Chapter 6

Treatment of Textile Wastewater Using a Novel Electrocoagulation Reactor Design

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Abstract

This study explored the best operating conditions for a novel electrocoagulation (EC) reactor with the rotating anode for textile wastewater treatment. The influence of operating parameters like interelectrode distance (IED), current density (CD), temperature, pH, operating time (RT) and rotation speed on the removal efficiency of the contaminant was studied. A comparative study was done using conventional model with static electrodes in two phases under same textile wastewater. The findings revealed that the optimal conditions for textile wastewater treatment were attained at RT = 10 min, CD = 4 mA/cm^2, rotation speed = 150 rpm, temperature = 25°C, IED = 1 cm and pH = 4.57. The removal efficiencies of color, biological oxygen demand (BOD), turbidity, chemical oxygen demand (COD) and total suspended solid (TSS) were 98.50, 95.55, 96, 98 and 97.10%, respectively, within the first 10 min of the reaction. The results of the experiment reveal that the newly designed reactor incorporated with cathode rings and rotated anode impellers provide a superior treatment efficiency within a short reaction time. The novel EC reactor with a rotating anode significantly enhanced textile wastewater treatment compared to the conventional model. The values of adsorption and passivation resistance validated the pollutants removal rate.

Keywords: rotated anode reactor, textile wastewater, electrode consumption, electrocoagulation

1. Introduction

Electrocoagulation (EC) process involves in situ coagulant formation with sacrificial anode dissolution. Generally, the anode is prepared using iron or aluminum (Al) [1, 2]. The metal ions

interact to generate insoluble OH^- ions. The generated insoluble hydroxides adsorb the contaminants from the solution either by electrostatic attraction or complexation before the coagulation [3, 4]. Lessening of the electrodes' internal resistance drop (IR-drop) is one of the most essentials toward reducing the total cost of EC operation to enhance the current performance by enhancing the state of turbulence. Both oxygen and hydrogen gas emerged near the cathode and anode as soon as each gas bubble nucleates. The bubbles are like insulating spherical figures, generating a film that fouls oxide over the electrode surface (passivation effects). This issue increases the total electrical resistance of the cell, thereby needing a superior quantity of electrical energy to attain the optimal removal [5]. To moderate the bubble accumulation, the electrolyte flow around the electrodes must be augmented for the bubbles to be pushed out [6].

To proffer solution to these, the current EC reactor with rotating anode was conducted to enhance the reactors' overall efficiency [7]. Additionally, the leading objective of the present work is to study the treatment of textile wastewater using a novel EC reactor under optimum operating conditions and to compare the performance with that of conventional EC reactor.

2. Materials and methods

2.1. Wastewater characteristics

The wastewater used for the present study was obtained from one of the foremost textile industries in Babylon (Iraq). For dyeing of fabrics, the industry employs Imperon Violet KB (CAS #: 6358-46-9). **Table 1** presents the major characteristics of the textile wastewater, while **Table 2** shows the properties of the employed Imperon Violet KB.

2.2. EC rotating anode reactor

Figure 1 illustrates the new EC reactor employed in the current study. The reactor (10 L working volume) was made from Perspex and has a cylindrical form stirred tank setting (total length = 500 mm; inner diameter = 174 mm; external diameter = 180 mm). To keep the impeller structure and sustain the rotation of the electrode, a 32-mm-diameter rotating shaft was attached to a regulating speed motor. The motor is a DC electrical type and offers a number of steady-state speeds in the range of 0–1000 rpm. The electrodes were produced from the aluminum substance; the rotating anode comprises ten impellers. All the impellers have four rods (diameter = 12 mm, length = 30 mm) each and ten rings, which were employed as the cathode. Every one of the ring (thickness = 12 mm, internal diameter = 134 mm, diameter = 172 mm) was serially organized, maintaining 30 mm distance of apart. The entire active surface area is 500 cm^2; the reactor comprises three equally spaced baffles to establish the cathode rings by terminating the rotation and tangential flow arrangements of the mass fluid. The endorsed surface area-to-volume ratio ranges from 5 to 45 m^2/m^3 [8]. In the current model, the ratio was minimized (to 5 m^2/m^3) with the aid of a small area of the electrode for treatment of a great wastewater volume. The patent novelty filing was performed with application number PI 2015702202.

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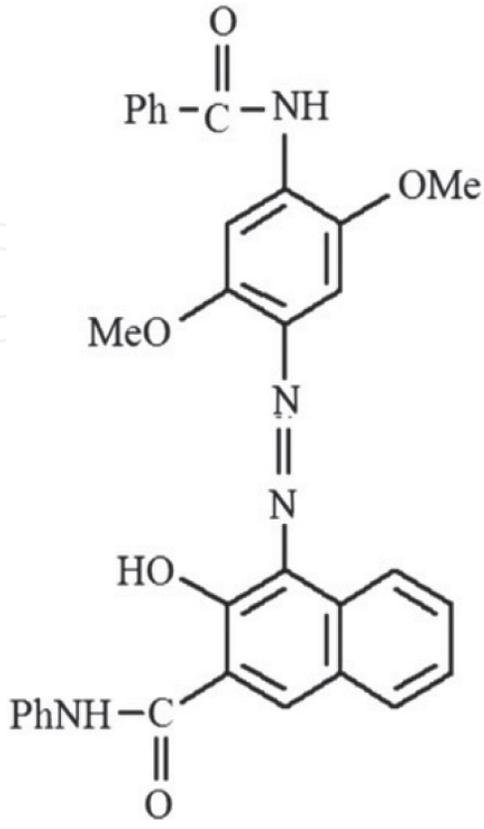
Parameters	Values
Electrical conductivity (μS/cm)	1455
Turbidity (NTU)	396
Total suspension solid, TSS (mg/L)	3270
Total dissolved solid, TDS (mg/L)	1250
Dissolved oxygen, DO (mg/L)	0.72
pH	4.50
Chlorides, Cl^- (mg/L)	35
Sulfate (mg/L)	678
Phosphate (mg/L)	7.2
Nitrates (mg/L)	11
Phenols (mg/L)	335
Oil and grease (mg/L)	3.2
BOD (mg/L)	112
COD (mg/L)	990

Table 1. Characteristics of textile wastewater.

2.3. Experimental procedure

The performance of EC process was determined based on color removal, TSS and COD. The experiment was initially performed by investigating the influence of CD and the anode rotation speed. The overall competence of the reactor was investigated using three major variables: overall rotation speed of the anode, CD and processing time. The value of RT of 10–30 min was maintained. Three values of CD (4, 6 and 8 mA/cm^2) with different steady-state anode rotation speed (75, 150 and 250 rpm) were observed at room temperature (25–27°C). The selection of the current densities was based on some initial studies, which show an insignificant change in the total removal efficiency when the value of CD exceeds 8 mA/cm^2. For all the runs, a 10 L sample was used for the EC process, and nine different batches of EC runs were performed. Upon concluding each run, a primary sample was removed, and the cells were washed with a 5% HCl solution for 10 min and subsequently washed using a sponge. The anode and cathode were linked to the positive and negative parts of DC power supply (YIZHAN, 0–6 A; 0-40 V, China). 30 V was used as the main voltage was for each experiment. For voltage measurement, a voltmeter was attached to the cell in parallel. For each run, the current was kept constant by using a variable resistance and monitored using an ammeter. For each iteration, the samples were left to settle for 30 min and subsequently filtered. About 100 ml of supernatant sample was collected for examination and analysis in replicates. The same parameters were examined for the entire replicated sample.

Color	Imperon Violet KB
Chemical structure	
Chemical formula	$C_{32}H_{26}N_4O_5$
The molecular weight (g/mol)	546.57
λ_{max} (nm)*	533

*Absorbance of 0.34 at 533.

Table 2. Properties of Imperon violet KB.

The experiment was performed using four different sets of operating conditions to obtain best parameters. The influence of pH on the EC system was investigated at varying pH values (5–10 by addition of 0.5 M NaOH). Some secondary electrolytes like Na_2SO_4 and NaCl (0.0, 0.02, 0.05 and 0.10 kg/m^3) were added to the wastewater toward investigating the effect of electrolyte support on the removal efficiency. The influence of temperature was studied, ranging from 25 to 45°C using water circulation to sustain the temperature as the EC process proceeds. The IED between the cathode rings and anode impellers were attained for various distance (1, 1.5 and 2 cm). At the end of experimentation, the best operating condition was determined again in triplicate to confirm the accuracy of the EC operation and repeatability for treatment of textile wastewater pollutants. For comparison study using same textile wastewater, the results of the conventional model with parallel electrodes in two phases have been observed by our previous works using EC alone by aluminum plates [9] and on enhancing of EC process by combining with electro-oxidation (EO) using titanium plates [10].

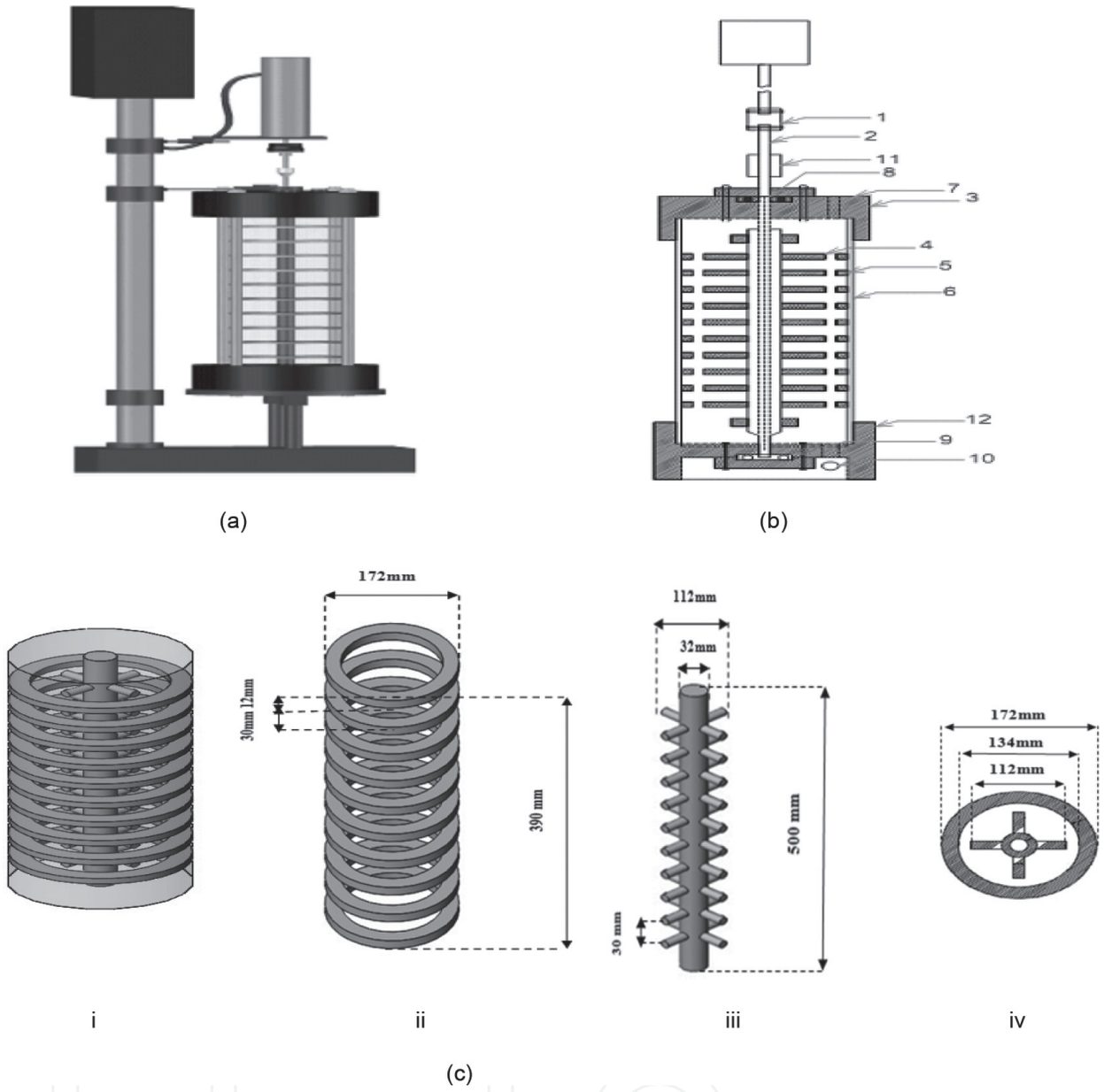


Figure 1. (a) Illustration of EC rotating anode setup. (b) Representation of the EC rotating anode system: (1) motor variable speed, (2) stainless steel shaft (D = 32 mm), (3) Teflon flange cover (upper) (H = 100 mm, D = 280 mm), (4) impeller anode aluminum rod (D = 12 mm, L = 30 mm, no = 4), (5) aluminum ring cathode (T = 12 mm, d.In = 132 mm, D.Out =1 72 mm, no = 10), (6) Perspex reactor (L = 500 mm, d.In = 174 cm, D.Out = 180 mm), (7) upper ports (D = 10 mm, no = 3), (8) ball bearing, (9) thrust bearing, (10) lower port (D = 10 mm), (11) zoom couping and (12) Teflon flange cover (lower) (D = 280 mm, H = 100 mm). (c) Electrode configurations: (i) cathode and anode, (ii) anode impellers, (iii) cathode rings and (iv) top view of cathode rings and impeller anode.

The passivation and adsorption phenomenon was also investigated using the electrochemical impedance spectroscopy. The experiment was performed using AC signal potential amplitude maintained at 10 mV, and the observed frequency range was 0.01–10^5 Hz. A potentiostat was employed to carry out the electrochemical impedance assays. The impedance experiments were performed in a single-partition, three-electrode system, consisting of an Al electrode

(1:25 of the original size) as the working electrode, a platinum wire as a counter electrode and Ag/AgCl (3 M KCl) electrode as a reference electrode.

2.4. Chemical analysis

The efficiency of the new EC reactor for the entire treatment was analyzed based on color removal performances, TSS and COD. For every iteration, the electrical potential was kept constant at 30 V. The COD was determined using a Closed Reflux-Titrimetric technique. The determination of TDS and TSS was performed using gravimetric technique. The phenol content was determined using HPLC. ODS Hypersil C18 column (4.6 mm×150 mm×5 μm) at 25 was employed for separation of aromatic and phenolic compounds with the aid of water/acetonitrile (40/60, v/v) being the mobile phase. The flow rate of the mobile phase and the injection volumes was 1 mL/min and 5 μL. 254 nm detection wavelength was used. The samples were subjected to filtration by using a 0.25 μm membrane filter. The amount of grease and oil (G&O) was determined using solvent extraction technique. The amount of dissolved oxygen (DO) and BOD was determined using DO meter. The turbidity, conductivity and pH were also determined in the present study. The color was analyzed through absorbance using a UV–Vis spectrophotometer with a wavelength corresponding to the peak absorbance value for the textile effluence (533 nm). The sample filtration was carried out with the aid of Whatman 934 AH filter. The rotating anode speed was monitored using a microprocessor digital meter. The ion was analyzed using ionic chromatography ICS-2000. The whole analytical works were performed based on the prescribed procedures in the standard techniques [11]. The determination of color removal, TSS and COD was done using formulas stated by [12–15] among others.

2.5. Sludge compaction analysis

The sludge of the textile wastewater was allowed to sit for 1 h to boost the alliance of the sediments. The two concentrations of cationic polymer (LPM 3135 polymer, 10 and 40 mg/L) were examined to enhance the settling process. The volume of the space engaged by the solid (mL) was measured at fixed time intervals. The weight of the wet residue (the solid portion) was determined, after which the samples were dried for approximately 24 h at 100°C to obtain the whole residual solids. The specific resistance to filtration (SRF) and the cake-dry solid was estimated to properly depict the dewater capability of the sludge using Buchner funnel filtration with pressure (0.015 mPas). The SRF formula (in m/kg) is defined as [16].

$$RF(SRF) = (2KbPA^2)/\mu a_w \quad (1)$$

where P is the pressure during sludge filtration (mPas), A is the filtered area, μ is the viscosity of the filtrate (N.s/m^2), a_w is the weight of the solid per unit volume of filtrate (kg/m^3) and Kb is the slope of the *V* vs. t/*V* plot. Whatman glass fiber filter (Grade 934-AH) was used. Measuring and estimating dryness of the general cake were performed by the following equation:

$$\text{Sludge dryness (\%)} = 100 \times \left[(m_3 - m_1)/(m_2 - m_1)\right] \quad (2)$$

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where m_1 and m_2 are the mass of the cup (with the membrane) after and before the filtration process and m_3 is the mass of the same cup after the drying for 24 h at 100°C.

A sludge volume index (SVI) was implemented to decide the settling properties of the sludge suspensions. The SVI (mL/g) is the volume (in mm) used by 1 g of a suspension subject to 30 min of settling [11]. The SVI is defined as.

$$SVI = VD_{30}/TSS \tag{3}$$

where TSS is the concentration of suspended solids (g/L) and VD_{30} is the volume of settled sludge after 30 min (mL/L).

2.6. Economic analysis

The total operating costs for treatment of wastewater process include electricity, equipment, chemical usage, labor, maintenance and sludge disposal. For EC process, the major costs of operation include the cost of electricity and electrode material. In this study, the cost of chemical supplements and sludge disposal was added as well. The total cost of operation (TCO) was computed using [3].

$$TCO = a\,C_{energy} + b\,C_{electrode} + d\,C_{sludge} + e\,C_{chemicals} \tag{4}$$

$$C_{energy} = UIRT/V \tag{5}$$

$$C_{electrode} = M_w\,I\,RT/ZFV \tag{6}$$

where C_{energy} = denotes intake of energy per cubic meter of wastewater (kWh/m^3); $C_{electrode}$ = intake of electrode for treatment of 1 m^3 of wastewater (kg/m^3); C_{sludge} = quantity of sludge per m^3 of wastewater (kg/m^3); $C_{chemical}$ = amount of chemicals (kg/m^3).; a = total cost of electricity (about 0.075US$/kWh); b = cost of iron or aluminum (2.5US$/kg); d = sludge disposal cost excluding the drying and including transportation (0.06US$/kg); e = cost of chemicals that can be added: LPM 3135 polymer (3.0US$/kg), NaOH (0.5US$/kg), Na_2SO_4 (0.25US$/kg) and NaCl (0.06US$/kg); U = voltage; I = intensity of the current; RT = EC electrolysis time; V = textile wastewater working volume; M_w = molar mass of the iron (55.84 g/mol) or aluminum (26.98 g/mol); Z = quantity of electrons moved (3); F = Faraday constant (96,500 C/mol).

The operating expense was computed according to the Iraqi market prices for the year 2017. For EC rotating anode, the total consumption of electrical energy was estimated as follows:

$$C_{energy}\,(kWh/m^3) = \left(C_{energy}\right)_S + \left(C_{energy}\right)_M \tag{7}$$

where $(C_{energy})_M$ signifies the rate at which the DC motor anode rotation consumed electrical energy and $(C_{energy})_S$ signifies the amount of electrical energy consumed by the reacting system

(electricity received by the cathode and the anode because of DC power supply). The values of $(C_{energy})_M$ and $(C_{energy})_S$ were determined from Eq. (5).

3. Results and discussion

3.1. Efficiency and reproducibility of the novel EC reactor

The investigations of the best parameters have been discussed in our previous research [17]. The major EC operation in the textile wastewater was executed in triplicate to confirm the efficiency and reproducibility of the application when the best operating conditions (CD = 4 mA/cm^2, temperature = 25°C, RT = 10 min, pH = 4. 57, rotation speed = 150 rpm and d_e = 1 cm) are used. The performance of the novel EC system was investigated based on the levels of BOD, Al, color, phenols, turbidity, COD, G&O, TDS, DO, nitrates, sulfate, phosphate and TSS. The summary of the results of the parameters is shown in **Figure 2** and **Table 3**. The EC operation exhibited 97.1% total removal efficiency of COD. After the EC treatment process, the G&O and BOD_5 in the wastewater had values of 0.1 and 5 mg/L, respectively. The hydrophobic capacity of G&O resulted in a higher affinity combining with the H_2 bubbles created at the cathode. The (G&O)-H_2 complex gathered on the surface of the liquid, which could be skimmed with ease [18].

The proposed EC design enables superior efficiencies and simultaneously reduces energy consumption in comparison with other reports. Un and Aytac [12] studied textile wastewater treatment by EC process in a packed-bed electrochemical reactor. They reported 96.88% removal efficiency for COD and observed that the color was almost completely removed after 1 h of EC

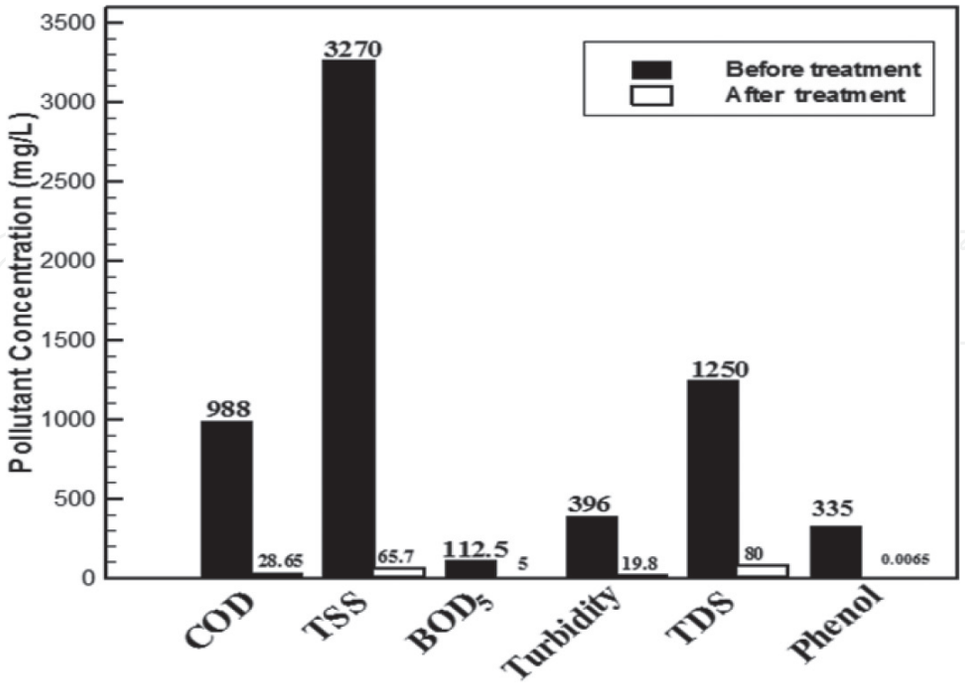

Figure 2. The removal efficacy of several parameters of the textile wastewater using the best operating condition.

Parameters	Raw effluent	Treated effluent	Allowable limit (EPA) 1996	Removal (%)
Electrical conductivity (μS/cm)	1455	2000	ID	—
Initial pH	4.57	4.57	—	—
Final pH	—	6.92	6–8	—
Energy consumption (kwh/m^3)	—	0.966	—	—
Electrode consumption (kg/m^3)	—	0.038		—
Sludge production (kg/m^3)		1.44		
Polymer consumption (kg/m^3)		0.01		
O&G (mg/L)	3	0.1	5–40	96.66
BOD_5 (mg/L)	112.5	5.00	5–45.5	95.55
COD (mg/L)	988	28.65	20–500	97.10
TSS (mg/L)	3270	65.70	60–300	98.00
Color observance at 533 NM	0.3400	0.0051	ID	98.50
TDS (mg/L)	1250	80.00	5–180	93.60
Turbidity (NTU)	396	19.80	15–50	96.00
DO (mg/L)	0.7	14.5	4.5–15	
Sulfate (mg/L)	678	17.00	ID	97.50
Phosphate (mg/L)	7.2	0.23	ID	96.80
Nitrates (mg/L)	11	0.2	ID	98.18
Phenols (mg/L)	335	0.0065	10	99.99
Chlorides Cl^- (mg/L)	33	0.4	ID	—
Aluminum (mg/L)	1.50	6.00	—	—
Electrical energy cost (US$/$m^3$)	—	0.072	—	—
Electrode consumption cost (US$/$m^3$)	—	0.095	—	—
Sludge disposition cost (US$/$m^3$)	—	0.086	—	—
Polymer cost (US$/$m^3$)	—	0.030	—	—
Total operating cost (US$/$m^3$)	—	0.283	—	—

Table 3. Efficiency and reproducibility of EC rotating anode in textile wastewater treatment using the best operating conditions (CD = 4 mA/cm^2, temperature = 25°C, rotation speed = 150 rpm, RT = 10 min, pH = 4.57, d_e = 1 cm).

operation. However, in this work, the 97% COD removal efficiency was obtained after 10 min reaction. Merzouk et al. [15] also studied the textile wastewater treatment using electro-flotation and EC using a batch reactor (electrode gap = 1 cm, conductivity = 2.1 μS/cm, pH = 7.6 and density = 11.55 mA/cm^2). With the best operating conditions, the obtained results are as follow: TSS = 85.5%, color = 93%, COD = 79.7%, BOD_5 = 88.9% and turbidity = 76.2%. Comparing with

the above results, this study utilizes only EC under the best operating conditions and exhibits superior removal efficiencies: TSS 98%, color >98%, BOD_5 = 95.55%, COD 97% and turbidity = 96%. In recent time, El-Ashtoukhy et al. [19] examined phenol removal from wastewater generated from oil refinery using a fixed-bed anode electrochemical reactor consisting random Al raschig rings. At pH = 7, CD = 8.59 mA/cm^2 and concentration of NaCl = 1 g/L, around 80% phenol reduction was observed after 2 h using 40 mg/L as the primary phenol concentration.

In this study, the concentration of primary phenol is 350.0 mg/L, and after 10 min, about 99.99% was extracted, while 0.009 mg/L of phenol remains with the cured wastewater. Furthermore, Martinez-Delgadillo et al. (2012) investigated Cr (VI) reduction to Cr (III) with the aid of Fe (II) in a rotating ring iron electrode. Their report shows up to 99.9% removal of Cr (VI) between 22 and 42 min contact time at an angular velocity ranging from 0 to 230 rpm (at 5 A). In the current study, the optimal reaction time and current were 10 min and 2 A, to confirm the reduction in power consumption and low cost of operation. Moreover, this work also reports high TDS removal efficiency (93.6%) when the best set of operating parameters were used, and the phosphate concentration was decreased to 0.23 from 7.2 mg/L. The Al electrode suspension displayed a rise in the whole dissolved concentration to 6.00 from 1.5 mg/L during the operation. In comparison with the quality standards of global textile wastewater [20, 21], the findings support the analysis of the efficacy of the EC system for treatment of textile wastewater for various usages. The outcomes show that the COD, turbidity, TDS, BOD and DO are all lower than the acceptable limit. Conversely, the generally pH level of the treated effluence was basic (6.9 ± 0.04) to some extent, which is under the acceptable limit. Similarly, the oil and grease, as well as the total phenols, fall under the acceptable limit. Under optimal conditions, the real electrode consumption was 0.038 kg/m^3, while the energy consumption was 0.966 kWh/m^3, 0.9 kWh/m^3 for DC power supply consumption and 0.066 kWh/m^3 for DC motor of rotating anode. For settling metallic sludge study after adding 0.01 kg/m^3 LPM3135 polymers, a 5% sludge dryness and 63 mL/g SVI were noted in the course of the analysis. The sludge production was 1.44 kg/m^3. Furthermore, the SRF utilized in these investigations was (4.6×10^{12}m/kg). The results revealed that the main cost of the treatment operation per m^3 [Eq. (4)] of wastewater, using the best set of operating parameters, is roughly 0.283 US$.

3.2. Comparison performance of the EC rotating anode with the conventional model

Table 4 shows a comparative study between EC rotating anode and the conventional static electrodes in two-phase EC process alone and EC-EO process depending on the results of each model at the optimal conditions. Each model has the same optimal applied current to volume ratio (0.2 A/L). Although the EC model with rotating anode has the lowest surface area to volume ratio (5 m^2/m^3), it can be seen that this reactor model obtained the best removal efficiency of contaminant textile wastewater (COD, TSS and the color). The minimum reaction time (10 min) was achieved by EC model with rotating anode compared with a conventional model in two phases (90 min) which demonstrated the activity of electrodes for the treatment and reduced significantly the energy consumption to 0.966 kwh/m^3. Furthermore, the rotation speed of anode affects the energy consumption by reducing the main voltage and passivation films. The EC process with rotating anode showed excellent treatment without setting the initial pH or using supporting electrolyte. The electrode consumption and sludge production were less than the conventional model with static electrodes. As for the operating costs, the

EC model with rotating anode was lower than the conventional model with static electrodes (EC rotating anode = 0.283US$/m^3, while conventional static electrode including EC = 1.76 US$/m^3 and EC-EO =1.69 US$/m^3).

3.3. Passivation and adsorption phenomenon

Electrochemical impedance spectroscopy is one of the most effective methods for investigation of electrochemical constraints of the electrolyte/electrode interface [22–24]. The impedance method was employed to study the effect of color adsorption on the Al anode and rotation speed (rpm) of the electrode on electrode passivity. The electrolyte was real textile effluence, and the potential of 0 V vs. Ag/AgCl, and frequency ranging from 0.01 to 10^5 Hz, was used for performance evaluation of the electrolyte/anode interface. **Figure 3(a)** presents the Nyquist plot for the anode at varying speed of rotation (0, 75, 100 and 150 rpm). Two semicircles were detected at low frequencies and high frequencies. **Figure 3(b)** presents the best fits for the Al electrode impedance spectra. The fitting parameters comprise the solution resistance (R_s) in parallel with a combination of the double-layer capacitance (C_{dl}) and impedance of the faradic reaction. On the other hand, the faradic reaction impedance comprises passivation resistance (R_{ct}), accompanied by adsorption capacitance (C_{ads}) and adsorption resistance (R_{ads}) [25–28]. **Table 5** summarizes the impedance parameters. Temporarily, the first semicircle diameter signifies the values of R_{ct}, and the diameter of the second semicircle signifies the values of R_{ads}.

Parameters	EC rotating anode	EC static electrode	EC-EO static electrode
Materials	Al-Al	Mp Al-Bp Al	Mp Ti-Bp Al
COD removal (%)	97.10	92.60	93.50
TSS removal (%)	98.00	96.40	97.00
Color removal (%)	98.50	96.50	97.50
Initial pH	Natural	6.00	6.00
Conductivity (μS/cm)	2000	1980	1910
Current/volume ratio (A/L)	0.2	0.2	0.2
Surface area/volume ratio (m^2/m^3)	5	12	12
RT (min)	10	90	90
Electrode consumption (kg/m^3)	0.038	0.1	0.087
Energy consumption (kwh/m^3)	0.966	8.49	9.00
Sludge production (kg/m^3)	1.44	3.50	2.88
NaOH (kg/m^3)	No add	1.26	1.20
NaCl (kg/m^3)	No add	0.1	No add
Operation cost (US$/m^3)	0.283	1.76	1.69

Table 4. Comparison of the EC rotating anode with the conventional model static electrode (EC alone and EC-EO) at optimal conditions.

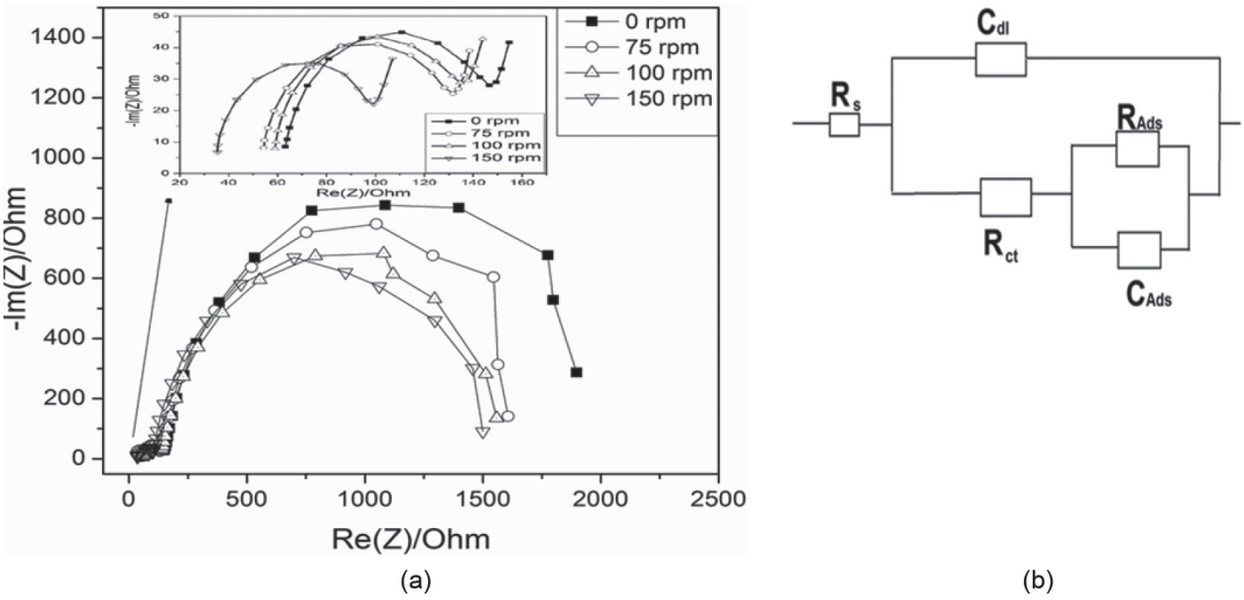

Figure 3. (a) Nyquist plots of the Al anode in an aqueous textile wastewater solution at 25°C temperature and varying electrode speed of rotation. (b) Equivalent circuits utilized to fit the Nyquist plots.

Rotation speed (rpm)	R_s(Ω)	R_{ct}(Ω)	C_{dl}(μF)	R_{ads} (Ω)	C_{ads}(μF)
0	63.30	96.98	0.128	1774	7.18
75	56.90	88.89	0.129	1531	7.36
100	59. 08	90.00	0.145	1369	7.13
150	40.54	41.65	0.412	1151	8.31

Table 5. Electrochemical impedance data extracted from the Nyquist plots at varying speed of rotation (rpm).

From **Table 5** and **Figure 3(a)**, it is clear that the values of R_{ct} and R_{ads} significantly declined with a rise in the rotation speed of the Al anode from 0 attaining the lowest value at 150 rpm. Therefore, the fouling rate of the anode was lessened, and the rate of adsorption of color to the interface of the anode increased at 150 rpm. Conversely, the highest values of the adsorption capacitance and double-layer capacitance were observed at 150 rpm. This elucidates the improvement in the rate of removal upon rotating the anode at 150 rpm as the EC experiment proceeds. It also confirms that the designed model can be a panacea to the limitation of the previous model.

4. Conclusions

The use of novel EC reactor in textile wastewater treatment exhibits a higher removal efficiency than the erstwhile models. The efficiency of the textile effluence pollutant removal with high values was achieved using a lower CD, precisely 4 mA/cm^2, at initial reaction period (10 min) at 1 cm interelectrode distance (IED) and 150 rpm anode rotation speed. A rise in the value of CD enhanced the efficiency of EC process in the treatment of textile wastewater. The setting of the

solution pH to increase the solution temperature and the addition of any chemicals (Na_2SO_4 or NaCl) is not required. The economic viability of the operation of the reactor is influenced by the parameters. The energy and electrode consumption of the EC increases as the CD increases. The optimal energy and electrode consumptions were 0.038 kg/m^3 and 0.966 kWh/m^3, which led to the lower cost of operation (0.283US$/m^3). The novel EC reactor with rotating anode significantly enhanced the textile wastewater treatment by improving the pollutant removal rate, reducing reaction time of treatment, without any additional chemicals during the process, and reducing the operation cost compared to conventional model (EC and EC-EO). It was found that the passivation phenomenon reduced with the increased rotation speed of anode, which enhanced the EC process performance and validated the novel reactor design.

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Conflict of interest

The authors whose names are listed in the beginning of this chapter certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership or other equity interest; and expert testimony or patent-licensing arrangements) or nonfinancial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) on the subject matter or materials discussed in this manuscript.

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