FMDB *Transactions on Sustainable Applied Sciences*

Performance Evaluation of Electrocoagulation for Treating Imperon Violet KB-Contaminated Textile Wastewater

Ahmed Samir Naje[1,*], Ghazi Faisal Naser[2], Isra'a Sadi Samaka[3], Zaid Abed Al-Ridah[4], Hussein A. M. Al-Zubaidi[5], Zaid Gaber Ghaib[6]

[1,6]Department of Water Resources Engineering Management, College of Engineering, Al-Qasim Green University, Al-Qasim, Babylon, Iraq.
[2]Department of Chemical Engineering, College of Engineering, Al-Muthanna University, Samawah, Al-Muthanna, Iraq.
[4]Department of Civil Engineering, College of Engineering, Al-Qasim Green University, Al-Qasim, Babylon, Iraq.
[3,5]Department of Environmental Engineering, College of Engineering, University of Babylon, Al-Hillah, Babylon, Iraq.
ahmednamesamir@gmail.com[1], ghazifaisal84@yahoo.com[2], israasadienv@gmail.com[3], zaidabedreda79@gmail.com[4], alzubaidihussein@gmail.com[5], zaydjaber1@gmail.com[6]

Abstract: The textile industries in the Baghdad governorate's wastewater discharges have been found to contain Imperon Violet KB dye. The objective of this research is to examine the electrocoagulation degradation of the textile dye Imperon Violet KB in an aqueous solution with an initial concentration of 100 mg/L. Researchers looked into how EC operational factors like current density, touch time, pH, initial dye concentration, and electrolysis support affected the process. The best results occur when the current density is 1.43 mA/cm2, the time is 20 minutes, and the primary pH is 6. The removal rates for colour, turbidity, and COD were 95%, 99.5%, and 85%, respectively. The final pH changes with the original pH, while the current density remains the same, and the passage time changes. The efficiency of colour removal decreases as the initial concentration increases. Using NaCl as an electrolyte aid improved conductivity and voltage. The colour removal rate is 95.5% at a NaCl concentration of 1.6 g/L. The kinetic analysis showed that the dye breaks down according to a second-order rate equation.

Keywords: Imperon Violet KB; Electrocoagulation Degradation; Iron Electrodes; Kinetic Study; Wastewater Discharges; Chemical Coagulation; Chemical Treatment Systems; Contaminated Water.

Received on: 23/07/2024, **Revised on:** 10/10/2024, **Accepted on:** 27/02/2025, **Published on:** 05/12/2025

Journal Homepage: https://www.fmdbpub.com/user/journals/details/FTSASS

DOI: https://doi.org/10.69888/FTSASS.2025.000571

Cite as: A. S. Naje, G. F. Naser, I. S. Samaka, Z. A. Al-Ridah, H. A. M. Al-Zubaidi, and Z. G. Ghaib, "Performance Evaluation of Electrocoagulation for Treating Imperon Violet KB-Contaminated Textile Wastewater," *FMDB Transactions on Sustainable Applied Sciences*, vol. 2, no. 2, pp. 117–127, 2025.

1. Introduction

Industrialisation has led to a rapid increase in the discharge of coloured, chemically complex waste into natural bodies of water, posing a significant threat to the environment and public health worldwide. Numerous colouring agents found in wastewater from industries such as textiles, leather processing, plastics, paper production, fruit processing, and cosmetics manufacturing

---

[*] Corresponding author.

are recognised as toxic, carcinogenic, and mutagenic. Some synthetic dyes are not only toxic over time, but they can also cause short-term reactions in people who come into contact with contaminated water, such as allergies, dermatitis, and skin irritation [15]. Dye-laden wastewater not only has direct health effects but also causes severe aesthetic pollution and reduces light penetration into aquatic ecosystems. This affects photosynthesis, the balance of dissolved oxygen, and the overall stability of rivers, lakes, and reservoirs [21]. Wastewater from the finishing and dyeing stages of the garment and textile industries is particularly problematic because it contains a wide range of organic dyes, suspended solids, surfactants, salts, and chemical additives that do not readily break down in nature. Because of this, wastewater must be properly treated before release into the environment to meet regulatory limits and avoid long-term environmental damage. Chemical coagulation and other traditional physicochemical treatment methods are commonly used to remove colour and turbidity. However, these methods often require a large amount of coagulant chemicals, which can cause secondary toxicity and produce excessive sludge that must be disposed of properly. Adding chemicals in large amounts can also increase operational costs and leave contaminants in treated water, making conventional treatment processes less sustainable. In this context, electrochemical coagulation (EC) has emerged as a promising, environmentally friendly alternative that addresses many of the challenges posed by chemical treatment systems. The EC process uses simple, compact equipment, is easy to use, has a short reaction or retention time, requires few or no external chemicals, and produces much less sludge than traditional coagulation methods [11].

These benefits make EC a promising technology for cleaning up industrial wastewater, especially in industries where coloured effluents and high chemical oxygen demand (COD) are the main signs of pollution. To achieve the best performance from EC and ensure treatment is always effective, you need a good grasp of the electrochemical processes that control pollutant removal. One of the biggest problems in wastewater treatment is removing dissolved ionic species, such as heavy metal ions and charged organic molecules. These species can stay stable in water and are hard to separate using simple sedimentation or filtration methods [17]. The EC system meets this challenge by using electro-dissolution of sacrificial metal anodes, typically aluminium or iron, to generate coagulant species on-site. During electrolysis, several physicochemical reactions occur simultaneously. These include oxidation at the anode, reduction at the cathode, the formation of metal hydroxide complexes in the bulk solution, the adsorption of pollutants onto these complexes, and finally, the separation of the pollutants through sedimentation or flotation [16]; [18]. These stages, which occur one after the other but remain connected, are the basic way EC technology works. Aluminium or iron atoms at the electrode interface release metal ions into the solution. These ions then react with hydroxide ions produced when water is reduced at the cathode, forming amorphous metal hydroxide flocs. These hydroxide species have a large surface area and a strong adsorption capacity, enabling them to trap dissolved dyes, suspended particles, colloidal impurities, and organic molecules that contribute to COD. When destabilised particles come together, they form larger flocs that can either settle under gravity or float due to the tiny hydrogen bubbles that form at the cathode. The flotation phenomenon improves the efficiency of pollutant separation because gas bubbles that attach to the floc reduce its density, moving contaminants toward the liquid surface, where they can be easily removed.

At the same time, polymeric metal hydroxo complexes formed during electrode reactions offer additional pathways for adsorbing and neutralising charge, making it even easier to remove contaminants [14]. C technology has been successfully used to treat a wide range of industrial wastewater, not just textile effluents. These include wastewater from food processing, metal finishing, oil refineries, pulp and paper industries, and municipal sources. EC is very useful in integrated wastewater management systems because it can simultaneously reduce turbidity, colour intensity, suspended solids, heavy metals, and organic load. Also, not having to dose chemicals externally reduces the risk of secondary pollution and makes it easier to handle sludge. Compared to chemically generated sludge, EC-generated sludge is usually denser, more stable, and takes up less space. This means lower disposal costs and better environmental sustainability. Current density, electrode spacing, pH, treatment time, conductivity, and electrode material composition are all operational parameters that significantly affect EC efficiency. This means that different types of wastewater need to be optimised systematically. Kinetic analysis is very important for assessing how well EC works because it provides numbers on reaction rates, pollutant removal, and energy use. Researchers can design better reactors for scale-up by determining whether removal follows first-order, second-order, or diffusion-controlled kinetics. In the industry, treatment systems have to find a balance between how well they remove waste and how much they cost to run. This is why kinetic modelling is so important for figuring out how long treatment will take and how much electricity it will use. Additionally, kinetic studies elucidate the comparative roles of adsorption, coagulation, flotation, and electrochemical oxidation processes occurring concurrently in EC reactors.

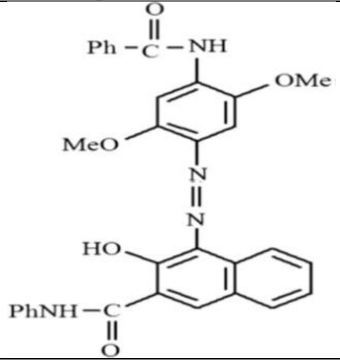
This kind of knowledge helps develop more effective hybrid treatment systems that combine EC with filtration, membrane separation, or biological polishing to enhance purification. Even though there has been significant progress in EC research, it is still hard to translate laboratory results into full-scale industrial applications. Long-term system reliability can be affected by electrode passivation, energy use, changes in wastewater composition, and the need for regular maintenance. To maintain steady coagulant generation and pollutant removal, electrical parameters need to be continuously monitored and adjusted. Improvements in the engineering of electrode materials, reactor design, and the use of renewable energy are likely to make EC even more sustainable and cost-effective. Furthermore, integrating EC with real-time sensing and automation technologies could facilitate adaptive control of treatment conditions, guaranteeing optimal performance amidst varying industrial discharge loads [20]. The current study aims to assess the efficacy of electrochemical coagulation for eliminating turbidity, colour, and chemical oxygen demand from industrial wastewater, while conducting an extensive kinetic analysis. The study seeks to elucidate reaction mechanisms, establish optimal treatment conditions, and evaluate the viability of electrocoagulation (EC) as a dependable large-scale treatment technology by examining pollutant removal efficiency across diverse operational parameters. The results are expected to help the broader field of sustainable wastewater management by showing how electrochemical processes can reduce pollution, reduce chemical use, and improve water quality before it is released or reused. In the end, effective EC-based treatment methods could help protect aquatic ecosystems, keep people healthy, and support environmentally friendly industrial growth in areas where the economy and manufacturing are expanding rapidly.

2. Materials and Method

2.1. Wastewater Characteristics

The textile dye (Imperon Violet KB) was used at the Baghdad textile factory and supplied to us by the Baghdad cotton gabardine production unit (Table 1).

Table 1: Characteristics of dye and chemical structure

Commercial Name	Imperon Violet KB
Chemical Structure	
Color Type	CAS Number of 6358-46-9
Appearance	Fine Powder
Molecular Formula	$C_{32}H_{26}N_4O_5$
Molecular Weight (g/mol)	546.57264
Color	Violet
Common Name	2-Naphthalenecarboxamide
CAS Number	6358-46-9

The State Company for Textile and Leather Industries, which is based in Baghdad, Iraq, owns and operates this factory (Table 2). Chemicals are manufactured by the company Merck (Darmstadt, Germany).

Table 2: Initial dye solutions features

Feature	Value
λmax (nm)	533
Conductivity (μS/cm)	739
Turbidity (NTU)	320
COD (mg/L)	353
pH	7.4

2.2. Setup of Experiment

The EC experiments are carried out using aqueous solutions of a textile dye (Imperon Violet KB) found in wastewater discharges from the Baghdad textile complex. The experiment used a reactor with measurements of 20 cm width, 15 cm length, and 15 cm depth, as seen in Figure 1. The treatment water volume for each run was 4.5 L. With monopolar link anodes and cathodes, six iron plates were wired in series with the main power supply. Both the anode and cathode plates had 10 × 10 cm2 electrodes, 0.1 cm thick, with a 1 cm inter-electrode distance. Each electrode has a surface area of 100 cm2. After being collected, the electrodes were immersed in salt water. The anode and cathode groups are connected to the negative and positive terminals of the DC power supply. A magnetic field regulated the stirring speed. In the current study, a YIZHAN DC power supply with a voltage range of 0-40V and a current range of 0-6 A was used. At each run, the voltage was set to 12 V while the Fe electrodes were present, and the stirring speed was set to 400rpm. The tests were carried out at room temperature with an initial pH of 7.4. The dye concentration is initially 100 mg/L, and the sample volume is 250ml, of which 0.2g to 0.8g/L of NaCl is applied to improve the solution's electrical conductivity. The current is set to the optimal value during the chosen electrolysis period at the start of each EC test. The electrodes are immersed in 0.1 M HCl for 5 minutes after each test and then rinsed with acetone and purified water. After the experiment, the solution is allowed to stabilise for 12 hours before purification. A scale (Denver Instrument, Germany) is used to measure the chemicals. 0.1N NaOH or 0.1M H_2SO_4 is used to adjust the pH, which is then calibrated with a pH meter (HANNA HI, 2215). With the (AQUALYTIC AL 450T-IR) turbidimeter, the turbidity was calculated. A (CONSORT C 3010) conductivity meter was used to determine conductivity. The COD calculations followed the American Public Health Association [4] standard scheme. A UV-Vis spectrophotometer (ANALYTIKJENA Specord 210 plus, Germany) was used to monitor colour removal after the operation, and the residual dye concentration was calculated from a calibration curve with a maximum at 533nm. The efficiencies of turbidity, colour, and COD removal were measured using the calculations from previous [1].

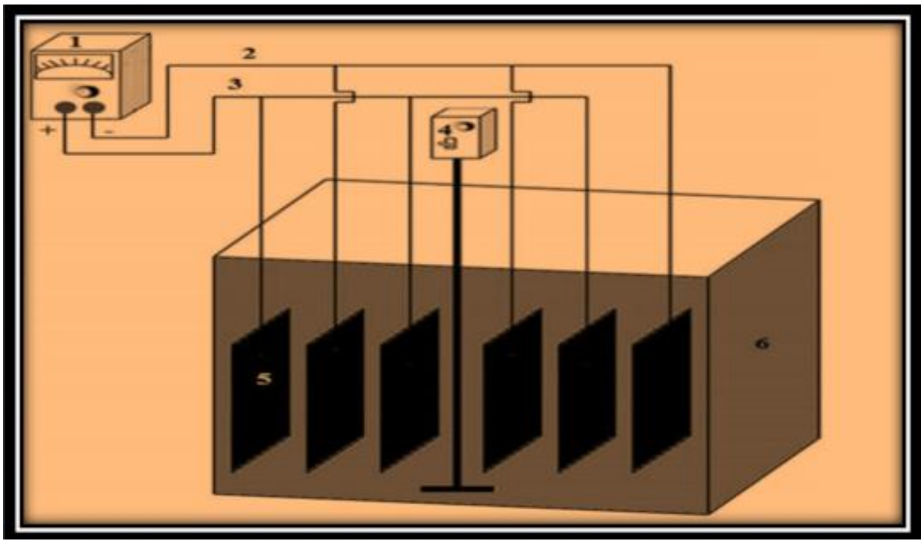


Figure 1: Experimental configuration with monopolar mode connection in parallel: (1) DC power supply; (2) Cathode; (3) Anode; (4) Mechanical stirrer; (5) Iron electrodes; (6) EC reactor

3. Results and Discussion

3.1. Effect of Current Density and Passage Time

In EC, current density is a critical parameter, particularly for the kinetics of fading abatement [18]. As seen in Figure 2, the same process efficiency can be achieved by reducing the electrolysis time and increasing the current density. With a 15-minute electrolysis period and a current density of 1.67 mA/cm^2, the efficiency is 91%; with a 25-minute electrolysis period and a current density of 1.19 mA/cm2, the efficiency is 91%. These results are consistent with previous research, which shows that as current density decreases, the time required to achieve the same efficiency increases. Likewise, rising current density improves removal efficiency for a given electrolysis time. Thus, at a current density of 1.19mA/cm^2 and a 15-minute electrolysis time, the efficiency is 80%. As seen in Figure 3, with a current density of 1.67 mA/cm2 and a contact time of 15 min, the efficiency is 91%. This fact has been explained by several studies [12]; [13]; [3]. Experiments have shown that the colour solution gradually becomes transparent at the start of the EC, which is attributed to the oxidation of organic molecules and the neutralisation of ionic compounds by the coagulant cations [2]; [5]. A plateau in the current density is observed after the desired time, indicating that the method has reached its optimal productivity. For a constant current density of 1.43 mA/cm2, Figure 3 indicates an improvement in turbidity removal rate as a function of time (1 to 25min). The solution was fully clarified in 10 minutes, with a 99.8% reduction in turbidity. For 20 minutes, however, the colour removal efficiency and COD abatement rate were 91% and 83%, respectively. The rate of COD reduction is lower than the rate of dye colour loss. Similar findings have been reported in the literature. This could indicate that a fraction of the dye is electrochemically oxidised, as its colour is removed during the EC process.

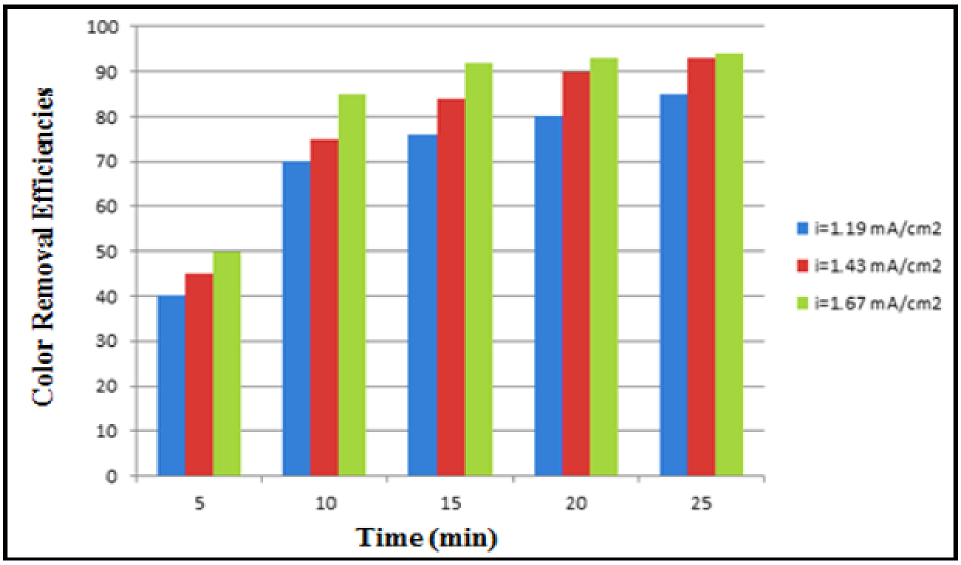


Figure 2: Color removal efficiencies with conditions: conductivity= 1620µS/cm, pH $_{\text{initial}}$ = 7.4, C_0= 100mg/L and rpm= 400

The azo bond of the dye may be broken by electrochemical oxidation, but the degradation of the aromatic rings is unaffected [19]. This ensures that a small amount of pollutant or EC by-products remains in the water. A plateau is found after the optimum times have passed.

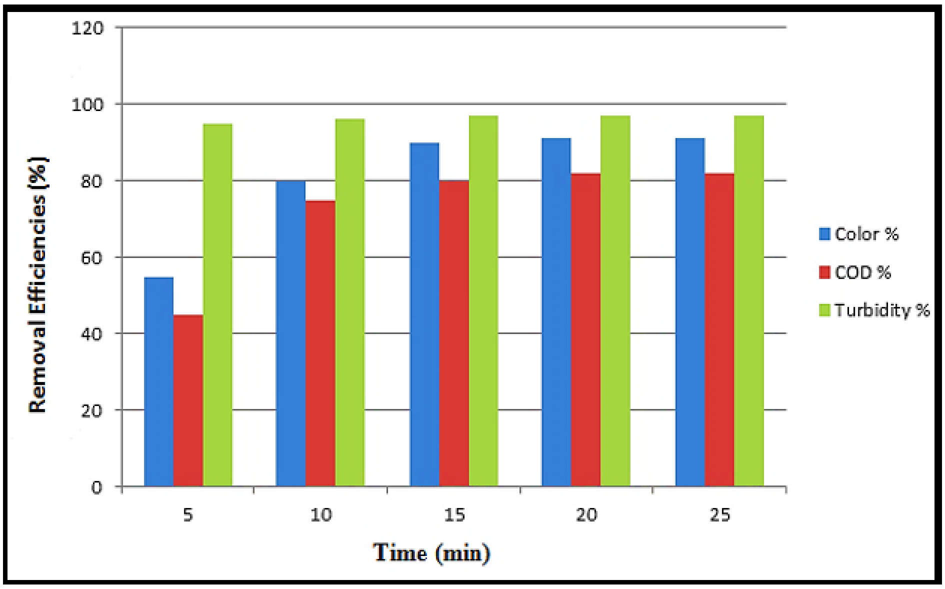


Figure 3: Efficiencies of turbidity, colour, and COD removal under conditions: i= 1.43mA/cm^2, conductivity= 1620µS/cm, pH $_{\text{initial}}$ = 6, C_0= 100mg/L, and rpm= 400

3.2. Effect of Initial pH

The initial pH is considered one of the major determinants of EC efficiency [6]; [14]. For various initial pHs, the effect of time on the evolution of final pH and colour removal has been investigated. Figure 4 shows the progression of colour removal efficiency at the initial pHs (2.5, 4.5, 6, and 8). At a current density of 1.43 mA/cm2 and a period of 20 minutes, the efficiencies obtained are 90% and 91%, respectively, for initial pH values of 4.5 and 6. Given the initial pHs, the nature of the pollutant, and the predominance diagram of the $Al(OH)_{3S}$ precipitate, which governs pollutant adsorption as a function of pH, the differences in colour removal efficiency between the four original pHs tested have been verified [22].

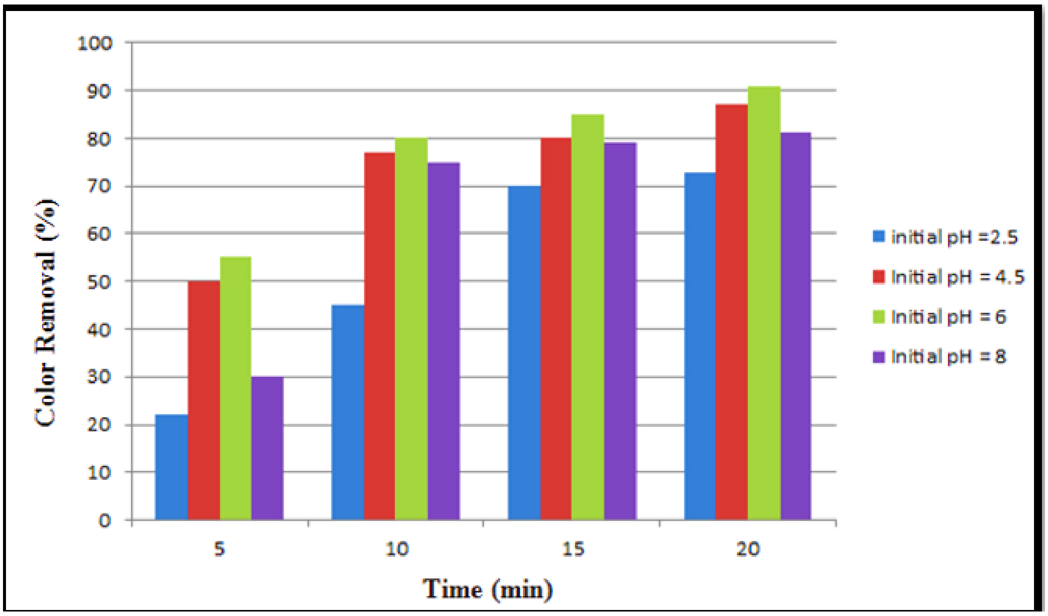


Figure 4: Efficiencies of color removal under conditions: i= 1.43mA/cm^2, conductivity =1620µS/cm, C_0= 100mg/L and rpm= 400

The Al (OH)3S precipitate becomes active at pH 4-9. This pH spectrum includes the original optimum pH of 6. The scale of hydrogen bubbles, on the other hand, is heavily influenced by pH.

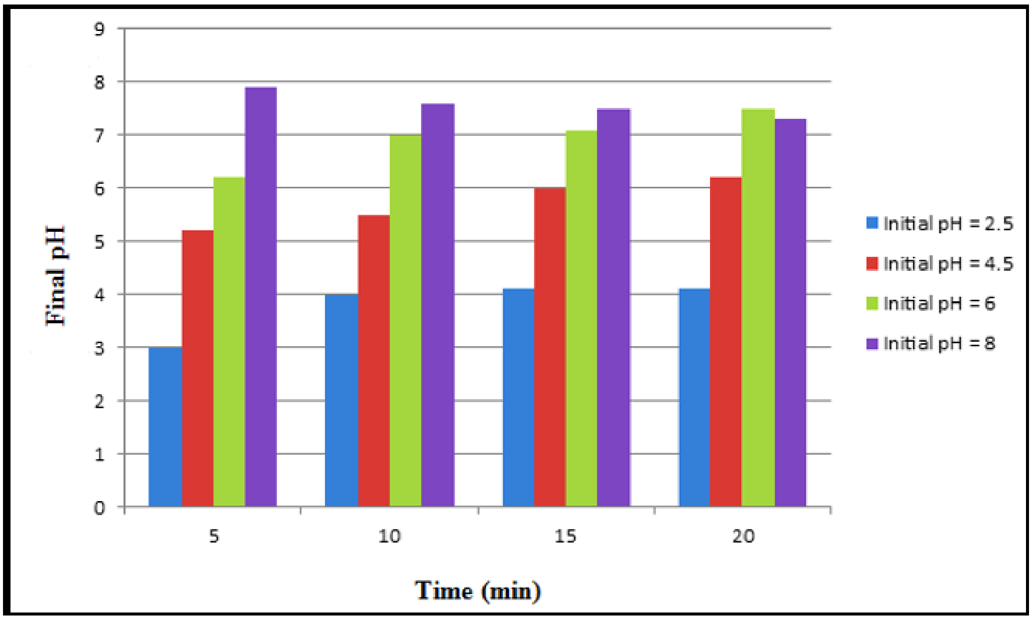


Figure 5: Final pH values as a function of the initial pH under conditions: i= 1.43mA/cm^2, C_0= 100mg/L, conductivity = 1620µS/cm, and rpm= 400

Figure 5 depicts the progression of the final pH over time at a present density of (1.43mA/cm2), with initial pHs of 2.5, 4.5, 6, and 8, and times ranging from 1 to 20 minutes. However, it's worth noting that pH fluctuates during EC. For acidic initial pHs of 2.5, 4.5, and 6, respectively, the final pH increased from 2.68 to 4.49, 4.5 to 6.36, and 6.04 to 7.4, with a marginal decrease from 7.98 to 7.59 for a weakly basic initial pH of 8. As seen in Figure 6, the final pH varies with increasing current density during EC, as reported in the literature. This is because a rise in current density generates a large amount of OH-, given an initial pH of 6. In fact, times ranging from 1 to 20 minutes and a final pH ranging from (6.12 to 7.54), (6.04 to 7.4), and (6.01 to 7.2) for current densities of (1.67, 1.43, and 1.19 mA/cm2) have been observed, respectively.

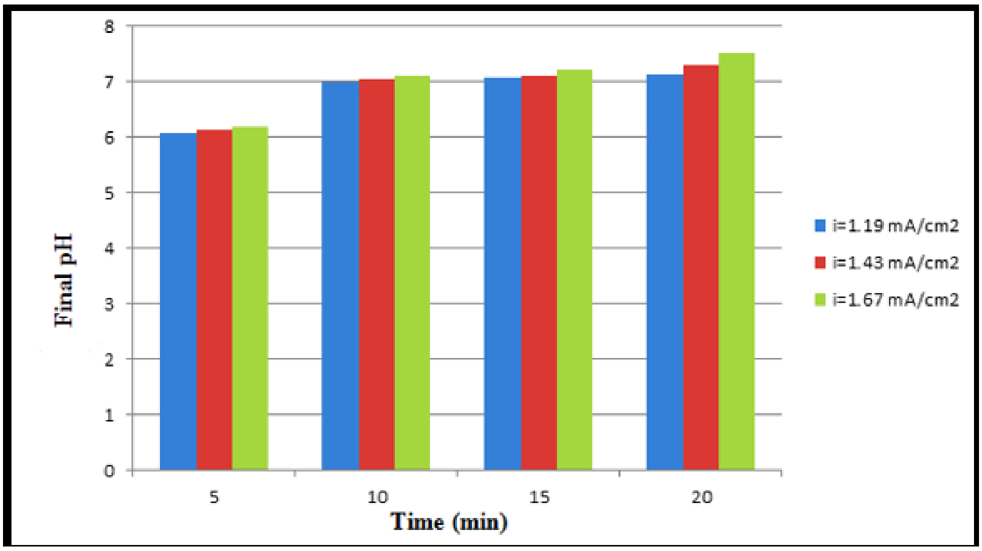


Figure 6: Final pH values as a function of the current density under conditions: initial pHi= 6, C_0= 100mg/L, Conductivity = 1620µS/cm, and rpm= 400

Figure 7 illustrates the evolution of turbidity, colour elimination, and COD as a function of initial pH from 5 to 10 at a current density of 1.43 mA/cm2 and a time of 20 min. Turbidity, colour reduction, and COD yields were 99.8%, 91%, and 84%, respectively, at the optimum initial pH of 6. At an initial pH of 10, yields are reduced by 72, 60, and 45 per cent for turbidity, colour, and COD removal, respectively. According to the literature, this is attributed to the formation of the soluble species Al(OH)4- at the expense of the precipitate Al(OH)3S [14]; [10].

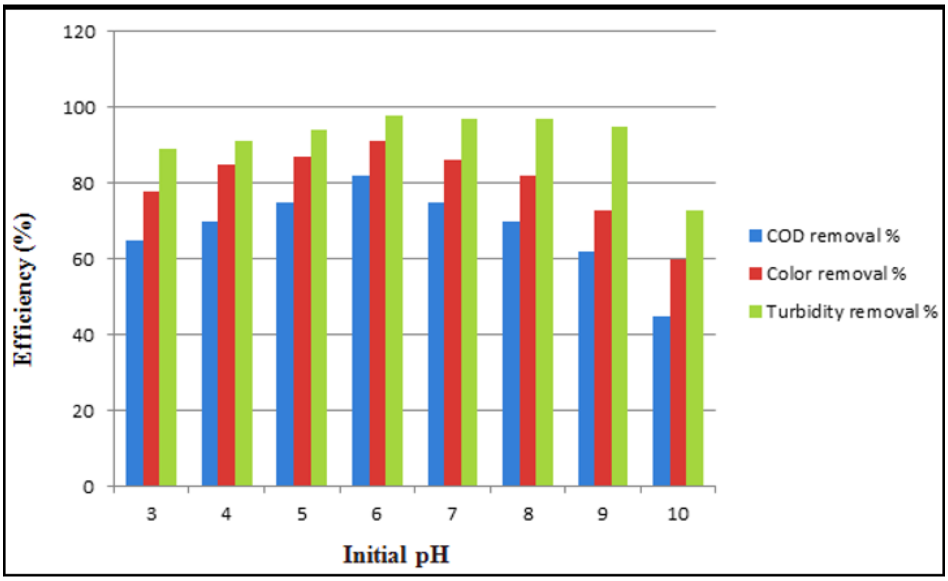


Figure 7: Turbidity, colour, and COD removal with initial pH under conditions: contact time=20min, i= 1.43mA/cm^2, conductivity =1620µS/cm, C_0= 100mg/L, and rpm= 400

3.3. Effect of Colour Initial Concentration

The concentration of residual colour was studied at the initial concentrations (50, 100, 150, 200, 250, and 300 mg/L) under optimal conditions (1.43 mA/cm2 current density and pH 6 at the initial time). By varying the time from 1 to 45 minutes, it can be seen that the residual concentration decreases as the initial concentration increases. The volume of dissolved aluminium ions at the anode is the same for all concentrations of dyes for a given current density and electrolysis duration. A specific number of aluminium hydroxide complexes are fixed in the solution. As such, the flocks are unable to take in the large number of chemical molecules needed; this will necessitate additional time. The remaining concentrations at 20 minutes for the original concentrations of 100 and 300 mg/L are 9 and 50 mg/L, respectively. For a starting concentration of 300 mg/L, the minimum concentration achieved after 40 minutes is 29 mg/L. Clear water was harvested at the same location and under the same conditions as before, with a range of 50-200 mg/L.

3.4. Effect of NaCl Addition

Due to the decrease in resistance of the contaminated water, increasing conductivity by inserting sodium chloride is known to minimise the potential (U) between the electrodes at a steady current density [7]. Chloride ions may also be oxidised to produce activated chlorine, such as hypochlorite anions, which have a strong oxidising capacity toward dyestuffs. The anode's iron plate is attacked by an abnormal concentration of NaCl [8]. The reduction in colour removal is due to a shift in ionic strength resulting from changes in the medium's conductivity [14]. The kinetics and equilibrium of reactions between species exchanged during EC are influenced by ionic strength. For a concentration of 1.6g/L NaCl, a period of 20 minutes, and a current density of 1.43mA/cm^2, the maximum rate of colour removal is on the order of 91.5 per cent. To investigate voltage as a function of conductivity, the experimental voltage and conductivity values are used to quantify voltage using two models. Eq. 1 shows the relationship between cell voltage and current density in the case of unpassivated iron electrodes [9]:

$$U = -0.76 + \frac{e}{k} i + 0.2 \mathrm{Ln} i \qquad (1)$$

The deviation between the experimental and Chen models is extremely high. The following model is used to make the equations. The following empirical equation was used to calculate the initial voltage after the addition of NaCl:

$$U = 0.1 + \frac{e.i}{К} + 0.2 \mathrm{Ln} i \qquad (2)$$

Where:

- **e:** Distance between Electrodes (m)
- **i:** Current Density (A/m^2)
- **U:** Potential of EC (V)
- **К:** Conductivity (S/m)

The potential U is inversely proportional to the solution's conductivity, as given by Eq. 2, which has been validated in practice. Figure 8 compares the experimental values of initial U measured after the addition of various initial concentrations of NaCl (e = 1 cm, i = 1.43 mA/cm^2) with those calculated using the equation. It can be shown that the differences between the model and experimental values are most likely caused by iron passivation.

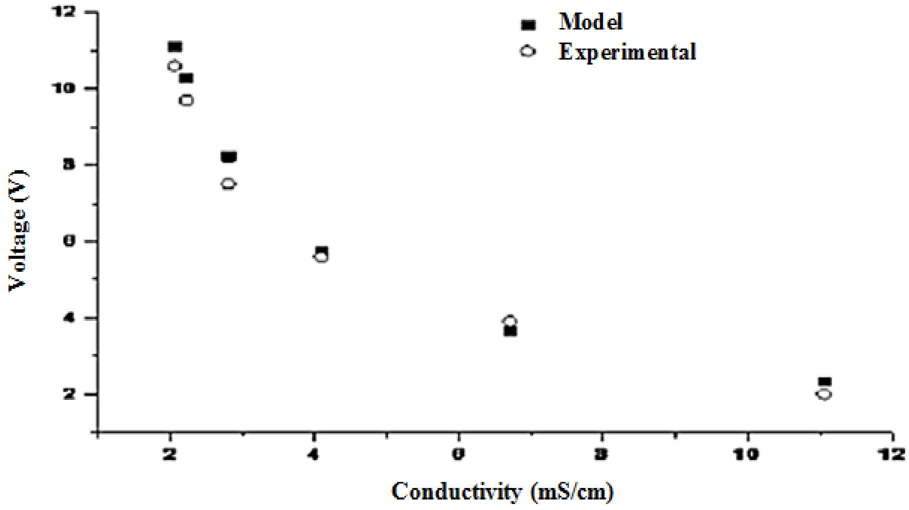


Figure 8: Variation of voltage (V) with conductivity (mS/cm) for the model and experimental

3.5. Kinetic Study

Figure 9 shows the effect of reaction time on dye removal at various initial concentrations. The second-order kinetic model according to Equation 3:

$$\frac{1}{C_t} - \frac{1}{C_0} = kt \qquad (3)$$

Where C_t, C_0, and k are the dye concentrations at any time t, the initial dye concentration, and the kinetic constant, respectively.

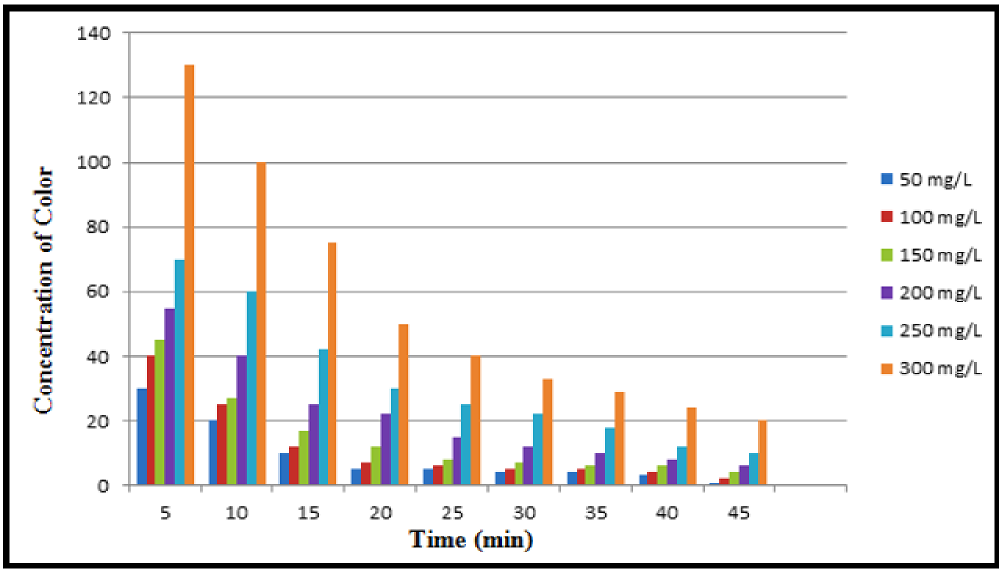


Figure 9: Reduction of Imperon Violet KB concentrations under conditions: i= 1.43mA/cm^2, pHi= 6, conductivity = 1620µS/cm, and rpm= 400

Figure 10 shows line graphs of (1/C_t - 1/C_0) = f(t) for various initial dye concentrations (50 to 300 mg/L), followed by 45 minutes at an initial pH of 6 and an applied current density of 1.43 mA/cm2. The reaction rate follows second-order kinetics, with values ranging from 0.0008 to 0.0116 (mg/L)- 1/min as the original dye concentration decreases from 300 to 50 mg/L. All of the regression coefficients are greater than 0.99. Table 2 shows the outcome values of the rate constant k and the regression coefficient R^2.

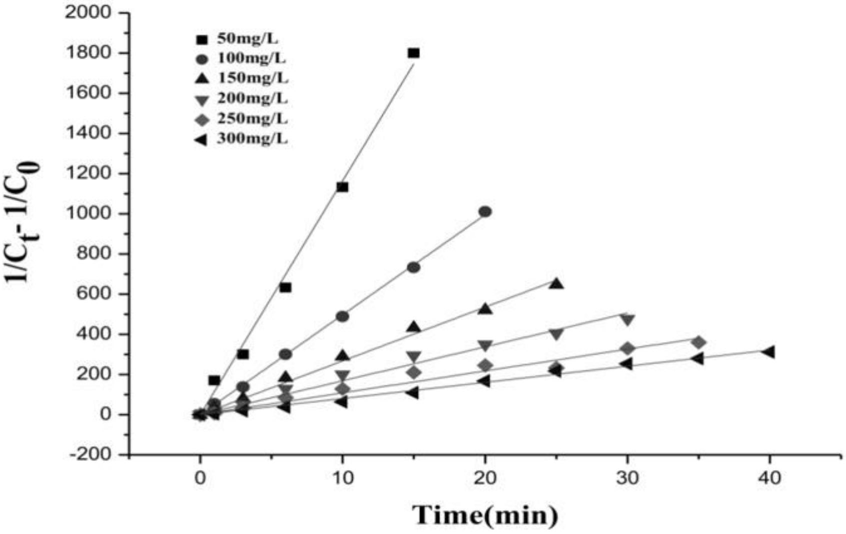


Figure 10: Kinetic constants for the concentrations of Imperon Violet KB under conditions: i= 1.43mA/cm^2, initial pH= 6, conductivity = 1620µS/cm, and rpm= 400

The results of the kinetic study show that the rate constant (K) decreases as the initial concentration (C_0) increases from 50 to 300 mg/L. This means that reactions happen more slowly at higher concentrations. The high R² values (0.991–0.9996) indicate that the kinetic model fits the measured concentrations well (Table 3).

Table 3: Results of kinetic study

C_0 (mg/L)	50	100	150	200	250	300
K (mg/L)$^{-1}$/ min	0.0116	0.0049	0.0027	0.0017	0.0011	0.0008
R^2	0.9968	0.9996	0.9969	0.991	0.9948	0.9964

4. Conclusion

When used with the dye solution for Imperon Violet KB, the EC method showed 99.8% efficiency in lowering turbidity, 91% in reducing colour, and 83% in reducing COD, compared to other methods. The current density is 1.43 milliamperes per square centimetre, the contact period is twenty minutes, the pH is six, and the conductivity is sixteen hundred and twenty volts per centimetre. When it comes to the chemical composition of aqueous solutions used to print on cloth, these are the ideal conditions. It was determined that the conclusion was successful because the EC demonstrated its effectiveness and dependability. It achieved a nearly 100% reduction in turbidity in just 10 minutes, compared to 20 minutes. Whenever the initial pH was lower than 7, the end pH was lower than the original pH. This showed that the effectiveness of the colour removal process decreases as the initial concentration increases from 50 to 300 millilitres. An additional 1.6 grammes of L are required to achieve the maximum possible colour reduction of 91.5%. To analyse the decrease in textile dye concentrations, a second-order kinetic law is used.

Acknowledgement: The authors gratefully acknowledge the support and facilities provided by Al-Qasim Green University, Al-Muthanna University, and the University of Babylon for the successful completion of this research. All authors sincerely appreciate the collaborative efforts and academic environment of these institutions.

Data Availability Statement: Data supporting the results of this study are available from the authors upon a justified request. The authors ensure transparency while maintaining participant confidentiality.

Funding Statement: This work was supported by research grants and institutional funding obtained by the authors. The funders played no role in the design, execution, or reporting of the study.

Conflicts of Interest Statement: All authors declare that they have no known competing financial or personal interests that could have influenced the work reported in this manuscript. Proper acknowledgment of all sources has been ensured.

Ethics and Consent Statement: Before the commencement of the study, necessary ethical clearance was obtained in accordance with applicable institutional and international guidelines. Where relevant, informed consent was secured from participating individuals and organisations, and all authors affirm adherence to ethical research practices.

References

1. R. K. Verma and S. Kumar, "Intensification of electrocoagulation treatment of simulated tannery wastewater using rotating electrodes: Parametric, isotherms, kinetic and techno-economic studies," *Chemical Engineering and Processing – Process Intensification*, vol. 209, no. 3, p. 110150, 2025.
2. N. Adhoum and L. Monser, "Decolourization and removal of phenolic compound from olive mill wastewaters by electrocoagulation," *Chemical Engineering and Processing*, vol. 43, no. 10, pp. 1281–1287, 2004.
3. R. Ahlawat, V. C. Srivastava, I. D. Mall, and S. Sinha, "Investigation of the electrocoagulation treatment of cotton blue dye solution using aluminium electrodes," *Clean – Soil, Air, Water*, vol. 36, no. 10–11, pp. 863–869, 2009.
4. American Public Health Association, "Standard Methods for the Examination of Water and Wastewater," 20th ed. *American Public Health Association*, Washington, District of Columbia, United States of America, 2000.
5. N. Assas, L. Ayed, and A. Marouani, "Decolorization of fresh and stored black olive mill wastewater by Geotrichum candidum," *Process Biochemistry*, vol. 38, no. 3, pp. 361–365, 2002.
6. M. Bayramoglu, M. Eyvaz, and M. Kobya, "Treatment of the textile wastewater by electrocoagulation: Economical evaluation," *Chemical Engineering Journal*, vol. 128, no. 2–3, pp. 155–161, 2007.
7. M. Bayramoglu, M. Kobya, O. T. Can, and M. Sozbir, "Operating cost analysis of electrocoagulation of textile dye wastewater," *Separation and Purification Technology*, vol. 37, no. 2, pp. 117–125, 2004.
8. L. S. Calvo, J. P. Leclerc, G. Tanguay, M. C. Cames, G. Paternotte, R. A. Valentin, and F. Lapicque, "An electrocoagulation unit for the purification of soluble oil wastes of high COD," *Environmental Progress*, vol. 22, no. 1, pp. 57–65, 2003.
9. X. Chen, G. Chen, and P. L. Yue, "Investigation on the electrolysis voltage of electrocoagulation," *Chemical Engineering Science*, vol. 57, no. 13, pp. 2449–2455, 2002.

10. G. Chen, “Electrochemical technologies in wastewater treatment,” *Separation and Purification Technology*, vol. 38, no. 1, pp. 11–41, 2004.
11. N. Daneshvar, A. Oladegaragoze, and N. Djafarzadeh, “Decolorization of basic dye solutions by electrocoagulation: An investigation of the effect of operational parameters,” *Journal of Hazardous Materials*, vol. 129, no. 1–3, pp. 116–122, 2006.
12. P. K. Holt, G. W. Barton, and C. A. Mitchell, “The future of electrocoagulation as a localized water treatment technology,” *Chemosphere*, vol. 59, no. 3, pp. 355–367, 2005.
13. N. K. Khosla, S. Venkachalam, and P. Sonrasundaram, “Pulsed electrogeneration of bubbles for electroflotation,” *Journal of Applied Electrochemistry*, vol. 21, no. 11, pp. 986–990, 1991.
14. M. Kobya, E. Demirbas, O. T. Can, and M. Bayramoglu, “Treatment of Levafix orange textile dye solution by electrocoagulation,” *Journal of Hazardous Materials*, vol. 132, no. 2–3, pp. 183–188, 2006.
15. A. S. Koparal, Y. S. Yildiz, B. Keskinler, and N. Demircioglu, “Effect of initial pH on the removal of humic substances from wastewater by electrocoagulation,” *Separation and Purification Technology*, vol. 59, no. 2, pp. 175–182, 2008.
16. C. A. Martínez-Huitle and S. Ferro, “Electrochemical oxidation of organic pollutants for wastewater treatment: Direct and indirect processes,” *Chemical Society Reviews*, vol. 35, no. 12, pp. 1324–1340, 2006.
17. M. Y. A. Mollah, R. Schennach, J. R. Parga, and D. L. Cocke, “Electrocoagulation (EC): Science and applications,” *Journal of Hazardous Materials*, vol. 84, no. 1, pp. 29–41, 2001.
18. M. Y. A. Mollah, S. R. Pathak, P. K. Patil, M. Vayuvegula, T. S. Agrawal, J. A. G. Gomes, M. Kesmez, and D. L. Cocke, “Treatment of Orange II azo-dye by electrocoagulation (EC) technique in a continuous flow cell using sacrificial iron electrodes,” *Journal of Hazardous Materials*, vol. 109, no. 1–3, pp. 165–171, 2004.
19. J. B. Parsa, H. R. Vahidian, A. R. Soleymani, and M. Abbasi, “Removal of Acid Brown 14 in aqueous media by electrocoagulation: Optimization parameters and minimizing of energy consumption,” *Desalination*, vol. 278, no. 1–3, pp. 295–302, 2011.
20. X. Chen, G. Chen, and P. L. Yue, “Separation of pollutants from restaurant wastewater by electrocoagulation,” *Separation and Purification Technology*, vol. 19, no. 1–2, pp. 65–76, 2000.
21. Y. Yang, G. Wang, B. Wang, Z. Li, X. Jia, Q. Zhou, and Y. Zhao, “Biosorption of Acid Black 172 and Congo Red from aqueous solution by nonviable Penicillium YW 01: Kinetic study, equilibrium isotherm and artificial neural network modeling,” *Separation and Purification Technology*, vol. 102, no. 2, pp. 828–834, 2011.
22. A. E. Yilmaz, R. Boncukcuoglu, and M. M. Kocakerim, “A quantitative comparison between electrocoagulation and chemical coagulation for boron removal from boron-containing solution,” *Journal of Hazardous Materials*, vol. 149, no. 2, pp. 475–481, 2007.