH | 7.56 |
| DO (mg l$^{-1}$) | 6.22 |
| Color (Pt/Co) | 11,040.00 |
| TSS (mg l$^{-1}$) | 2496.00 |
| COD (mg l$^{-1}$) | 2286.30 |
| $BOD_5$ (mg l$^{-1}$) | 1286.00 |
| Turbidity (NTU) | 2456.60 |
| Conductivity (μS/cm) | 1836.00 |

where, $C_0$ and $C$ are the solution concentrations before and after electro-coagulation respectively.

## 3. Results and discussion

### *3.1. Effect of the EC process conditions on the turbidity removal*

It has been established that pH is an important parameter influencing on performance of the EC process [14]. The turbidity removals in 9.0 and 12.0 V, were shown in Figs. 1 and 2, respectively. The results revealed that maximum turbidity removal was achieved when pH of the effluent was 7.5 in both voltages. This result was observed by many investigators and was attributed to an amphoteric behavior of $Al(OH)_3$ that does not precipitate at pH less than 4 [18,20]. In addition, it was demonstrated that solubility of $Al(OH)_3$ will increase at pHs higher than 8 and lead to the formation of soluble $Al(OH)^{4-}$, which is useless for water treatment [21]. From practical point of view, as the original pH of the mill effluent was around 7.56, hence there is no need for chemical to adjust the pH.

By comparing of Figs. 1 and 2, it can be ascertained that the turbidity removal is significantly higher at a given time when the voltage increases from 9.0 to 12.0.

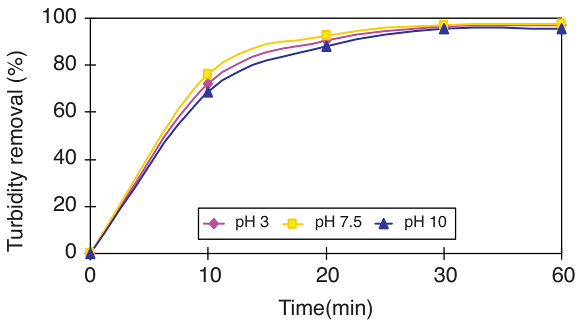


Fig. 1. Turbidity removal versus electrolysis time at different pH (voltage = 9).

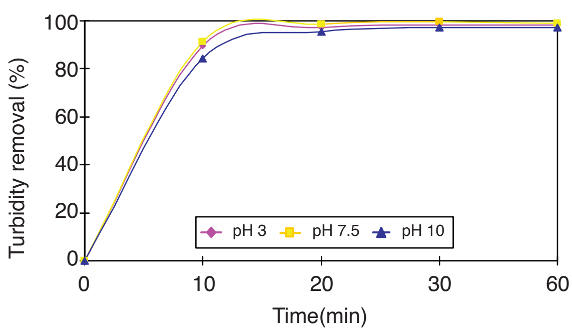


Fig. 2. Turbidity removal versus electrolysis time at different pH (voltage = 12).

This can be attributed due to the fact that at higher voltage, the extent of anodic dissolution increases and then lead to higher turbidity removal. Further, the applied voltage determines the rates of coagulant and bubble production, which in turn can influence on the process efficiency. An increase in the gas bubbles density with reduction in their size could enhances pollutant degradation and sludge floatation [18].

According Fig. 1 (voltage 9), optimum turbidity removal has been observed at 30 min electrolysis time. Further increase in the treatment time from 30 to 60 min, had only a negligible effect on the turbidity removal, only from 96.4% to 97.1%. Fig. 2 shows that 20 min can be select as an optimum time of electrolysis. During this time about 99.6% of turbidity removed. This is in agreement to that found by Bukhari [22]. He revealed that the maximum turbidity reduction was 95% near neutral pH and treatment time of 20 min.

### *3.2. Effect of the EC process conditions on BOD removal*

It has already been reported that the electrolysis time has an important role on the performance of the process [14]. Experiments were carried out at various times (10, 20, 30, and 60 min) in order to verify the effect of electrolysis time on the EC process efficiency.

The results obtained for BOD removal at different pH level and electrolysis times are shown in Figs. 3 and 4. It can be observed that BOD removal increases by extension of the treatment time. By applying the 12 V, BOD removal increased very fast so that 95.4% of the initial BOD is reduced up to an electrolysis time of 20 min beyond this time, BOD was slightly removed, from 95.4% to 97.2% after 60 min. In the case of 9.0 V, the highest BOD removal (95.7%) was observed after 60 min at all pH levels. The results are confirmed with previous works carried out on treatment of virgin pulp and paper effluent [9] and treatment of textile wastewaters [15]. This method was also successfully

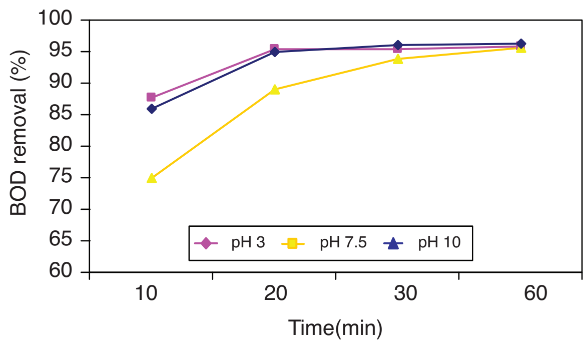


Fig. 3. Removal of BOD as a function of electrolysis time at different level of pH (voltage = 9).

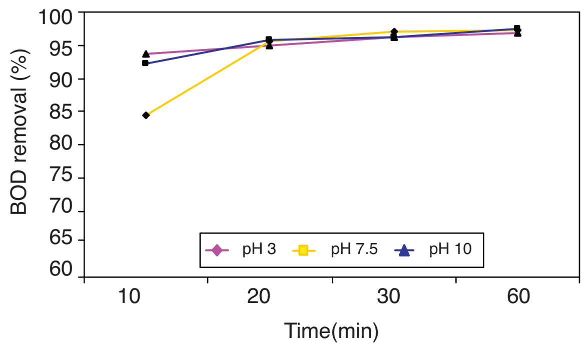


Fig. 4. Removal of BOD as a function of electrolysis time at different level of pH (voltage = 12).

implemented at pilot level in a paper mill in Taiwan and showed a reduction in COD of wastewater from 2280 mg/l to 570 mg/l and in suspended solids (SS) from 2997 mg/l to 300 mg/l [23].

## 4. Conclusion

It can be concluded from this study that electro-coagulation technique can be a useful method for the treatment of recycling paper mill effluent. The EC method is very simple, low equipments and investment need and as reported is feasible for using in commercial level. The influence of variables such as electrolysis time, voltage and initial pH on the turbidity and BOD removal has been determined. It seems that an efficient electro-coagulation treatment need at least to 30 min by applying voltage constant of 12.0. Under these optimal conditions, maximum turbidity and BOD removal could be achieved without adjusting the pH of the effluent.

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