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Environment -Friendly Processes: Electrocoagulation and Activated Carbon Filtration for Reuse of Textile Wastewater

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Abstract

Electrocoagulation is a simple method used for removing contaminants and recycling wastewater by using aluminum, stainless steel and iron electrodes. Textile wastewater was collected from the textile processing industry. This promising treatment consists of two steps, electrocoagulation as a first step completed with Activated carbon filtration as a second step reported in this work. The contaminants of the solution combined in the situ forming metal hydroxide flocs, which filtered as a precipitate or skimmed as a float. To revenue the best advantage of this system, the two processes should run in a rational sequence. Several important parameters, such as applied potential, Electrode material and conductivity were studied to achieve higher removal efficiency. Scanning electron microscope (SEM) analysis, Atomic force microscopy (AFM) and the electrical connection of electrodes were investigated. The results showed clearly that the stainless steel electrode can enhance effectively color removal by 98.8 %, reduced COD to 256 mg /L, while Activated carbon filtration can almost remove the total dissolved solids (TDS) and, turbidity. The findings showed that in textile wastewater at pH=10.5 the stainless steel is superior to iron and aluminum as a sacrificial electrode material and Mono-polar Connection in Parallel is the best connection as it decreases the potential difference, and energy Consumption was 2.5 kWh/m3.

Keywords

Waste-water; Electrocoagulation; Flocculation; AFM; SEM; Adsorption.

Introduction,

The textile industry contains poisoning substances besides considerable amounts of organic dye compounds [1, 2]. These dyes are used widely in industries such as paper printing, pharmaceutical and, toy industries [2-4]. The carcinogenic dye compounds used in dyeing processes are released to the environment through wastewater. Discharging dye effluent into rivers and lakes results in a decreased water quality, oxygen transfer into water and gas solubility as well as high toxicity, carcinogenicity and mutation for living creatures including humans. The electrocoagulation process has been effectively used for treatment of textile wastewater. Various studied used this simple cell for treatment the water junk food wastes, oil waste, chemical, mechanical polishing waste, organic matter from landfill leachates, defluorination of water, industrial cleaner overflows, mine wastes and heavy metal solution [5-7]. This technique uses a direct current source with a variety of anode and cathode geometries, including plates, balls, fluidized bed spheres, wire mesh, Rods and tubes immersed in the effluent, which causes dissolved of electrode Plates into the effluent [2, 8, 9]. Metal electrode ion and metal hydroxides may form coagulated species that interact with collective particles or precipitate and adsorb dissolved contaminants. EC has become one of the most reasonable wastewater treatment processes around the world by reducing electricity consumption [10-12]. Some researchers have recently improved the efficiency of continuous bipolar-mode electrocoagulation and compared with a biological system [2, 9, 13-15]. The findings showed that not only the coloring and COD have a harmful effect on the activated sludge biomass but also the salt content of textile wastewater has negative effects [11, 16, 17] General mechanism summarized as follows [18, 19].

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At the anode:

$M(s) \rightarrow M^{+n}_{(aq)} + ne^-$ (1)

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

At the cathode:

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

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

According to the equations (1–4), the electro-generated metal ions (M^{+n}) formation of coagulants in aqueous phase hydroxides and polyhydroxides having a strong affinity for the formation of coagulants in the aqueous phase [14, 20] Additionally, the gases formed separate particles and coagulant aggregates at the electrodes by elevating them up through a flotation while accelerating collisions between particles and coagulant adsorption of soluble or colloidal contaminants on coagulants and removing by sedimentation or floatation [21].

The goal of this work is treatment of textile industry effluent using electrocoagulation method, activated carbon filtration and select the best sacrificial electrode material at the textile factory's pH.

2. Materials and methods

Textile wastewater used in this study was collected from dye textile factories in industrial cities. Granular Activated carbon filtration was used base from Cocount shell with Granular size 6 × 12,surface area >1200 mg/g , hardeness 98% , micro pours radius >20 , pH 9-11, black color and no odour or taste or dissolve in water and organic solvent.. Laboratory analyses of wastewater are carried out according to the Standard Methods for Examination of Water and wastewater [21] . COD was measured using dichromate as oxidizing an agent and measured calorimetrically using Nanocolor Linus spectrophotometer after acid digestion on a Lovibond RD 125 digester. The pH was measured with a Thermo Electron Corporation pH Meter and Electric Conductivity was determined using Lovibond conductivity meter. Different samples were taken at 10 min intervals time up to 60 min and analyzed to determine residual dye concentration. The residual dye concentration in the solutions was analyzed by using UV/VIS spectrophotometer (Jenway 6300) at 600 nm wavelength. During the runs, the reactor content was stirred at 150 rotations per minute using a magnetic stirrer (VELP Scientifica) to allow a complete mix of the reactor content. The dye removal efficiency was calculated as: Dye removal efficiency (%) = $(Abs_i - Abs_f)/ Abs_i \times 100$ (5)
where Abs_i is the initial absorbance of dye solution (initial dye concentration) and Abs_f is the final absorbance of the dye solution (final dye concentration).In this study, each treatment was repeated twice and the absorbance measurement of each sample was repeated three times and measured values represent the average values of the results. Electrical energy consumption was calculated using the Eq.

$E=UIt$ (6)

where E is the electrical energy in Wh, U the cell voltage in volt (V), I the current in ampere (A), and t is the time of EC process per hour. Electrodes were abraded with a series of emery papers (grades 220, 400, 800, 1200 and 2400) and then washed with distilled water and ethanol. After treatment, the electrodes were cleaned with double-distilled water, dried with a cold air blaster, and then The surface morphology were examined by using scanning electron microscope (SEM) and atomic force (AFM) tech, using flex axiom Nanosurf C3000.

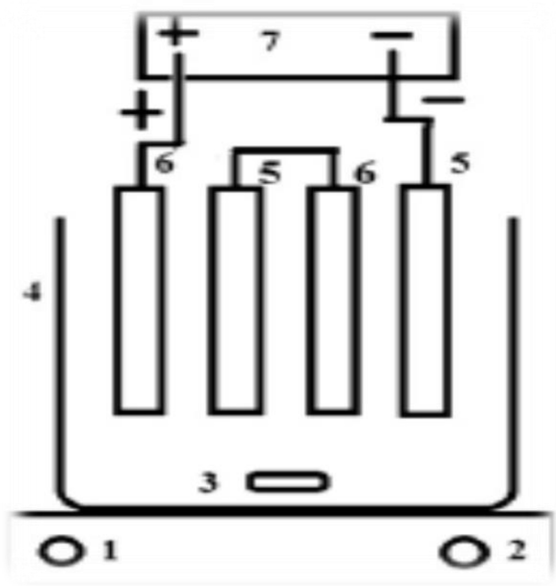

Fig. 1. Monopolar electrodes in serial connections (MP-S) adopted from [7]
1-Temperature controller, 2 -stirring controlling, 3-Magnetic bar, 4- cell, 5-Cathod, 6- Anode, 7- Power supply.

In the monopolar electrodes in serial connection, each pair of sacrificial Electrodes is internally connected with each other. Adding the cell voltage results in a greater a higher potential difference for a given current. Conductive metal plates are usually referred as “sacrificial electrodes.” The sacrificial anode decreases anode's potential for dissolution and minimizes cathode passivation. The sacrificial anodes and cathodes are the same materials. The four electrodes with cells are arranged in series by size of 10cm × 5cm × 1mm separated by a space of 1 cm and dipped in the wastewater. The electrodes are connected to the positive and negative terminals of the DC power supply (Range 30V/3A) as shown in Fig. 1.

In this study, effects of initial pH, voltage and electrolysis time were studied. The experiments were carried out in batch process at room temperature. During the reaction, treated samples were taken at 10 minutes regular interval time for COD and color measurement. The various characteristics of real textile wastewater are shown in Table 1.

3 -Result and discussion

Table 1 Characteristic of raw textile wastewater.

Chemical Oxygen demand(COD) mg/L	600
Total dissolved solid mg/L	1745
Turbidity (NTU)	166
pH	10.5
color	1.3,Dark Red
Conductivity	74300

Table 2 The regulatory authorities are the Ministry of Environment and Forests (MoEF), Central Pollution Control Board (CPCB) at the central level, and the State Pollution Control Board (CPCB) at the state levels.

Chemical Oxygen demand(COD) mg/L	250
Total suspended solid mg/L	2100
Turbidity (NTU)	-
PH	6-9
color	400
BOD	30

3.1. Effect of applied Potential

3.1. Effect of applied Potential

Experiments of electrocoagulation were carried out at various voltages 1,2,3,4 and 5 Volts. The pH was 10.5 for textile wastewater effluent. The amount was 1 liter. The variations in the efficiency of color removal and COD removals with time electrolysis are shown in Fig. 2. using Aluminum, Iron and Stainless Steel electrodes for treatment the textile wastewater. Fig. 2. showed the maximum color removal for Aluminum electrode was 94.46 percent at 5 Volt and 60 min, COD removal was 504 mgL^{-1}. However, the maximum efficiency of color removal and COD reduction were 94.29 percent, 365 $mg\ L^{-1}$ respectively for stainless steel electrode at 4Volt and 40 min are shown in Fig. 2.

The average COD removal at 40 min for iron was 470 mgL^{-1} Fig. 2. at 2V. The maximum efficiency for color removal was 97.22 percent. These results are agree with [7, 24, 25]) which indicated that anodic dissolution and the release of coagulating ion species occurred during the electrolysis process. The performance of color and COD removal depends mainly on the concentration of metal ions produced from the electrode materials. As the electrolysis process proceeds, anodic dissolution takes place leading to the release of coagulants. By extending the electrolysis time, the level of metal ions and their hydroxide flocs increase that are effective in the destabilization and capture the pollutants by Electro-dissolution of the sacrificial anode to the wastewater and the cathode produces the hydrogen bubbles that turbulence in the system and bond with the pollutants, decreasing their relative specific weight and flocculation process is increased so in case of the aluminum electrode the removal of COD is low due to the amphoteric properties of the aluminum hydroxide which does not precipitate at very low pH [26-28]. Furthermore, the high pH leads to the formation of Al $(OH)_4$, which is soluble and useless for adsorption of dye . Many studies reported that if $pH < 2$ and $pH > 10$ the aluminum hydroxide particles did not have deposition leding to decrease in the efficiency of the pollutant removal in this process [19, 29, 30]

One key parameter of EC treatment is the pH of the solution that plays an important role in electrocoagulation for both materials, it is clear that COD and turbidity removals show the same trend. The highest removal efficiencies have been obtained with aluminum in acidic medium with $pH < 6$ while the iron is more efficient in neutral and alkaline medium [31-34]

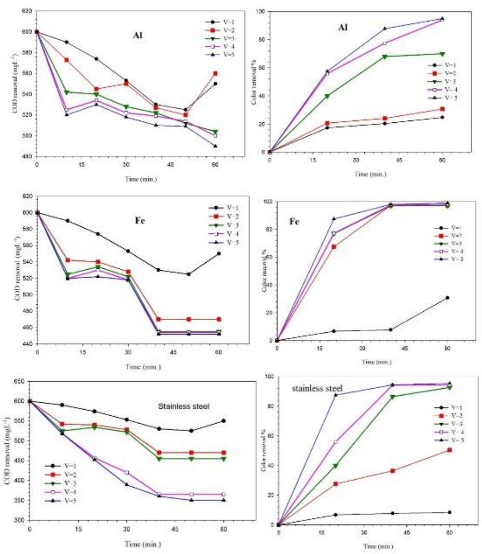

Fig. 2 .Color removal efficiency and COD removal using Aluminum, Iron and Stainless steel Electrodes at pH=10.5

3.2. Effect of Electrode material

The electrocoagulation process electrodes are very important part of the electric cell. The right selection of its materials is concerned with different types of wastewater. In this work, aluminum electrode, iron electrode and stainless steel electrode are used to study the best electrode for treatment of textile wastewater. Fig. 2. compare the treatment efficiency for three electrodes under the same electrical current=2A and pH =10.5.

3.2.1. Effect of Electrode material on TDS removal efficiency

Total dissolved solids (TDS) indicated the presence of high levels of soluble pollutants in the Textile wastewater. Fig. 3[A]. showed that, the best removal percentages achieved by stainless steel electrode at pH 10.5. 4 Volt for 1 hour's period. Activated carbon reduced the total soluble salt which we decided in the previous paper that it has a negative effect on the biomass sludge. [2]

3.2.2 Effect of Electrode material on COD, Turbidity, Color removal and Conductivity

Table 3 showed that, for Textile waste water, the stainless steel electrode was more effective than the iron and aluminum electrodes, which can reduce COD, Turbidity, Color removal and Conductivity. Therefore; all subsequent experiments were carried out with stainless steel electrode.

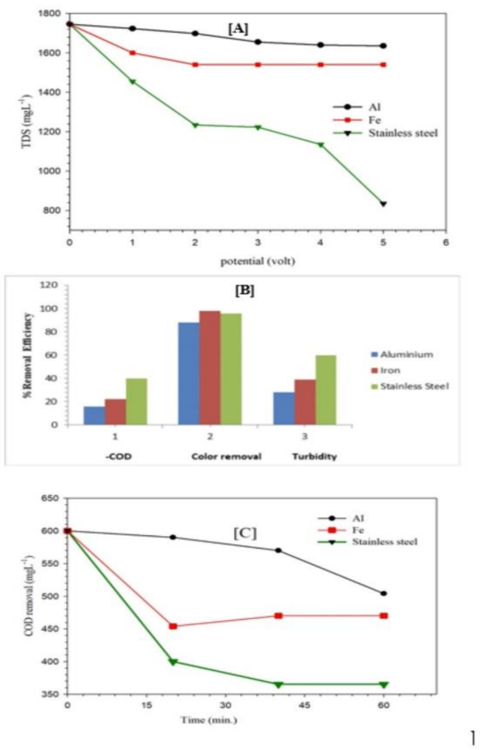

Fig. 3. [A] TDS removal efficiency with Applied Voltage , [B] Effect of anode materials on COD removal, Color removal and Turbidity removal, [C] COD removal with electrolysis time at initial pH=10.5, electrical current=2A and distance between electrodes =1 cm.

Table 3 Characteristics of real textile wastewater and treated effluent.

Analytical parameter	Raw wastewater	Al	Fe	Stainless Steel
Chemical Oxygen demand(COD) mg/L	600	504	470	365
Total dissolved solid mg/L	1745	1635	1540	835
Turbidity (NTU)	166	120	100	67
pH	10.5	10.3	11.4	9.2
color	1.3,Dark Red	94.46 %	94.29 %	97.22%
Conductivity (ms/cm)	74300	68500	62900	61200

3.3. Effect of electrical Conductivity on COD removal efficiency

Owing to the chemical substances applied from dyeing and finishing at a high concentration, the textile wastewater processes in the textile sector have a large abroad variation in ionic strength. The greater ionic strength increases current density at the same cell voltage, or the cell voltage decreases with increasing wastewater conductivity [30] . Therefore, it is necessary to investigate the effect of electrode materials on wastewater conductivity and COD, as we can see in Fig. 4. According to the experimental results, stainless steel electrode consider the best electrode material for decreasing wastewater conductivity and that is reduce COD values. Therefore, we concluded that no adjustments are needed for the pH and conductivity of the wastewater, and only select the electrode material which have effect of operational variables on the process and also its performance may be explored with wastewater as discharged from the textile dyeing plant.

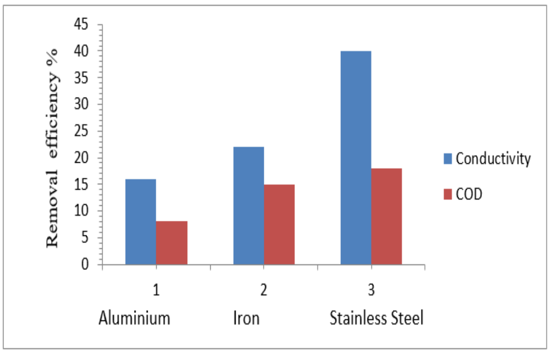

Fig. 4. Effect of electrode materials on wastewater conductivity and COD.

3.4. Influence of the of Electrical Connection on stainless steel electrode

Fig. 5. Showed that (a) Mono-polar Connection in Parallel shows an EC cell with a pair of anodes positioned between two parallel cathodes which are connected to a DC source. (b) Mono-polar Series Connection reveals an EC cell with a pair of interconnected anodes which does not interconnect with the outer electrode. (c), Bipolar Connection in Series there is no electrical connection between the inner electrodes; only the outer electrodes are connected by a power supply. The outer electrodes are single pole and the inner electrodes are bipolar. This connection mode has a simple configuration which facilitates maintenance during operation [32].

The present study indicated that the appropriate connection was Mono-polar Connection in Parallel as it decreases the potential difference and the time of decolorization that leads to a decrease in the energy consumption and that agrees with the previous study [21, 33] which showed that MP-P mode is the most cost- effective for both electrode connection type as it reduced color removal by 98.8 %, COD and reduced to 256 mg /L, and energy Consumption was 2.5 kWh/m^3[34], while Bipolar Connection in Series = 4 kWh/L and Mono-polar Connection in Series =10.66 kWh/L

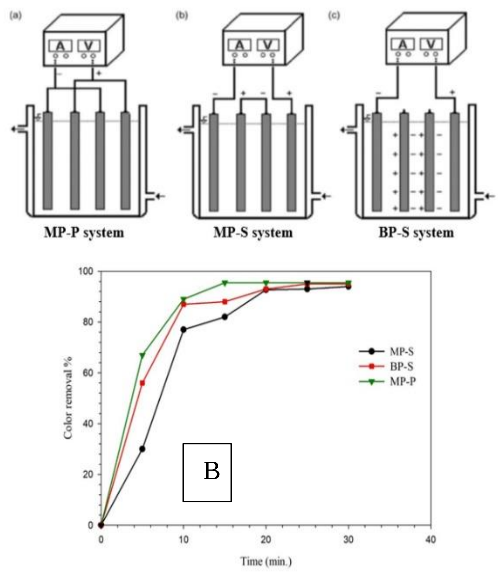

Fig. 5. Types of Electrical Connection [21]and the effect of different connection modes on color removal as a function of time.

4. Surface analysis

4.1. Scanning electron microscope (SEM) analysis

Scanning electron microscope (SEM) is a technique used to study the surface morphology, Fig.(5): showed the scanning electron microphotographs (A) Al, Fe (B) and (C) Stainless Steel in initial pH=10.5, electrical current=2A,distance between electrodes =1 cm. After treatment of textile waste water, aluminum surface is aggressive corrosion attack and is very rough as a result of many cracks and scratches on the Al surface as compared to the Fe (B) and (C) Stainless.

4.2. Atomic force microscopy

Atomic force microscopy (AFM) is an accepted method for quantifying metal surface roughness, and material surface morphology in three dimensions. AFM is used for the study of surface morphology of, Al, Fe and steel samples. The average roughness of, Al, Fe and steel samples in textile solution were found as 95.056nm, 29.528nm and 25. 875nm, It is clearly shown in Fig. 6 . that Al, Fe sample is badly damaged. Stainless steel more efficiently due to the lower value of surface roughness.

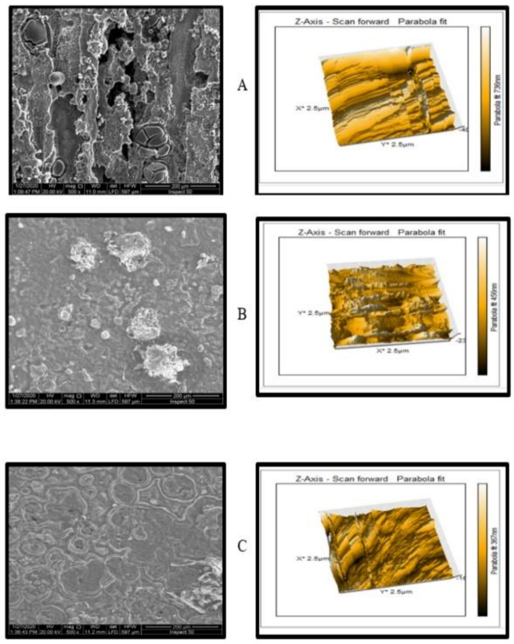

Fig. 6. SEM and AFM images for Al, Fe and Stainless Steel at initial pH=10.5, electrical current = 2A and distance between electrodes =1cm

Conclusion

Electrocoagulation has a wide variety of capabilities in reused wastewater. It is the method of destabilizing suspended, emulsified, or dissolved contaminants in aqueous medium by application a minimal amount of applied potential with respect to the energy consumption Therefore; it reduces extra costs involved for the process. It even replaces the traditional treatment process which has proved to be less efficient and costly processes. Taking the benefits into account. The use of electrocoagulation as a first step completed with activated carbon filtration has allowed significant results to be obtained. Indeed, it is found that during the combined treatment for stainless steel electrodes at 20 min, the decolonization rate reaches 98.8 %, COD are reduced to 256 mg L^{-1}, at pH = 10.5 the energy consumption for Mono-polar Connection in Parallel was =2.5 kWh/L is lower compared with Bipolar Connection in Series =4 kWh/L and Mono-polar Connection in Series =10.66 kWh/L, Scanning electron microscope (SEM) and Atomic force microscopy (AFM) indicated, stainless steel electrodes is the least damaged and lowest value of surface roughness.

On the other side, using the activated carbon decreased the total soluble salt so the biological methods are used without adverse effects at activated sludge biomass so we reuse treated effluent in industrial processes and complete COD efficiency by biological method. This indicates that the technique is efficient and reliable for a wide range of potential applications.

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