REVIEW ARTICLE

Application of Electrocoagulation Technique in Textile Waste Water Treatment: A Review

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ABSTRACT: Textile waste water generating from dyeing and finishing processes is categorized as high strength waste water due to its strong color and high COD. It is a growing as a major source of environmental pollution. The variability in composition of textile effluent has become hard to treat for conventional treatment processes. Electrocoagulation process can be considered as a reliable, safe and economically feasible method for treating textile effluent. Electrocoagulation treatment of textile waste waters have been analyzed on a bench scale by several researchers and found good results with regard to removal of COD, color, turbidity and dissolved solids at varying operating conditions. In the present review electrocoagulation principle and its application in textile waste water treatment were discussed.

KEYWORDS: Electrocoagulation, chemical oxygen demand, textile effluent, electrodes.

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1. INTRODUCTION

Textile industries are the major water consuming industries in India. The waste water that are generating from textile dyeing and finishing processes is almost around 160 million metric tonnes every year (1). Textile wastewater is well known for its high chemical oxygen demand, strong color, and large amount of suspended solids, high pH, salt content and high turbidity, aerosols (2). The waste water when discharged to the water bodies causes a serious threat to the aquatic life. Several techniques such as physical, chemical, biological, advanced oxidation, adsorption, ozone treatment and electrochemical methods are used for the treatment of industrial effluents (2). The commonly used conventional biological treatment methods need large operational area,time taking and are not effective for effluent containing toxic elements and metals(3). Advanced oxidation techniques are although effective but results in high processing cost and are generally used to obtain high purity of water. The chemical coagulation techniques are very slow but excessive use of chemicals causes secondary pollution as it needs to remove the traces of chemicals left in the treated water and it also generates more sludge(4). The physical adsorption processes results in low color and COD removal efficiencies (5). Electrocoagulation has proved to be a potential technique for treating industrial effluent due to its simplicity, environmental compatibility and versatility. Electrocoagulation (EC) is an efficient and innovative technology that combines both the functions and advantages of coagulation, flotation, and electrochemistry methods in treating waste water. The wastes that are generated in different processes of a textile industry are shown in Table-1.

1.1 Origin of textile effluent and its characteristics

The effluent characteristics of general textile effluent (Khandegar) (6), it shows the range of pollutants in mg/L produced during various operations in the typical textile industry, and also the range at which the effluent to be discharged.

Table1: Types of textile waste waters produced in during the process in textile industry (1)

Process	Wastes generated during the process
Desizing	Sizes,enzymes,starch,waxes,ammoni, fibre lint,yarn waste
Scouring	Disinfectants and insecticides, residues, NAOH, surfactants ,soaps ,fats,waxes, pectin,oils,sizes,spent solvents,enzymes
Bleaching	H_2O_2,AOX,sodium silicate or organic stabilizer,high pH
Mercerizing	High pH,NaOH
Dyeing	Colour, metals, salts, surfactants, organic processing assistants, sulphide,acidity/alkalinity, formaldehyde
Printing	Urea,solvents and colored metals
Finishing	Resins,waxes ,chlorinated compounds,BOD,COD,suspended solids

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Table 2: Characteristics of wastewater from textile chemical processing

Characteristics	Scouring	Bleaching	Mercerizing	Dyeing	composite
pH	10- 12	8.5-11	8-10	9-11	8-10
TDS (mg/L)	12,000-30,000	2500-11,000	2000-2600	1500-4000	5000-10,000
TSS (mg/L)	1000-2000	200-	100-400	50-350	100- 700
BOD (mg/L)	2500-3500	100-500	50-120	100-400	50-550
COD (mg/L)	10,000-20,000	1200-1600	250-400	400-1400	250-8000
Chlorides (mg/L) -	-	-	350-700	-	100-500
Sulphates (mg/L) -	-	-	100-350	-	50-300

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1.2 Electrocoagulation process set up

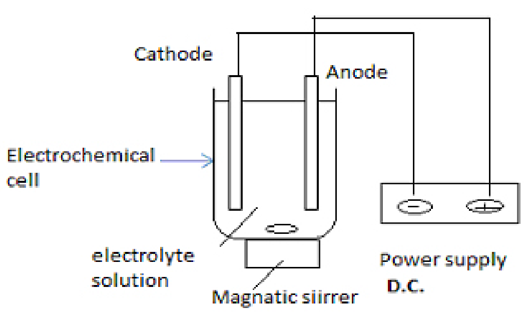

Fig1: Experimental setup (Patel N Bet al,2012)(7)

The electrocoagulation set up consists of two electrodes which act as anode and cathode. The electrodes are connected to a power source and the electrodes are immersed in the aqueous solution is shown in Figure 1. The current is allowed to pass through the solution from electrodes. Simply, an electrolytic cell consists of two electrodes, anode and cathode, immersed in an electrical conducting solution (the electrolyte), and are connected together, through an electrical circuit externally to a current source and control device**.** The other available methods for treating textile effluents like elimination of COD by electrocoagulation with aluminium and iron electrode were reported by Edwar Alejandro Aguilar Ascón, 2018 [21]. He conducted experiments in an electrocoagulation reactor with aluminum and iron electrodes. The COD removal percentage was a response variable for the experimental factorial design. The factors influencing the process were current intensity, treatment time, and pH. The best results in the percentage of removal of the COD were very similar to that obtained at a pH of 8.2 and 7, with values of 83% and 84%, respectively, with a current intensity of 7 A and a treatment time of 15 min. However, at 5 A and 10 min, the values that exceed 80% removal were obtained. Statistical analysis indicates that only current intensity and time were significant for the response variable. Finally it was concluded that Electrocoagulation is a viable process for the treatment of this type of effluent, in addition to being more versatile compared with biological processes.

1.3 Principle of Electrocoagulation

Electrocoagulation is a process in which the anode material undergoes dissolution and forms metal hydroxides. The EC process generally involves three stages: 1). electro-coagulation 2) electro-flotation and 3) electro-oxidation. The possible interactions taking place in EC mechanism are stated in Figure 2.The metal gets dissolute at the anode and forms metal ions continuously. These metal ions react with the water molecules and forms metal hydroxides. The metal hydroxides thus formed having high surface areas are more beneficial in adsorbing organic pollutants and trapping of colloidal particles. The metal hydroxides destabilize the pollutants agglomerated and formed into large flocs and settled. These flocs thus formed are concentrated and removed by either sedimentation or floatation. Evolution of hydrogen and oxygen gas aids in mixing and flocculation of the pollutants.

1.3.1 Mechanism

Reactions:

At the anode:

$$M_{(S)} \longrightarrow M^{n+}_{(aq)} + ne^- \qquad (1)$$

$2H_2O_{(l)} \rightarrow 4H^+_{(aq)} + O_{2(g)} + 4e^-$ (2)

At the cathode:

$M^{n+}_{(aq)} + ne^- \rightarrow M_{(S)}$ (3)

$2H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2OH^-_{(aq)}$ (4)

Where M is the metal electrode

The EC mechanism and the reactions taking place in the process are explained above in detail.

In EC process coagulants obtained in situ method involves three main successive stages:

- Formation of the coagulants by electrolytic oxidation of the 'sacrificial electrode';
- Destabilization of the contaminants, particulate suspension, and breaking of emulsions;
- Aggregation of the destabilized phase to form flocs (9).

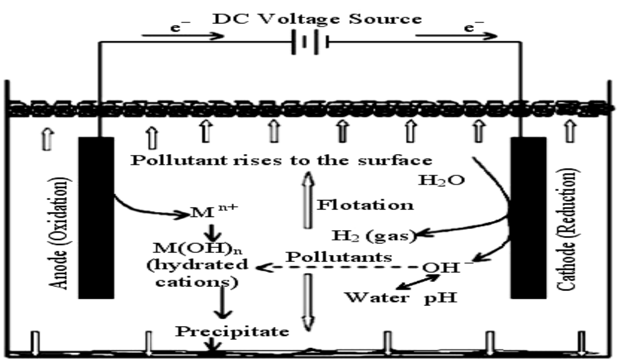

Fig 2: Mechanism of electrocoagulation (Omprakash sahu,2013) [8]

1.4 Advantages of Electrocoagulation Process

- Electrocoagulation process is very simple and efficient compared to other processes
- It avoids secondary pollution causes by the excessive usage of chemical coagulants
- It is more capable of removing smaller colloidal particles because of the applied electricity, the agglomeration of flocs rate is high resulting in the faster removal of pollutants
- The fast moving particles agglomerates and settles as top layer .The flocs formed in this process can be easily removed by filtration.
- It is purely based on electricity and can be conveniently used in rural areas by a solar panel attached to it.

2 . Factors Affecting Electrocoagulation

The important factors that affects the electrocoagulation performance criteria are (1) Electrode material (2)Current density (3) Distance between electrodes (4) Voltage (5) pH .

2.1Effect of electrode material

In electrocoagulation process the electrode material shows significant effect on effluent treatment. For drinking water treatment, the electrodes that are used should be non toxic and corrosion resistant. Norazzizi Nordin[10] conducted experiment using platinum (Pt), iridium (Ir), palladium (Pt), nickel (Ni), cobalt (Co), aluminum (Al), silver (Ag) for treating textile waste water .In his experiment he found that Pt,Ir,Pd metals remained unchanged even after treatment. Whereas Co,Ni,Al,Ag are completely corroded. Moh faiqin niam etal [11]stated that iron electrodes has a disadvantage of turning the effluent color into green or hard yellow due to the formation of Fe^{2+} ions (green) and Fe^{3+} ions (yellow) during electrolytic treatment. With the Aluminum electrode, the effluent becomes clear and stable, with no change in color. Plate types of electrodes are generally used for the treatment because a large surface area enables direct dissolution of anode and cathode. Ahmed Samir Naje et al [20] reported that the EC involves dissolution of the sacrificial anodes to provide an active metal hydroxide as a strong coagulant that destabilizes and amasses particles and then removes them by precipitation or adsorption. EC process is influenced by operating parameters such as applied current density, electrodes material and configuration, type of electrical connection, pH and conductivity of the solution, and mixing state.

2.2 Current density

Current density is the key factor in the EC process. As it not only determines the coagulant dosage rate but also influences the gas bubble formation. High current density causes high upward flux resulting in proper mixing, and more pollutant degradation. Low current densities generates low flux rates, poor mixing takes place and decreases the pollutant removal efficiency. Power consumption depends on the type of material used.

A simple relationship for an amount of electrode material dissolved can be derived from Faraday's law:

$w = itM/eF$

where w = amount of electrode material dissolved (in grams of M per square centimeter)

t =time (in seconds)

e= no. of electrons

F= Faraday's constant 96,500 C mol−1

M =molecular weight of metals

2.3 Distance Between Electrodes

Increase in electrode distances beyond 4 to 5 cm does not show any significant effect on the COD, color and turbidity removal,. Constantly increasing the electrode gap results in high ohmic drops and higher energy consumption, which increase the operating costs? So the favorable electrode distance should be maintained at 1.5-5 cm.

2.4 Voltage

Voltage influences the electrocoagulation process very much. Voltage can be related to current density, effluent's conductivity, electrodes spacing and its surface state by the following equation

$U=\delta * d/k$

Where U = applied tension, V

δ = current density, A/m^2

d = distance between electrodes, m

k = electrolyte conductivity, S/m.

2.5 Effect of pH

pH is also another important factor that shows significant effect on the pollutants removal.At low pHvalue the metal electrode becomes unstable and even more reactive as it releases more ions and enhances the metal dissolution. At high value the release of metal ions becomes slow and it reduces the color and COD removal efficiencies. Although less pH is favorable but flocs does not formed at low pH and hence settling will not be done properly. For proper removal of pollutants the pH should be maintained in the range of (3-9) [20].

3 EC applications in textile effluent treatment

Mehmet kobya et al [1] studied the electrocoagulation treatment of textile waste water using iron and aluminium electrodes and reported that the performance of the electrodes depends on pH of the effluent. In his experiments he concluded that the iron electrode is more efficient in removing COD and color in basic and neutral medium ($pH \geq 7$), where as aluminum is more efficient for acidic medium($pH<6$).From the result it was stated that pH plays a major role in COD and color removal of the textile effluent and also found that for same COD and turbidity removal efficiencies iron consumes less power compared to aluminium. Daneshvar et al [12] studied EC using Fe-St electrodes at $80mA/cm^2$ current density and achieved 93% COD removal efficiency. Rajkumar et al [13] conducted experiment using (Ti-RuO_2-IrO_2)-Stain Steelelectodes as anode and cathode and achieved 100% COD removal efficiency. Ajjam et al [14] performed EC using Fe as sacrificial electrode and observed that 69.2%, 62.5% and 54.3% removal in turbidity, COD and TSS, respectively, were achieved within 60 minutes at a current density of 12 mA/cm^2 while 90.1%, 85.2% and 83.1% removal in turbidity, COD and TSS, respectively, were achieved within 60 minutes of EC treatment at 20mA/cm2 current density. Finally it was concluded that high removal efficiencies obtained at high current densities. Akanksha et al [15], reported the electrocoagulation experiment using iron, aluminium, and steel electrodes and compared the electrodes performances, the experiment was conducted for different voltages (8v,10v,12v,14v) and for different electrolysis time. For the iron electrode the maximum COD removal efficiency was 90.12% at 8V and 80 min and color removal was 99.46% at 14V and 80 min, whereas for the aluminum and steel electrodes the max COD removal efficiencies are observed at14 v and 80 min and max color removal for Al electrode was obtained at 10v in 20 min and for steel it was at12v and 80 min. For better COD removal efficiencies iron is proved to be best electrode in terms of both electrode and energy consumptions. Ghanim [2] studied the EC experiment using iron electrodes and found that the optimum conditions for maximum COD, TSS and Turbidity removals were (56.54 min. and $20mA/cm^2$), (53.13 min. and 20 mA/cm^2) and (54.74 min. and 20 mA/cm^2), respectively. Yavuz Demirciet al[16] connected Aluminum and iron electrodes to an EC reactor in three different types: monopolar-parallel (MP-P), monopolar-serial (MP-S), and bipolar-parallel (BP-P). The results show that MP-P mode is the most cost effective for both electrode connection types. All connection types show similar results in reducing color and turbidity, MP-P is preferred as a low cost treatment. The results show that, according to electrical and sacrificial electrode costs, iron is superior to aluminum but aluminum electrode leads to high turbidity, color and COD removal efficiencies. Norazzizi Nordin et al [10] performed EC using different electrodes, and found that Pt and Ir as the best electrodes as they do not change after treatment Bahadır K. K¨orbahti et al [17] conducted experiment using iron electrodes in batch EC process and obtained good results of COD, color and turbidity removals of 93.9%, 99.5%, and 82.9%, respectively, at 40% pollution load, 8V and 37.5 g/L electrolyte concentration and 30^0C and COD, color and turbidity removal percents were maximized at 100% pollution load. In another run under 30^0C reaction temperature, 25 g/L electrolyte concentration and 8v, 35.5 mA/cm^2 current density, at 100% pollution load, and found the COD, color and turbidity removals of 61.6%, 99.6% and 66.4%, respectively. Sachin et al [18]; Deepak Sharma [19] also conducted experiments on treatment of textile and paper & pulp industrial effluents using electrocoagulation. Patel et al., [7] studied the electrocoagulation technique in reducing the direct black 22 and acid red 97 using iron and aluminium electrodes in batch process and found that both the electrodes are more efficient at pH 8. At the end it was reported that iron is superior to Al in overall performance.

4 CONCLUSION

Rapid growth of population has increased the demand for the basic needs. This laid down the clear path for the enhancement of industrialization**.** The excessive usage of chemicals and dyes in textile industries causes severe water pollution. In waste water treatment plants Industries are using various methods to treat the outlets. The choice of selection of treatment techniques depends on concentration and toxicity of pollutants and the ease of operation .EC is now an attractive growing concern due to its versatility, eco-friendly nature, cost effective and of simple operation. The set up used For EC is small in size compared to other processes. This paper has given the review of electrocoagulation applications in textile effluent treatment. The EC is successfully employed for the removal of color, turbidity, COD and dye removal. This technique will surely make inroads into the waste water treatment due to its numerous benefits.

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