

A Study on the Removal of Direct Blue 71 Dye From Textile Wastewater Produced From State Company of Cotton Industries by Electrocoagulation Using Aluminum Electrodes

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ABSTRACT

The removal of direct blue 71 dye from a prepared wastewater was studied employing batch electrocoagulation (EC) cell. The electrodes of aluminum were used. The influence of process variables which include initial pH (2.0-12.0), wastewater conductivity (0.8 -12.57) mS/cm , initial dye concentration (30 -210) mg/L, electrolysis time (3-12) min, current density (10-50) mA/cm² were studied in order to maximize the color removal from wastewater. Experimental results showed that the color removal yield increases with increasing pH until pH 6.0 after that it decreased with increasing pH. The color removal increased with increasing current density, wastewater conductivity, electrolysis time, and decreased with increasing the concentration of initial dye. The maximum color removal yield of 96.5% was obtained at pH 6.0, wastewater conductivity 9.28 mS/cm , electrolysis time 6 min ,the concentration of initial dye 60 mg/L and current density 30 mA/cm² .

Key words: blue dye, color removal, electrocoagulation, textile wastewater, water treatment.

دراسة ازالة الصبغة الزرقاء 71 الناتجة من مياه الصرف النسيجي للشركة العامة للصناعات القطنية بطريقة التخثير الكهربائي وباستخدام اقطاب الالمنيوم

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مدرس

قسم الصناعات الكيماوية – معهد التكنولوجيا/ بغداد – الجامعة التقنية الوسطى

الخلاصة

ازالة الصبغة الزرقاء 71 الناتجة من مياه الصرف النسيجي بحثت باستخدام خلية التخثير الكهربائي ذات اقطاب الالمنيوم . تم دراسة المتغيرات التشغيلية التالية الرقم الهيدروجيني الابتدائي (2 – 12) ، التوصيل الكهربائي (0.8 - 12.57) ملي سمنز/سم ، تركيز الصبغة الابتدائي (30 – 210) ملغم/لتر، زمن التخثر (3 – 12) دقيقة، كثافة التيار (10 – 50) ملي امبير / سنتيمتر مربع لتحقيق اقصى ازالة للون من مياه الصرف الصناعي . نتائج التجارب بينت ان نسبة الازالة تزداد مع زيادة الرقم الهيدروجيني لغاية 6.0 بعد ذلك تنخفض .وتزداد بسبة الازالة مع زيادة كثافة التيار والتوصيل الكهربائي وزمن التخثير .

اقصى ازالة للون تم الحصول عليها بلغت 96.5% عند الرقم الهيدروجيني 6.0 ، التوصيل الكهربائي 9.28 ملي سمنز/سم .
زمن التخثر الكهربائي 6 دقيقة ، تركيز الصبغة الابتدائي 60 ملغم / لتر ، وكثافة تيار 30 ملي امبير/سنتيمتر مربع.
الكلمات الرئيسية : الصبغة الزرقاء ، ازالة اللون ، التخثير الكهربائي ، مياه الصرف النسيجي ، معالجة المياه.

1. INTRODUCTION

A serious provenience of environmental pollution is the wastewater produced from textile dying and related units. The main environmental trouble related with loss is essential quantity of unstable dyes during dyeing process and then liberation in the wastewater, **Khandegar, and Saroha, 2013**. A main defiance for sufferable growth is the treating of wastewater from industrialist processes and the employment where the treated water from the processes produces zero wastes. The aim of these developments is more effectual and cheap technical methods to treat wastewater, **Natthaphon et al., 2015**. The industry of textile is a serious intimidation to mainland water resources due to: first the huge water required and second the product flowing out consist of grave concentrations from dyes, surfactants, and other hazards material, **Ke et al., 2014**. The dye compound is poisonous to the ecological due to stability and has depressed biodegradation and may be carcinogen. The dying process lost midst one to fifteen percent of initial dyes used in during dyeing. This percent is freed in the wastewater causative poisonous to humans and other microorganisms, **Pirkarami et al., 2013**.

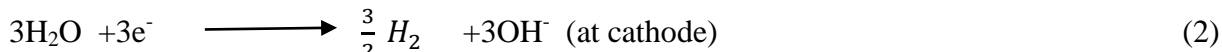
There are numerous methods in the literature used to remove color from wastewater. These methods consist of adsorption, chemical coagulation, photo-degradation, precipitation, chemical degradation, biodegradation, advanced oxidation, biosorption, membrane separation and electrocoagulation, etc. From these methods, electrocoagulation was found as a favorable technique in wastewater treatment, **Sharma and Nandi, 2013**.

The electrocoagulation process is preferable method to treat wastewater containing dyes than traditional coagulation process due to the low sludge produced, pollutants such as chloride or sulfate ions not produced, so it's friendly to environmental, simple, effective, frugal, tiny colloidal particles can be removed due to electric field control the motion of particle. The equipment is easy in operation, shortened time reaction, heliacal photovoltaic panel can be a source of energy to produce current electricity from solar energy, and the energy consumption can be reduced by gathering the hydrogen generated from the process. Furthermore the dye remove can be increased by connecting electrocoagulation with another method. **Phalakornkule, et al 2010, Zhang et al 2013**.

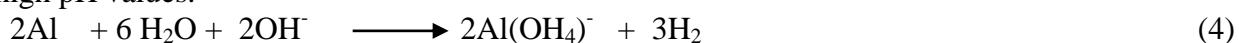
In traditional chemical coagulation the coagulant is added straight away in wastewater but in electrocoagulation process the coagulant produce by electrolysis of a sacrificial anode, generally in iron or aluminum which avoids extravagant quantity of coagulant. The electrolysis leads to dissolution of metal cations such as Fe^{3+} or Al^{3+} like chemical coagulation, **Holt, et al 2005**.

A diversity of industrial wastewaters can be treated successfully by using electrocoagulation. There are three major processes through electro-coagulation: formation of coagulants in liquid phase due to electrolysis of electrode surface, the pollutant adsorbed on coagulant and transference by floatation and sedimentation, **Chen, et al., 2000**.

The major reactions for electrode aluminum are:



The amorphous flocs $\text{Al}(\text{OH})_3$ formed according Eq. (3) which has a huge surface area, to trap colloidal flake and fast adsorption of organic soluble compound, **Picard et al, 2000**. The flocs is produced from combination the destabilized flake. The flotation produced by tiny hydrogen bubbles generated in cathode which remove most flocs and increases the separation of flakes from wastewater. Also at the cathode the OH^{-} ions produced simultaneously with H_2 at high pH values.



There are many interaction mechanisms conceivable amidst hydrolysis and dye molecules. In general two main mechanisms are regarded: adsorption (for high pH), and sedimentation (for low pH), **Gurses, et al., 2002**.

In general, iron or aluminum electrodes were used for current in electrocoagulation because their depressed frenzy, available, and fashioning of mostly amorphous metal hydroxides and oxyhydroxides that has banner specialties adsorption of dissolvable sort. Aluminum electrode is preferable to iron electrode due to the wastewater can be treated efficiently completed in equilibrium conditions with minimal solubility at pH in midst 6 and 7. The poly nuclear hydrolytic generated insures best adsorption of dissolvable and colloidal sort from wastewater. **Yousuf et al., 2010**

The aims of this study is to investigate the decolourization of a direct blue 71 dye from a prepared wastewater produced from The State Company for Cotton Industries using a batch electrocoagulation cell. The influence of operating variables on electrocoagulation process such as initial pH, wastewater conductivity, electrolysis (electrocoagulation) time, initial dye concentration and current density on the efficiency of treatment the textile wastewater containing direct blue 71 dyes was studied. The best values of these variables on the yield of color removal were also estimated.

2. EXPERIMENTAL

2.1 Prepared wastewater

A direct blue 71 dye was supplied from The State Company for Cotton Industries (S.C.C.I) in Iraq and the chemical structure of the dye is shown in **Fig. 1**. It's employed to make synthetic wastewater by dissolving appropriate quantities of dye in tap water (150 rpm). The mixing process of the blue dye with tap water is achieved using an electrical magnetic stirrer. The total concentration (C_o) can be changed between 30 and 210 milligram per liter. The dye and their concentration is like that of wastewaters from company.

The pH of the prepared wastewater was adjusted between 2.0 and 12.0 by the addition of 0.1 M H₂SO₄ (Fluka AG, Switzerland) or 0.1 M NaOH solutions (Hopkin & Williams production). The conductivity of wastewater was varied by addition of sodium chloride (NaCl) in the range of 0 – 6.0 g/L; it was high conductivity and high solubility.

2.2 Experimental set-up

Cylindrical electrocoagulation cell was of 0.5 L internal volume (V). Aluminum electrodes were positioned vertically parallel to each other with rectangular shape (6.0 cm × 4.0 cm × 1 mm) and 24 cm² area of each electrode as shown in **Fig 2**. 10 mm was a distance between the anode and cathode. During electrocoagulation process a DC power supply (Friedberg Hessen, Germany) was used to supply current (I) in order to achieve five current densities values to be applied; 10, 20, 30, 40 and 50 mA/cm². Electrocoagulation times were 3, 6, 9 and 12 min. respectively. After each experiment, all electrodes must be cleaned, sunken in 0.01 M HCl for 2 min to remove impurities and metal hydroxide precipitates from the electrodes, and then washed with water, dried with air and weighted. Whenever more than 10% of electrode weight was lost the electrodes must be replaced

3.3 Analytical methods

The concentration of dye (C) calculated by ultra violet (UV) spectrophotometer (Biotech Engineering Management, UV-9200, UK) with a range of (190–1000 nm). The concentration of direct blue 71 dye was measured at a wavelength of 587 nm was employed to measure the maximum wavelength of the direct blue 71 dye.

Dye concentration was measured by an absorbance value at a wavelength of 587 nm. In all samples, the remaining dye was measured after filtration. The decolonization yield (Y_{COL}) is defined:

$$Y_{COL} = \frac{C_o - C_t}{C_o} \times 100 \quad (5)$$

C_o is the initial concentration of dye in prepared wastewater and C_t is dye concentration at time t. The current and voltage used in the process were measured by digital ammeter and voltmeter, respectively.

3. RESULTS & DISCUSSION

3.1. The effect of Initial pH

Fig. 3 shows the effect of the initial pH of wastewater on the blue 71 dye decolonization. This figure shows that the blue decolonization increases with increasing the initial pH of wastewater to reach a maximum value when pH = 6. That gives the blue removal efficiency of 78%, and then the removal of blue dye slightly decreased with increasing the initial pH. At the initial pH of 8, blue removal efficiency was 76 %. After that the removal blue dye efficiency decreased with increasing the initial pH.

This phenomenon can be explained as follows: at low pH until 6.0, Al(OH)_2^+ , Al(OH)^{2+} and Al^{3+} cations were dominant which were responsible of the formation of electro coagulant flocks surface. The surface of the flocks became positively charged, which increase electrostatic could attract between negative charged dye anions and positive charged flocks sites, while the pH increasing gradually, a positive charge on the solution interface decreasing is observed conversely. When pH became high or pH more than 8.0, the anions Al(OH)_4^- soluble turn into prevailing causes decreasing of dye removal due to electrostatic repulsion between the negatively charged surface of flocks and the negatively charged anionic dye molecules, subsequently the removal of dye decreases at higher pH value. From figure 3, the maximal blue decolonization efficiency of 78% was obtained at initial pH 6.0, for this reason all subsequent experiments were selected at initial pH 6.0 value.

Al(OH)_3 formation during electrocoagulation causes pH variation, as described previously. **Fig. 4** shows the effect of the initial pH on the final pH. The transformation rely on the primary pH and Al(OH)_3 precipitation. At initial pH of more than 6.0 that is averting a high alteration of pH. At pH = 6.0, the solution pH tends a buffering, thence necessary to keep the pH values in a range so insoluble Al(OH)_3 was the predominant aluminum species to increase the effectiveness of the dye removal.

3.2. Influence of Wastewater Conductivity

The influence of wastewater conductivity on the removal efficiency was studied between 0.8 -12.57 mS/cm (addition of NaCl between 0 – 6 g/L) as shown in **Fig 5**. Experimental results illustrate the blue removal increases with increasing the conductivity of wastewater to reach a maximum value when the conductivity of wastewater was 9.28 mS/cm, which gave the blue removal efficiency 85.2%. Then the removal blue dye slightly increased with increasing the conductivity of wastewater. At the conductivity of wastewater 12.53mS/cm the blue removal efficiency was 86 %. Since the maximum removal efficiency and less salty solution after electrocoagulation was the aim, the conductivity of wastewater of 9.28 mS/cm was used instead of 12.57 mS/cm for the subsequent experiments.

This result may be demonstrated as follows: when the concentration of NaCl increases the conductivity of the electrolyte also increases and the passivation removed by the anions Cl^- , which increase the rate of electrolysis of a sacrificial anode by the partnership of Cl^- in the metal electrolysis reaction or by the combination of Cl^- in the film oxide.

3.3 Effect of Initial Dye Concentration

The effect of the initial dye concentration on the removal efficiency was studied at different concentrations between 30 and 210 mg/l which were treated by electrocoagulation, as shown in **Fig 6**. Experimental data denote the blue decolonization decreased with increasing the initial concentration. Decolonization efficiency slightly decreased from 85.2% when blue concentration was 60 mg/L to 81% at blue concentration of 90 mg/L and decreased gradually from 81% to 64% when increasing the concentration of blue dye from 90mg/L to 210 mg/L.

This may be attributed to the fact that for all fixed variables of experiments, the coagulant amount produced from electrode mass loss was also constant. When increasing the dye concentration the removal efficiency decreased due to the amount of coagulant becomes too low in comparison to the amount of dye content.

3.4 Effect Electro Coagulation Time

The removal of blue dye yield was examined in batch electro coagulation cell at different electrolysis time from 3 to 12 minute. **Fig. 7** shows the relationship between the dye removal yield and the electrolysis time. This figure exhibit that the blue decolonization increased with increasing the electrolysis time to reach a maximum value when the electrolysis time was 6 minutes. That gives the blue removal efficiency of 85.2%, and then the removal of blue dye approximately was constant with increasing the electrolysis time. For this reason, the time of 6 minutes was chosen for the later experiments.

3.5 The Effect of Current Density

The current density is the main variable for controlling the electro coagulation process. The current density is the important variable for energy and electrode provision, it determines the rate production of coagulant as well as the production of hydrogen bubbles (eq.3) which affect the growth and size of flocs. The effect of the current density on the removal of blue dye was studied for Al electrodes as show in **Fig.8**. In this figure, different current density applied 1.0, 20, 30, 40, and 50 mA/cm² was treated by electro coagulation. Experimental data illustrated the blue decolonization increased with increases in the current density. An increase in current density from 10 to 20 mA/ cm² increased the blue removal yield from 35% to 85.2%. Increasing the current density from 20 to 30 mA/cm² produced an increasing in the blue decolonization from 85.2% to 95.5 %. A further increae in the current density from 30 to 40 mA/cm² gives small increasing in the blue removal yield (from 95.5% to 96.2%) wherefore the optimum current density was selected to be 30 mA/cm² due to the consumption of electrical energy related with the square rate of the current.

4. CONCLUSIONS

Electrocoagulation was shown to be an efficient process for color removal from wastewater containing direct blue 71 which is a highly soluble dye up to 96.5% obtained at pH = 6.0, wastewater conductivity of 9.28 mS/cm, electrolysis time = 6 min, the concentration of initial dye was 60 mg/L and current was density 30 mA/cm². The color removal yield increased with increasing in pH until 6.0 after that it decreased with increasing pH. The color removal increased with increasing current density, wastewater conductivity, electrolysis time, and decreased with increasing the concentration of initial dye. The process efficiency was affected mainly by the current density, initial pH, electrolysis time, wastewater conductivity as well as initial dye concentration.



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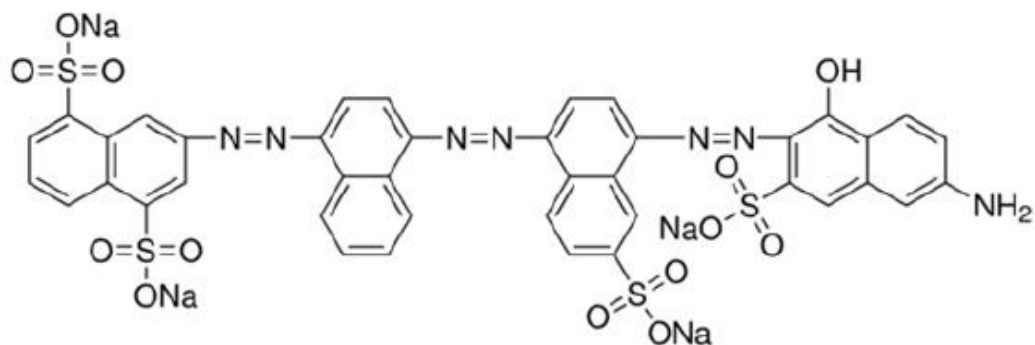


Figure 1. Chemical structure of direct blue 71.

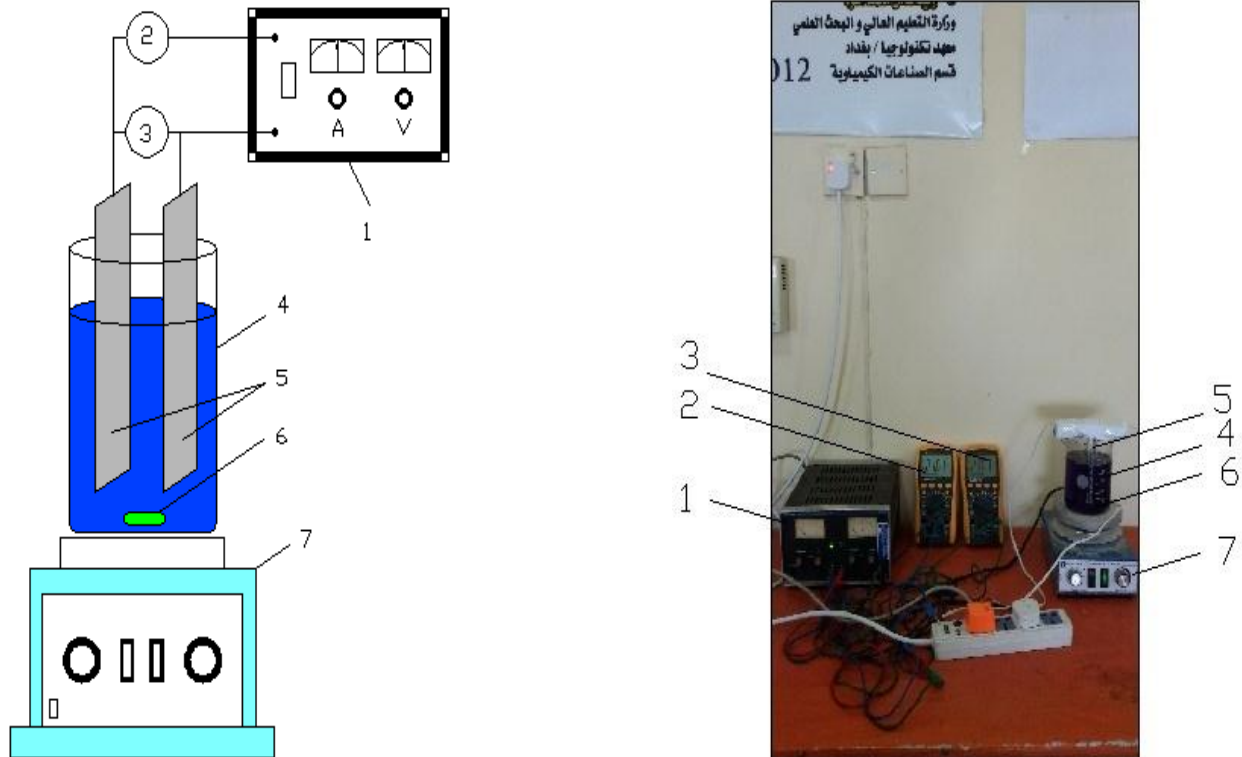


Figure. 2 The Schematic Diagram and Photo Picture of Electrocoagulation Reactor:

- (1) DC Power Supply; (2) Digital Ammeter; (3) Digital Voltmeter; (4) A cylindrical electrocoagulation cell; (5) Anode and Cathode; (6) Magnetic bar; (7) Electrical magnetic stirrer .

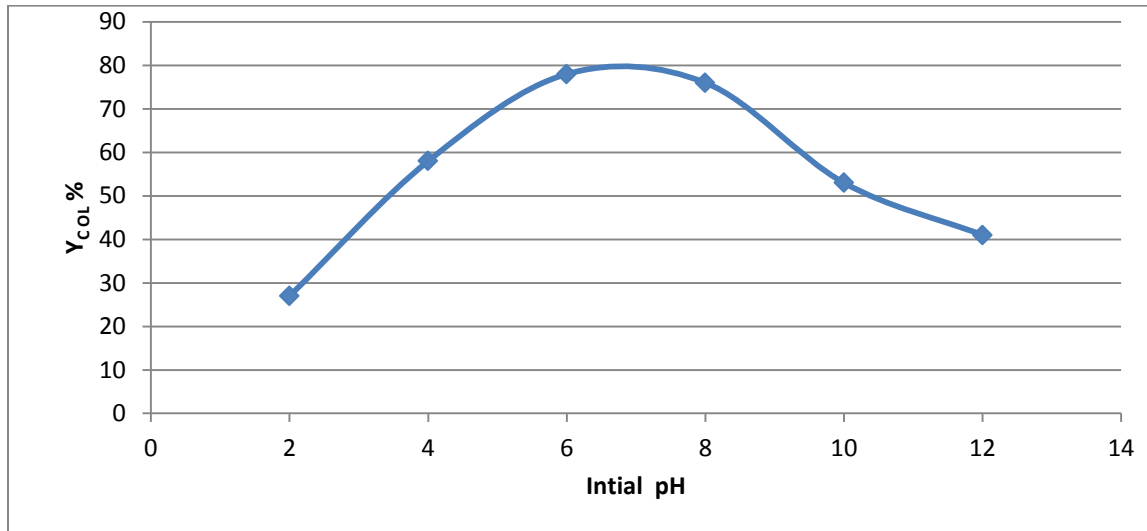


Figure.3 Effect of initial pH of wastewater on removal direct blue yield [initial pH of wastewater 2–12, current density of 20 mA/cm², initial dye concentration 60 mg/l., wastewater conductivity 7.6 mS/cm and electrolysis time 12 min].

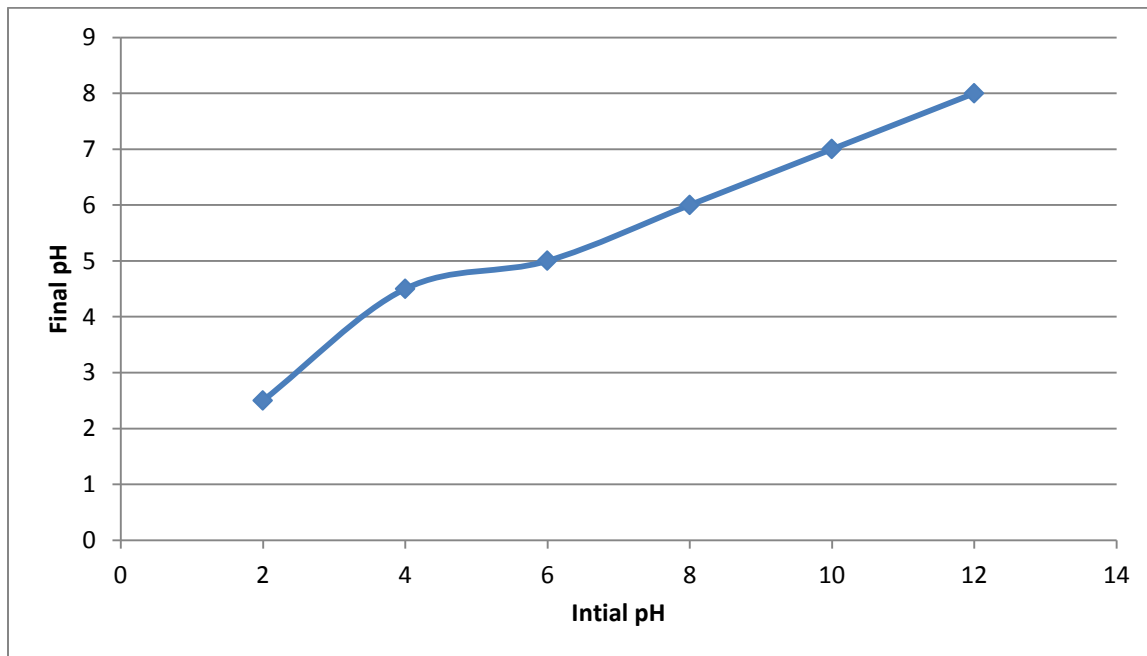


Figure 4. The effect of the initial pH on the final pH.

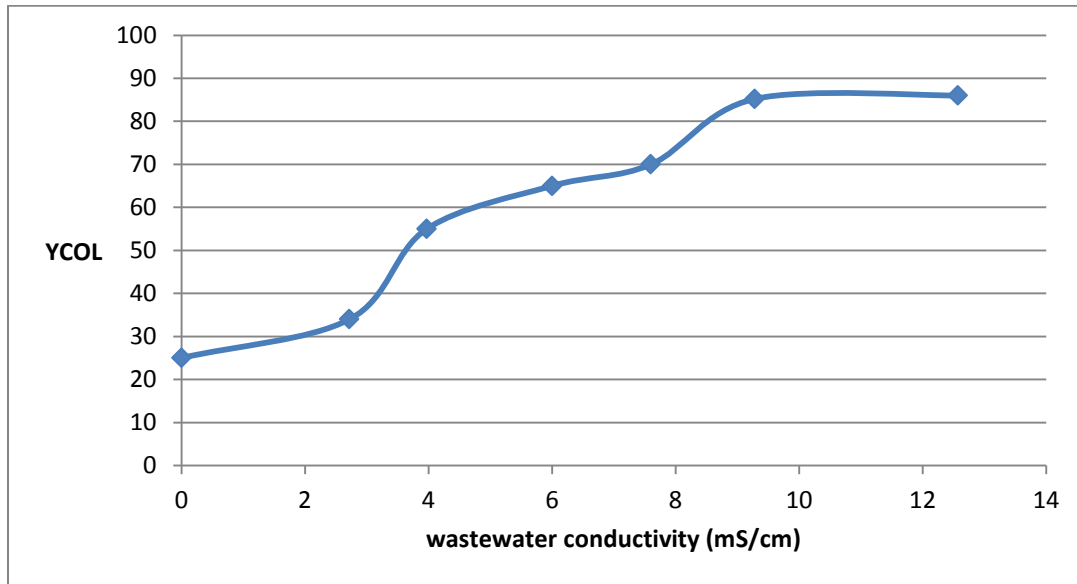


Figure 5. Influence of wastewater conductivity on removal of direct blue yield.[pH 6 , current density of 20 mA/cm^2 , initial dye concentration 60 mg/l and electrolysis time 12 min]

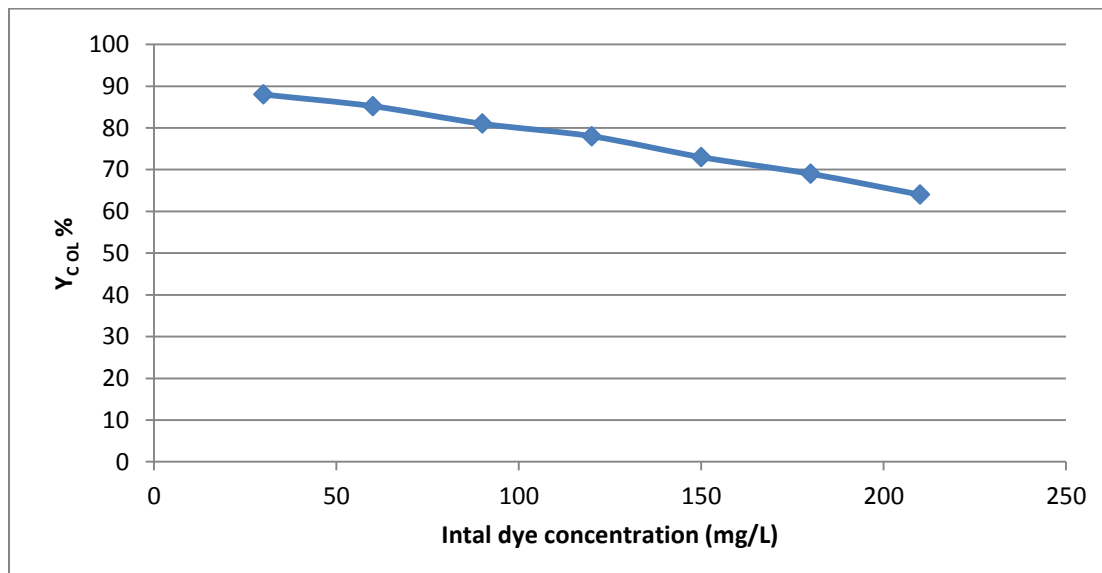


Figure 6. Effect of initial dye concentration of wastewater on removal direct blue yield [pH 6.0 , wastewater conductivity 9.28 mS/cm , current density of 20 mA/cm^2 and electrolysis time 12 min]

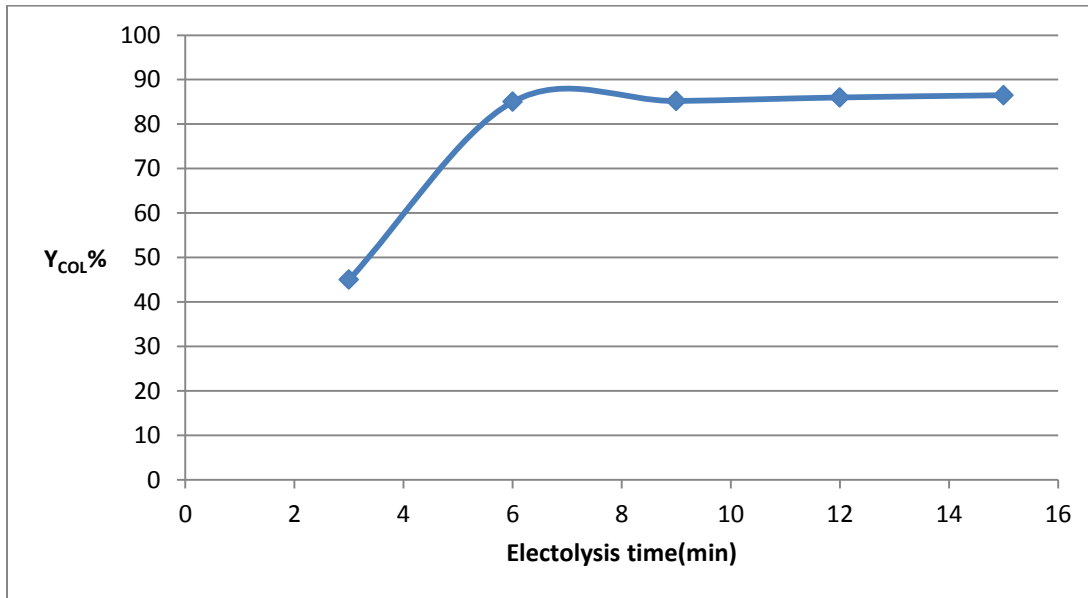


Figure.7 Effect of electrolysis time on the removal of direct blue yield [for pH 6.0, wastewater conductivity 9.28 mS/cm, current density of 20 mA/cm², the initial dye concentration 60mg/L]

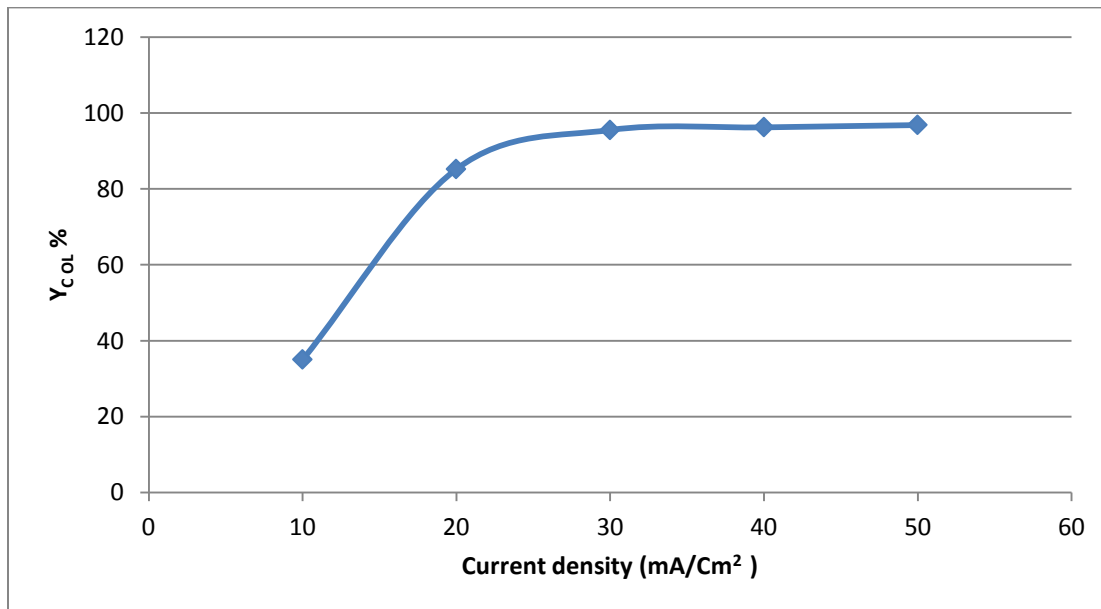


Figure.8 Effect of current density time on the removal of direct blue yield [at pH 6.0, wastewater conductivity 9.28 mS/cm, blue dye concentration 60mg/L, electrolysis time 6 min]