Performance Evaluation of Non Rotating and Rotating Anode Reactor in Electro Coagulation Process

Aditya Choudhary[a] and Dr. Sanjay Mathur[b]
[a] Research Scholar, Department of Civil Engineering, Malaviya National Institute of Technology, Jaipur – 302017
[b] Associate Professor, Department of Civil Engineering, Malaviya National Institute of Technology, Jaipur - 302017

Abstract: Electro coagulation process using various deigns and configurations have been tested from time to time and found to impart major role in the process. Mostly non rotating configurations were used in the available literature. The usage of rotating electrode reactors has come to light and found out to be effective configuration. The effect of rotating and non rotating reactor configurations along with other affecting parameters likes current density, detention time and energy consumption were investigated. Set of experiments were conducted using simulated sample prepared by dissolving basic red dye in tap water to carry out the performance evaluation of the two type of reactors configuration. A comparative study between the two configurations was made to investigate their effectiveness in term of COD removal efficiency and economics of treatment. The results show that rotating reactor configuration have consumed 15-17% less energy for maximum COD removal of 96.40% and thus have better removal efficiency and lower specific energy consumption than non rotating reactor configuration.

Keywords: COD removal, Electro coagulation, Energy Consumption, Rotating and Non Rotating reactor configuration, Textile wastewater

1. INTRODUCTION

The major challenge standing in front of the modern world is demand, supply and availability of clean water for domestic and industrial use [1]. Due to large quantity and diverse nature of industrial wastewater, the issue of its treatment remains a major environmental concern. So, the gap in demand and supply has made it compulsory to reuse the treated wastewater.

The textile wastewater from dyeing and finishing process has been a serious environmental concern for decades. The textile wastewater contains high color, varying pH, high COD concentration, high turbidity, suspended particles and low biodegradability [2]–[5] which makes it difficult to use conventional technologies available. A host of modern era imparted the use of very promising technique based on electrochemical technology like electro coagulation, electro flotation [6] etc. EC has been a very complex process involving various multitude mechanisms operating simultaneously to treat wastewater.

A wide variety of opinions exist in literature for key mechanism and reactor configurations. A systematic and holistic approach is required to understand EC and its controlling parameters [1]. Over the broad range of time period over which this technology is used it is surprising the

available literature does not reveal any systematic approach to EC reactor design, configuration and operation [7].

EC treatment of textile wastewater has been conducted on a laboratory scale and good removal of COD, color, turbidity, and dissolved solids at various operating parameters have been obtained [8]–[11]. And, the process has been found to be very efficient in COD removal and decoloration with low energy consumption [12].

The commonly explored variables for laboratory studies include wastewater characteristics such as pH & conductivity, and process variables such as current density, detention time, electrode material etc. Meanwhile, an important design variable not fully investigated in previous researches is the reactor configurations i.e. rotating and non rotating reactor configuration.

Since the rotating and non rotating reactor configuration has not been compared in detail for the process, it is the purpose of this study to compare the treatment of textile wastewater by both the configurations. The two performance criteria which are of primordial importance are COD and energy consumption in both the configurations is used for the comparison. Further goal of this study is to select the reactor configuration with highest removals and minimum energy consumption for the same to provide a solid universal and scientific understanding for future design.

2. MATERIAL AND METHODS

2.1 Reactor Design: The Contrast

Since EC is an enigmatic technology. Despite being widely used for decades, there appears to be no real consensus on the most appropriate approach for any given application, little in way of systematic reactor design rules, and almost nothing in way of generic a priori modeling approach [7]. The EC reactor for present study was designed considering the intersection of three more fundamental technologies – electrochemistry, coagulation and flotation that governs the process. All three of them were given due consideration in the design of reactor [7].

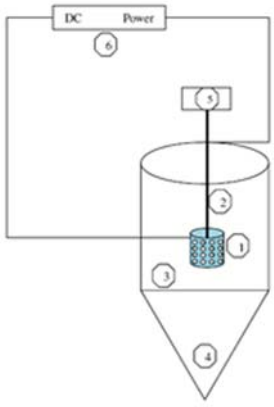

Figure I: Reactor Design- 1) 3D aluminum perforated cylindrical anode. 2) Aluminum rod cathode. 3) Textile Wastewater. 4) Sludge. 5) Mechanical stirrer. 6) DC Power Supply Unit.

In this investigation, a 3D perforated cylindrical aluminum anode and cathode was used for treatment of synthetic textile wastewater with EC. The reactor was made of Plexiglas having conical structure at the bottom to effectively collect and enhance the settling of the sludge produced at the time of EC. The anode was made of hollow Al cylinder having pores at regular distance in order to enhance the turbulence in the reactor. The effective area of the electrode was 284.52 cm^2. The cathode was an aluminum rod with 7 mm inner diameter, 1.2 cm outer diameter and 14 cm height. The aluminum rod and perforated aluminum cylinder were isolated by perforated epoxy resin. The inter-electrode distance was fixed at 2 cm. The experimental system used is represented in Figure I.

2.2 The Analysis

As shown by many investigators that aluminium was used as electrode material for treatment of textile wastewater [13]. The synthetic textile wastewater was prepared in laboratory. The wastewater was prepared by using tap water. The pH was adjusted using NaOH and H_2SO_4/HCl when required. The conductivity of the wastewater was adjusted using NaCl. The required currents were applied by a DC power supply (Kusam Meco, Model: KM-PS- 305-DII). The analytical determination of the Color and COD removal was investigated with the standard procedure (5220 D. Closed Reflux, Calorimetric Method) using an UV Spectrophotometer (Shimadzu, Model: UV-1800) [14]. The pH and conductivity were measured by pH meter (Hanna, Model: HI 98128) and conductivity meter (Lutron, Model: CD-4302).

The COD and Color removal efficiency (RE%) were calculated using the following equations:

$$\text{COD Removal Efficiency (\%)} = \frac{C_0 - C}{C_0} * 100 \quad (1)$$

Where; Co and C are the concentration of COD before and after treatment, respectively, in ppm or mg/L.

$$\text{Color Removal Efficiency (\%)} = \frac{A_0 - A}{A_0} * 100 \quad (2)$$

Where; Ao and A are the absorbance of dye before and after treatment, respectively.

The specific electrical energy consumption per mg COD removed (E_{COD}) were calculated as follows:

$$E_{cod} = V * I * \frac{t}{C_0 - C} * 60 \quad (3)$$

Where, V is voltage, I is current, t is time (usually taken as 60 min for specific energy consumption, C_0 and C are the initial and final COD concentrations.

3. RESULTS AND DISCUSSION

3.1 Effect of Detention Time

There is a significant effect of detention time on treatment efficiency in an electrochemical technique [15]. It was observed that increase in detention time had resulted in increase in COD removal efficiency, when other affecting parameters were kept constant. This effect can be explained by the Faraday's law, according to which an increase in detention time will lead more

generation of metal ions and hence more metal hydroxides generation ultimately resulting in increased removal efficiencies [16].

The mechanism of COD removal involves two stages namely destabilization and aggregation. The optimum COD removal depends on these stages which in turn (as a function of) depend on detention time. As shown in fig. II; in case of non rotating reactor configuration, when the detention time was changed from 20 to 30 min with a constant current density 8 mA/cm^2, the COD removal was increased from 67.58% to 78.91%. This coincides with the fact that for shorter detention time of 20 min, the time was not sufficient to complete the process. Therefore, the COD removal was better at 30 min of detention time. Whereas; in case of rotating reactor configuration, the optimum detention time was found to be 20 min as the rotation of the anode increases the turbulence inside the reactor. This shortens the detention time for the pollutant to get treated as the mixing inside the rector increases. The maximum COD removal achieved was 96.40% for 6mA/cm^2.

The detention time was further increased to 40 and 50 min, the COD removal efficiency decreases to 64.98% and 75.91% for non rotating and rotating reactor configurations. It was due to the fact that for increased detention time, the pollutant in wastewater goes on decreasing and simultaneously aluminum hydroxides generation increases. This increased aluminum hydroxides does not found pollutants for removal, so beyond optimal point, COD removal efficiency remains nearly constant [17].

While for quicker detention time i.e. 10 min, the COD removal efficiency was not good. It was observed to be 46.48% and 69.40% for non rotating and rotating configurations respectively. It was due to the fact that the metal ion (Al^{3+}) dosage was not sufficient to destabilize all colloidal and finely suspended particles [15].

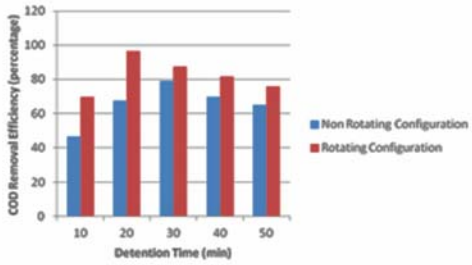

Figure II: Effect of detention time on COD removal efficiency of Non Rotating and Rotating Reactor configuration

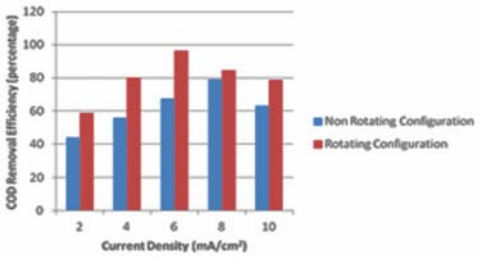

Figure III: Effect of Current Density on COD removal efficiency of Non Rotating and Rotating Reactor configuration

3.2 Effect of Current Density

Previously, it was shown that current density can influence the treatment efficiency of the electro coagulation process [18]–[21]. The current density is defined as the ratio of current input to the electrolytic cell to the surface area of the electrode. It was observed that current density influences the COD removal and increased current density increases the COD removal. It is very important parameter that affects the electro coagulation process because it directly

determines both coagulant dosage and bubble generation rates and strongly influences both solution mixing and mass transfer at the electrodes. So current density is the key operational parameter that affecting the system's response time and also influencing the dominant pollutant separation mode [22].

In case of non rotating and rotating reactor configuration, maximum COD removal efficiency was observed at 8 mA/cm^2 and 6 mA/cm^2 as shown in fig. III. In case of non rotating configuration 50% of removal efficiency was achieved at higher current density in comparison to rotating reactor configuration. As the current density was increased further the removal efficiency decreases.

The COD removal efficiency values showed the better performance of rotating reactor configuration over non rotating reactor configuration.

As the current density decreased, the time needed to achieve similar efficiencies increased. However, the cost of the process is required to determine by the consumption of sacrificial electrode and electrical energy. As the increase in current density augment the cost of treatment, one may use an optimum value of current density for efficient treatment and minimum cost [23].

3.3 *Energy Consumption*

In electro coagulation technique of treatment, total electrical energy consumed depends on applied voltage, current and detention. Many researchers have shown that optimized combination of applied voltage, time and current assure high treatment efficiency. The applied current directly affects metal ion generation, consequently treatment but if too high current is supplied it will be wasted in heating up of system i.e. efficiency of system will decrease [24]. Thus, energy consumed for unit COD removal was calculated for Non Rotating and Rotating Reactor Configuration.

For all experiments in continuous flow reactor, energy consumed for 60 minutes of running time, after pseudo steady state was calculated. Energy consumed for unit removal of COD (1 mg of COD) in each experiment was calculated and reported here as specific energy consumed. Specific energy consumed for unit COD removal was analyzed with corresponding Y_{COD} to find out the energy efficiency of the system.

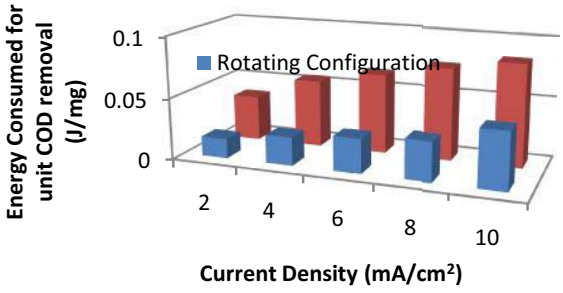

Figure IV: Specific Energy consumed at 20 min of detention time

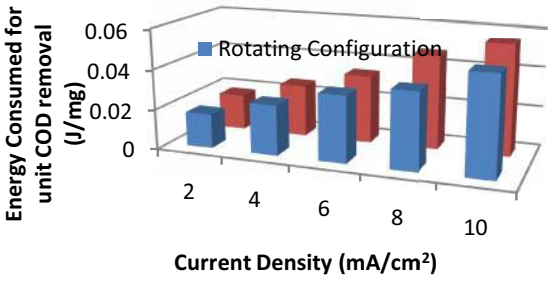

Figure V: Specific Energy consumed at 20 min of detention time

As shown in fig. IV; the energy consumed for unit removal of COD for 20 min of detention time varies from 0.037 to 0.083 J/mg for non rotating reactor configuration but for rotating reactor configuration it varies from 0.016 to 0.046 J/mg as current density was increased which was approximately 50% less than non rotating reactor configuration.

As the detention time was increased to 30 min with respect to current density as shown in fig. V, the energy consumption for non rotating reactor configuration varies from 0.018 to 0.055 J/mg but for rotating reactor configuration it was calculated to be 0.017 to 0.049 J/mg.

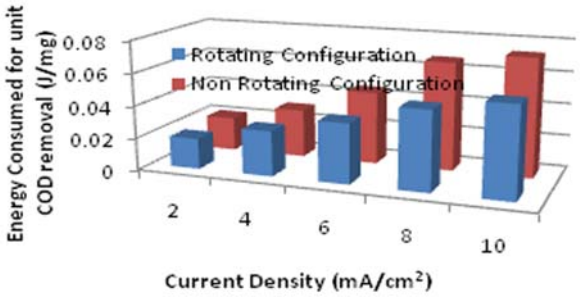

Figure VI: Specific Energy consumed at 40 min of detention time

Further, increasing the detention time to 40 min as shown in fig. VI, the energy consumption for both non rotating and rotating reactor configuration increases whereas COD removal decreases due to the fact that now the energy was wasted up in heating.

So, the energy consumed for maximum COD removal was found to be 0.028 J/mg. which was 17% less for the similar results in non rotating reactor configuration.

4. CONCLUSION

It was observed that in comparison of both the configurations used for the electro coagulation process. The rotating reactor configuration was found to give 10-15% better COD removal efficiency than non rotating reactor configuration. It was also concluded that the energy consumption decreases to 17-58% in rotating reactor configuration for unit COD removal, thus offers better energy efficiency. So, for the similar current density and detention time, the rotating reactor configurations have a better edge over non rotating reactor configurations.

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