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Removing Red No. 30 dye from Wastewater by Electrocoagulation Method using Stainless Steel (SS316) and Aluminum Electrodes

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ABSTRACT

In this work the removal efficiency of dyes, Red No. 30 from wastewater was studded by using the electrocoagulation method. Several factors influencing this process were examined such as type of electrode, two types of electrodes were used iron stainless steel 316 and aluminum electrode in dimensions (length 10cm, width 6cm, thickness 0.1cm) and three different distances taken (1cm, 2cm, 3cm) and three initial concentrations for dye, were taken (100,150 and 200 ppm), also Effect of variation voltage, five different values of the supplied potential were taken such as (5,10,15,20 and 25) volt, Effect of electrolyte solution added, (Na_2SO_4) salt was used as an electrolyte solution with different concentration of (25,50,75 and 100 ppm) .The best results were obtained for Red No. 30 dye at optimum conditions (concentration 200 ppm, voltage 25 volt, distance (1cm), and time 100 min) where the highest ratio of removal by using aluminum electrode was (99.36 %) and (96.32%) by using stainless steel 316 electrode. When adding (Na_2SO_4) salt as an electrolyte solution to the dye Red No. 30 best results were obtained, optimum condition of (concentration 25 ppm, voltage 25 volt, distance (1cm) and time 100 min) The highest ratio was removed by using aluminum electrode which was (86.31 %) and (78.03%) by using stainless steel 316 electrode.

Keywords: electrocoagulation, dye Removal, Red No. 30 dye, stainless steel electrode, aluminum electrode.

1. Introduction

To confront the danger of pollution, chemical and biological methods were used in treating them, but these methods do not perform the required role in many cases. Therefore, researchers tended to use electricity to treat pollutants and for the purpose of reducing the concentration of pollutants to a minimum of values that pose a threat to the environment. Electrochemical methods were used to treat environmental pollutants. [1,2]

2. Electrocoagulation

The process of electrocoagulation EC depends on the principle of soluble electrodes, whereby applying an electric current between two electrodes (mostly aluminum or iron) immersed in the treated solution, where the anodic dissolution of the electrode produces metal ions that interact with hydroxide ions forming hydro complexes that play the role of a coagulant and lead To form sediments for easy removal. [3] The electrocoagulation reactor (EC) may contain multiple pairs of positive and negative electrodes, which are in the form of plates, perforated plates, or tubes, and of different materials including iron, aluminum, stainless steel, titanium, and it can also be a series of The reactors each have electrodes of different materials [4]. This process includes three stages (5) as shown in figure (1).

1- Thrombi formation by electrolytic oxidation.
2- Destabilization of pollutants and suspension of particles.
3- Assembling the destabilizing phases to form lumps (ie, sediment formation).

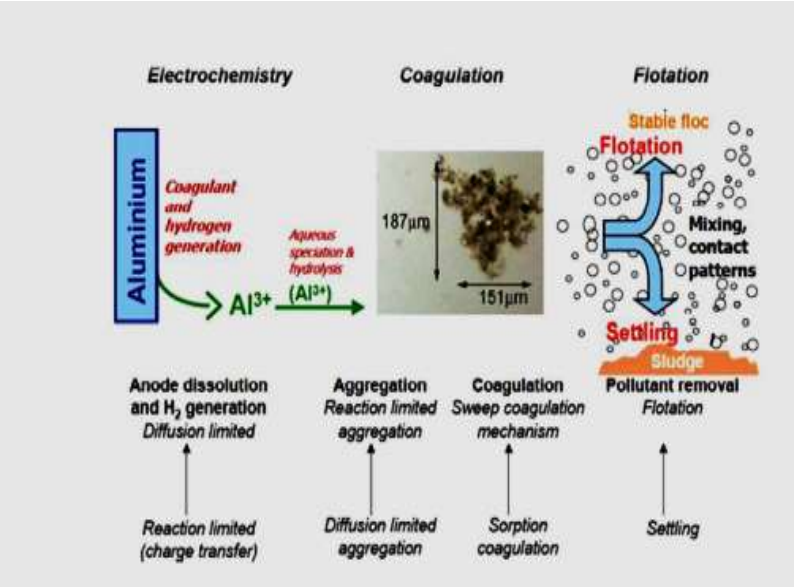


Fig. 1: Summery of electrocoagulation mechanism. [5]

3. Literature of Review

- (M.Behloul 2013) [6] and his et.al studied the removal of Malathion from aqueous solution using the electrocoagulation method (EC) by studying factors including (pH, initial concentration of the pesticide, current density, salt concentration (electrolyte solution), distance between electrodes) on the efficiency of removal, as well as the amount of electrical energy consumed. The optimal conditions obtaining for high removal were as follows: (pH = 6, the initial concentration of the pesticide is (40mg/L), the current density is (10 mA/cm2), concentration of the electrolyte is (2500mg/L), the temperature is (27°c). The distance between the electrodes is (2cm) and removal efficiency was obtained higher than (90%).
- (A.A. Amooey 2014) [7] and his group studied the removal of (Diazinon) by electrocoagulation (EC) technique using aluminum electrodes. Many factors affecting the electrocoagulation process were also studied, including (pH, decomposition time, current density, initial concentration of the pesticide, and conductivity of the solution) and the optimal conditions were (pH equal to 3, current density 14.5 mA/cm2, initial concentration of the pesticide 100). ppm, time 60 min) and the removal percentage was (84.12%).
- (Abu Ghalwa 2015) [8] etal removed three pesticides from the aqueous solution, namely (Fenamiphos, Imidacloprid, and abamectin) using the electrocoagulation method (EC) where many variables were studied in this process (the initial concentration of pesticide, the concentration of the electrolyte used, current density, temperature) using iron and aluminum electrodes and the optimum conditions for removing Imidaclorprid were (pH 6.9, pesticide concentration 50 ppm, the current density is 18.5 mA/cm^2, electrolyte solution concentration 1 gm/L, the temperature is 20 °C, time 90 min) and the removal percentage was (80.8%) using aluminum electrodes. But the optimal conditions for abamectin are (pH 3.7, pesticide concentration 150 ppm, current density is 50 mA/cm^2, electrolyte solution concentration is 1 gm/L, temperature is 30 °C, time is 60 min. and the removal percentage is (94 %) using stainless steel electrodes and the optimal conditions for Fenamiphos pesticide are (pH 6.7, pesticide concentration 50 mg/L, current density is 18.5 mA/cm^2, electrolyte concentration is 1 gm/L, temperature is 20 °C, time is 60 min. the percentage of removal is (90.3%) using stainless steel electrodes.
- (A.S. Othman, and Ahmed Aljebory 2019) [9] using the electrocoagulation method for removing three dyes from aqueous solutions which are (supra-green, Blue2, Alura Red) using aluminum electrodes and stainless steel electrodes SS318. The relevant variables (dye concentration, electrolyte concentration, type of electrode used, distance between electrodes) were the optimal conditions for obtaining the best removal ratio (dye concentration 50,100,150,200 ppm, electrolyte concentration 50,100,150 PPm, the distance between electrodes 2 cm) and the best results were at a concentration of 200ppm The aluminum electrode is Blue2 (86.60%), Alura Red (88.15%), supra-green (57.98%) and at a concentration of 50 ppm at the stainless steel electrode Blue2 (98.4%), Alura Red (7.72%), supra-green (77.22). %)).
- (Ahmed.S. Othman, and Ahmed M. Aqail 2019) [10] removed two pesticides from the aqueous solution, namely (Goldazeme and Kleizer) using the electrocoagulation method using aluminum electrodes and SS304 electrodes, where many related variables were studied (dye concentration, Electrolyte concentration, type of electrode used, distance between electrodes) and the optimum conditions for obtaining the best removal ratio were (pesticide concentration 25,50,75,100 ppm, electrolyte concentration 25,50,75,100 ppm distance between

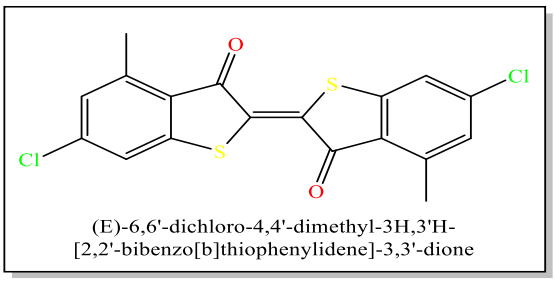
electrodes 1 cm) The best results were at a concentration of 100ppm The aluminum electrode is for Goldazime (94.20%) and Kliezer (86.45%), for the stainless steel SS304 electrode is for Goldazime (99.10%), Kliezer (95.37%).

- Shurooq Mahdi Al-Bayyati 2019[11] using the electrocoagulation process to remove Acid Orange 12 from wastewater was studied by using electrodes from aluminum with cell volume (500 ml). The dye concentration (50, 100, 150) ppm, initial temperature (20, 25,30, 35)°C, voltage (10, 20, 30)volt, initial pH (5, 7, 9), surface area of electrode (15, 24)cm^2, distance between electrodes (1, 2)cm and time of electrolysis (1-75)min. Experimental results showed that The maximum color removal efficiency reached 99.64% under the conditions of an initial dye concentration of 50ppm initial temperature 35°C, voltage 30V, initial pH 5, surface area 24 cm^2 , distance between electrodes 1cm and time electrolysis 75min.
- (Ahmed.S. Othman, and Roaa, Khaled, Atallah. B. Dakhil 2021[12] using electrocoagulation method to removing Yellow No.10 and Orange 1 dye from their aqueous solutions by using aluminum and stainless steel(304) electrode with many variable used different conc.(50,100,150)ppm and different applied voltage (5-25) voltage and electrolytic solution NaCl (50) ppm, with applied time (100) min .the result shown that maximum efficiency of removing Yellow No.10 and Orange.1 in aluminum electrode with out electrolyte (95.24% ,91.69%)respectively but in the presence of electrolyte the ratio of removing color dye is (97.3% ,93.77%) .but the ratio in stainless steel without electrolyte is(45.76%,32.46%) but with electrolyte(73.95%,80.15%) respectively

4. Chemical compounds

4.1- Red No 30

It is a red dye, also known as Orlaith Brilliant Pink R or Vat Red 1 with color guide CI-73360 or Pigment Red 181. This dye is used for dyeing cotton, silk, and nylon threads, and is used for printing on cotton clothes. It is also used in industry to color plastics, and it is highly soluble in water and its chemical formula:-



(E)-6,6'-dichloro-4,4'-dimethyl-3H,3'H-[2,2'-bibenzo[b]thiophenylidene]-3,3'-dione

λ_{max} = 572 nm, pH=8.5, Color = Red, Density = 1.58 gm/cm^3 Molecular Weight = 393.3 gm/mole, melting point = 529.1 °C , Solubility = 45 mg/L, Molecular formula = $C_{18}H_{10}Cl_2O_2S_2$

4.2- Cell Measurements

Electrocoagulation experiments were carried out using a glass cell made with dimensions (length 10 cm, width 8 cm, height 6 cm) and a capacity of (450 ml). Using pure aluminum and stainless steel (SS316) electrodes, each with dimensions (length 10 cm, width 6 cm, thickness 0.1 cm).. These electrodes were connected connected to a digital DC power supply (3 A)). The pH of the solutions before and after electrocoagulation (EC) is measured with a pH meter. To adjust the voltage used, different voltages (5,10,15,20,25 Volt) were taken.

4.3- Procedure

1. In each experiment, (450ml) of the dye samples prepared in the laboratory were placed in three concentrations (100.150.200ppm) in an electrocoagulation cell at a speed of shaking (200 rpm) and at laboratory temperature(28)C^o
2. Samples with a volume of (1ml) were taken periodically and at different times, samples were taken every 10min. Then it is filtered to remove suspended matter from the pesticide during electrolysis using filter paper.
3. The sample is analyzed using a spectrophotometer to determine the remaining concentrations of pesticides at (572) nm
4- The removal rate of the pollutant is then calculated by using the following relationship:

$R\% = [A_o - A_t / A_o] \times 100$ …… (1)

Where:- R% is the percentage of removal.

A0, A is the absorbance before and after treatment at a given wavelength.

4- At the end of each experiment, the electrodes are completely washed using distilled water and dilute hydrochloric acid, then dried and reused.

5. Results and Discussion

The factors affecting the efficiency of removing the dye Red No 30 under study have been studied by electrocoagulation method by studying some variables that have an effect on this method, including:

First: - the initial concentration of the dye.

Second: The effect of (potential difference) voltages.

Third: The effect of the distance between the electrodes.

Fourth: The effect of the added electrolyte concentration.

5.1- Pure aluminum electrode:

The electrocoagulation process was studied using two pure aluminum electrodes with dimensions (length 10 cm width 6 cm thickness 0.1 cm) in an electrolysis cell

5.1-1-Effect of initial concentration of the dye:

To find out the residual concentration of the dye at different times, a calibration curve was drawn by preparing different concentrations of the dye, and the maximum absorption was measured at the wavelength (572nm).Three concentrations of the dye were used (100, 150,200 ppm) and the absorption of the remaining concentration was measured over time, and the percentage of removal was calculated using equation (1) as in Figure (2).

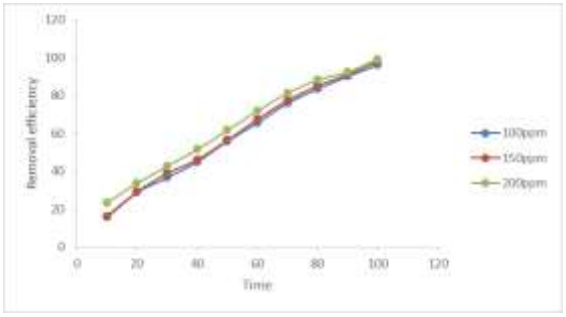


Fig. 2: Removal efficiency of Red No. 30 at a constant voltage of 25 Volt, with different concentrations, and at a distance of 1 cm).

We note from the above figure that an increase in the concentration of dye causes an increase in the removal rate. Increasing the initial concentration of the dye leads to an increase in the reactions taking place, including the oxidation of the dye, and the amount of the removed dye increases [13].

5.1-2: the effect of voltage

To study the effect of voltage on the removal efficiency of Red No. 30 different voltages (5,10,15,20,25 Volt) were used as shown in Figure (3)

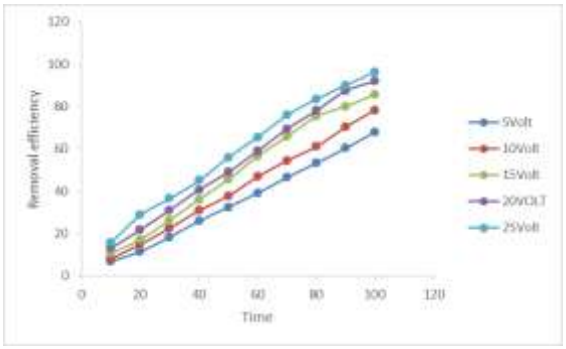


Fig. 3: Removal efficiency of Red No. 30 at different voltages. (100 PPm), with distance (1cm), . - We notice in the above figure that as the voltage increases, the current increases, and thus the time required for the electrocoagulation process to achieve a certain removal decreases. This is attributed to the increase in the concentration of ions liberated from the electrodes, which is directly proportional to the amount of current, and thus the metal hydroxide is formed, which is the main responsible for removal through the fluctuation of the remaining pollutant with the increase of the current. [14]

5.1-3- Effect of the distance between the electrodes

To study the effect of the distance between electrodes on the removal efficiency of Red No. 30 different distances were used (1cm, 2cm, 3cm) as shown in Figure (4).

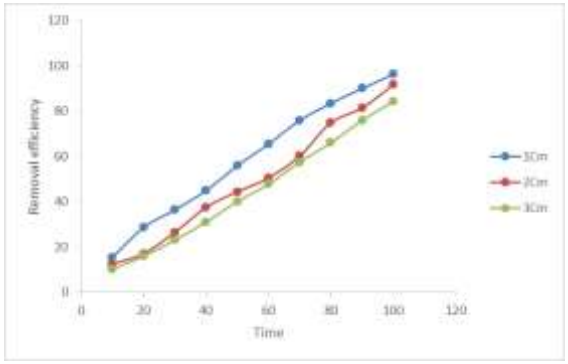


Fig. 4: Removal efficiency of Red No. 30 at a constant concentration of 100 ppm, at a constant voltage of 25 Volt, and at different distances.

Generally, the resistance of the solution decreases as the distance between the electrodes decreases due to the decrease in the electrical dispersion. The distance between the electrodes must be reduced to reduce energy consumption [15].The percentage of removal varies with the distance between the electrodes. It is known that during the electrocoagulation process, metal hydroxides are formed on the anode, which generates an additional resistance that increases even with an increase in the distance between the electrodes. [16]

5.1-4-Effect of electrolytes: The addition of the electrolyte is one of the factors affecting the removal efficiency of Red No. 30 Where salt (Na_2SO_4) was used as an electrolyte solution with different concentrations (25,50,75,100 ppm) with a concentration of 150 ppm of the dye

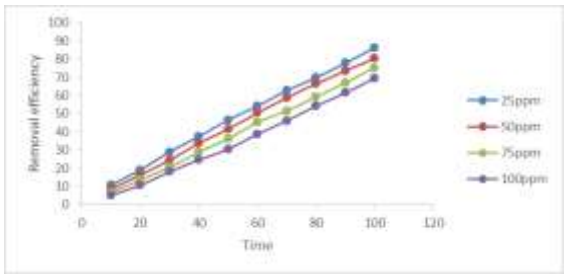


Fig. 5: Removal efficiency of Red No. 30 at (150 ppm) of dye with voltage (25volt) and a distance of 1 cm and different concentrations of electrolyte (25,50,75,100 ppm).

We note from figure(5) that when adding an electrolyte solution, the removal efficiency is decreasd [17]

5.2- Stainless Steel SS316 Electrode.

5.2-1-: Effect of Concertation.

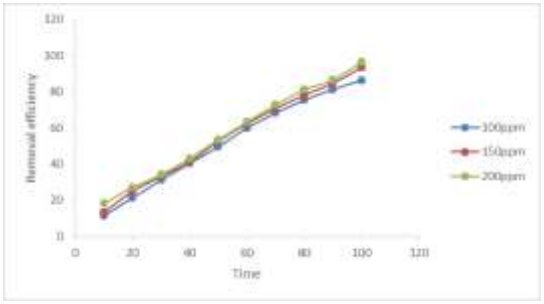


Fig. 6: Effect of initial concentration on the removal efficiency of Red No. 30 using with SS316 electrodes (Conc 100 PPm, Volt 25, Distance 1cm).

5.2-2- Effect of voltage

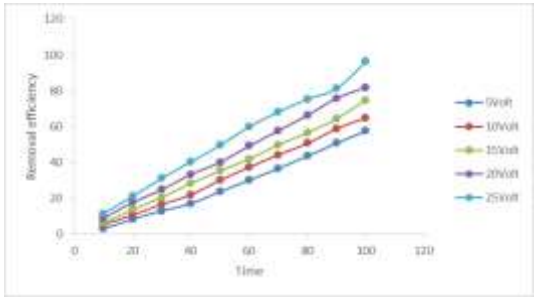


Fig. 7: Effect of Voltage on the removal efficiency of Red No. 30 using with SS316 electrodes (Conc 100 PPm, Volt 25, Distance 1cm).

5.2-3-Effect of distance

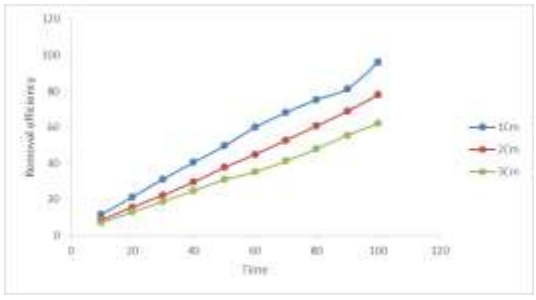


Fig. 8: Effect of distance on the removal efficiency of Red No. 30 using with SS316 electrodes (Conc 100 PPm, Volt 25, Distance 1cm)

5.2-4-Effect of electrolytes

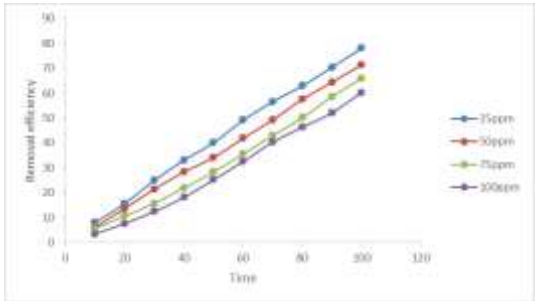


Fig. 9 : Effect of type of electrolyte on the removal efficiency of Red No. 30 using with SS316 electrodes (Conc 150 PPm, Volt 25, Distance 1cm and different concertation of electrolyte).

6- Mechanism of Electrocoagulation SS316

The technique depends on the formation of coagulants from the decomposition of the positive electrode when the electric current passes, as the metal ion is released and the hydroxide and other decomposition products of the metal ion are formed. In the stainless steel electrode (SS304), there are two mechanisms [18,19]

First - the first mechanical: -

Anode $4Fe_{(s)} \rightarrow 4Fe^{+2}_{(aq)} + 8e^-$ … (1)

$4Fe^{+2}_{(aq)} + 10H_2O_{(l)} + O_{2(g)} \rightarrow 4Fe(OH)_{3(s)} + 8H^+_{(aq)}$ … (2)

Cathode $8H^+_{(aq)} + 8e^- \rightarrow 4H_{2(g)}$ … (3)

Overall $4Fe_{(s)} + 10\ H2O_{(l)} + O_{2(g)} \rightarrow 4Fe(OH)_{3(s)} + 4H_{2(g)}$ .. (4)

Mechanism 2 :

Anode: $Fe_{(s)} \rightarrow Fe^{+2}_{(aq)} + 2e^-$ ….(5)

$Fe^{+2}_{(aq)} + 2OH^-_{(aq)} \rightarrow Fe(OH)_{2(s)}$ …(6)

Cathode: $2H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2OH^-_{(aq)}$ …(7)

Overall: $Fe(s) + 2H2O(l) \rightarrow Fe(OH)2(s) + H2(g)$… (8)

Second: - In the aluminum electrode, the mechanical is as follows: -

Anode: $Al(s) \rightarrow Al^{3+}_{(aq)} + 3e^-$ ….(9)

Cathode: $3H_2O_{(l)} + 3e^- \rightarrow 3/2\ H_2 + 3OH^-$ …(10)`

Overall: $Al_{(s)} + 3H_2O_{(l)} \rightarrow Al(OH)_{3(s)} + 3H^+$ …(11)

In addition, as a result of hydrolysis, the positive electrode is closer to the acidic electrode, in contrast to the negative electrode, which is closer to the base as a result of the emission of hydrogen gas, as in equation No. (7) [19].

The best results for dye Red No 30 with Aluminum electrodes, as the optimum conditions to obtain this ratio were (concentration 200 PPm, voltage 25 volt, distance 1cm) without the electrolyte, and (concentration 25 PPm, voltage 25 volt, distance 1cm) when adding the electrolyte solution as in Table (1).

Table 1: The highest percentage of removal of Red No30 dye using pure aluminum electrode and 316 stainless steel electrode without electrolytic solution and when adding electrolytic solution.

NO	Name of electrode	Removal rate by adding electrolyte	Removal rate without adding electrolyte
1	Aluminium Pure	86.31%	99.36%
2	Stainless steel316	78.03%	96.32%

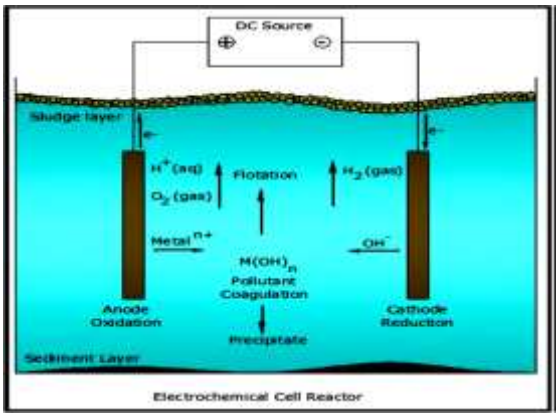


Fig. 10: shows the electrochemical reactions of two electrodes in an electrocoagulation cell [20].

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