

An Experimental Investigation on the Effect of The Operating Parameters For The Decolourisation Of Textile Waste Water By Electro Coagulation Process

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Abstract:- The aim of this paper was to investigate the decolourisation efficiency of the textile waste water by the electro coagulation process for a CLB Red Reactive dye using iron electrodes. The influence of various operating parameters such as the current density, electrolyte concentration, process time, dye concentration were analysed in a laboratory scale batch reactor. The absorbance was measured using a double beam UV-Vis Spectrophotometer through which the colour removal was calculated for varying current densities and operating time. The results showed that the colour removal is dependent on current density and the process time. Electrocoagulation process was found be an efficient, safe and reliable method for the treatment of textile waste water

Index Terms: - Electro coagulation, Textile wastewater, Decolourisation.

I INTRODUCTION

Our biosphere is under constant threat from continuing environmental pollution. Impact on its atmosphere, hydrosphere and lithosphere by anthropogenic activities cannot be ignored. Man made activities on water by domestic, industrial, agriculture, shipping, radio-active, aquaculture wastes ; on air by industrial pollutants, mobile combustion, burning of fuels, agricultural activities, ionization radiation, cosmic radiation, suspended particulate matter; and on land by domestic wastes, industrial waste, agricultural chemicals and fertilizers, acid rain, animal waste have negative influence over biotic and abiotic components. Among many engineering disciplines – Civil Engineering, Mechanical Engineering, Electrical Engineering etc., Textile Engineering has a direct connection with environmental aspects to be explicitly and abundantly considered. The main reason is that the textile industry plays an important role in the economy of the country like India and it accounts for around one third of total export. Out of various activities in textile industry, chemical processing contributes about 70% of pollution. It is well known that cotton mills consume large volume of water for various processes such as sizing, desizing scouring, bleaching, mercerization, dyeing, printing, finishing and ultimately washing. Due to the nature of various chemical processing of textiles, large volumes of waste water with numerous pollutants are discharged. Since these streams of water affect the aquatic eco-system in number of ways such as depleting the dissolved oxygen content or settlement of suspended substances in anaerobic condition, a special attention needs to be paid. Thus a study on different measures which can be adopted to treat the waste water discharged from textile chemical processing industries to protect and safeguard our surroundings from possible pollution problem has been the focus point of many recent investigations.

Textile industry involves wide range of raw materials, machineries and processes to engineer the required shape and properties of the final product. Waste stream generated in this industry is essentially based on water-based effluent generated in the various activities of wet processing of textiles. The main cause of generation of this effluent is the use of huge volume of water either in the actual chemical processing or during re-processing in preparatory, dyeing, printing and finishing.

The treatment of wastewater generated by the textile preparation, dyeing and finishing industry remains a significant environmental pollution problem due to its huge quantity, variable nature and biologically-difficult-to-degrade chemical composition.

Saving water to save the planet and to make the future of mankind safe is what we need now. With the growth of mankind, society, science, technology our world is

reaching to new high horizons but the cost which we are paying or will pay in near future is surely going to be too high. Among the consequences of this rapid growth is environmental disorder with a big pollution problem. Besides other needs the demand for water (“Water for People Water for Life” United Nations World Water Development Report UNESCO) has increased tremendously with agricultural, industrial and domestic sectors consuming 70, 22 and 8% of the available fresh water, respectively and this has resulted in the generation of large amounts of wastewater (Helmer and Hespanhol,1997; Lehr et al.,1980) containing a number of ‘pollutants’. One of the important class of the pollutants is dyes, and once they enter the water it is no longer good and sometimes difficult to treat as the dyes have a synthetic origin and a complex molecular structure which makes them more stable and difficult to be biodegraded.

Dyes exhibit considerable structural diversity and are classified in several ways. These can be classified (Hunger, 2003) both by their chemical structure and their application to the fiber type. Dyes may also be classified on the basis of their solubility: soluble dyes which include acid mordant, metal complex, direct, basic and reactive dyes; and insoluble dyes including azoic, sulfur, vat and disperse dyes. Besides this, either a major azo linkage or an anthraquinone unit also characterizes dyes chemically.

Some properties of dyes classified on their usage (Christie, 2007; Hunger, 2003) are discussed in brief here.

Acid Dyes: used for nylon, wool, silk, modified acrylics, and also to some extent for paper, leather, ink-jet printing, food, and cosmetics. They are generally water soluble. The principal chemical classes of these dyes are azo (including premetallized), anthraquinone, triphenylmethane, azine, xanthen, nitro and nitroso.

Cationic (Basic) Dyes: used for paper, polyacrylonitrile, modified nylons, modified polyesters, cation dyeable polyethylene terephthalate and to some extent in medicine too. Originally they were used for silk, wool, and tannin-mordanted cotton. These water-soluble dyes yield coloured cations in solution and that’s why are called as cationic dyes. The principal chemical classes are diazahemicyanine, triarylmethane, cyanine, hemicyanine, thiazine, oxazine and acridine.

Disperse Dyes: used mainly on polyester and to some extent on nylon, cellulose, cellulose acetate, and acrylic fibers. These are substantially water-insoluble nonionic dyes used for hydrophobic fibers from aqueous dispersion. They generally contain azo, anthraquinone, styryl, nitro, and benzodifuranone groups.

Direct Dyes: used in the dyeing of cotton and rayon, paper, leather, and, to some extent to nylon. They are water-soluble anionic dyes, and, when dyed from aqueous solution in the presence of electrolytes have high affinity for cellulosic fibers. Generally the dyes in this class are polyazo compounds, along with some stilbenes, phthalocyanines and oxazines.

Reactive Dyes: generally used for cotton and other cellulose, but are also used to a small extent on wool and nylon. These dyes form a covalent bond with the fiber and contain chromophoric groups such as azo, anthraquinone, triarylmethane, phthalocyanine, formazan, oxazine, etc.

Solvent Dyes: used for plastics, gasoline, lubricants, oils, and waxes. These dyes are solvent soluble (water insoluble) and generally nonpolar or little polar, i.e., lacking polar solubilizing groups such as sulfonic acid, carboxylic acid, or quaternary ammonium.

Sulfur Dyes: used for cotton and rayon and have limited use with polyamide fibers, silk, leather, paper, and wood. They have intermediate structures and though they form a relatively small group of dyes the low cost and good wash fastness properties make this class important from an economic point of view.

Vat Dyes: used for cotton mainly to cellulosic fibers as soluble leuco salts and for rayon and wool too overall at present there are more than 100,000 commercial dyes with a rough estimated production of 7×10^5 - 1×10^6 tons per year (Christie,2007; Hunger,2003; Husain,2006; Meyer,1981 ;Zollinger,1987). Of such a huge production the exact data on the quantity of dyes discharged in environment is not available. However, it is reported that 10–15% of the used dyes enter the environment through wastes (Hai et al., 2007; Husain; 2006). The big consumers of dyes are textile, dyeing, paper and pulp, tannery and paint industries, and hence the effluents of these industries as well as those from plants manufacturing dyes tend to contain dyes in sufficient quantities. Dyes are considered an objectionable type of pollutant because they are toxic generally due to oral ingestion and inhalation, skin and eye irritation, and skin sensitization leading to problems like skin irritation and skin sensitization and also due to carcinogenicity. They impart colour to water which is visible to human eye and therefore, highly objectionable on aesthetic

grounds. Not only this, they also interfere with the transmission of light and upset the biological metabolism processes which cause the destruction of aquatic communities present in ecosystem (Kuo;1992.)

In textile industry generate highly dispersible waste:

- Waste stream from continuous operation (e.g. preparatory, dyeing, printing and finishing)
- Print paste (printing screen, squeeze and drum cleaning)
- Lint (preparatory, dyeing and washing operations)
- Foam from coating operations
- Solvents from machine cleaning
- Still bottoms from solvent recovery (dry cleaning operation)
- Batch dumps of unused processing (finishing mixes)

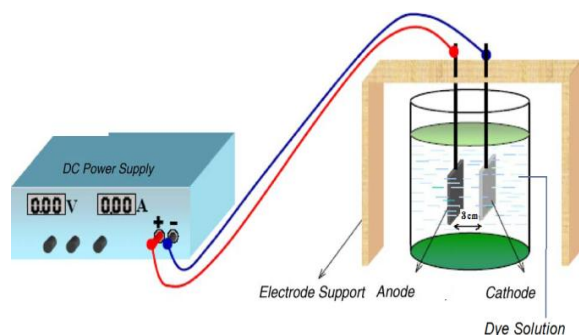
II WASTEWATER FROM TEXTILE INDUSTRY

Textile industry is one of the most complicated industries among manufacturing industry (Selcuk, 2005). The main sources of wastewater normally come from cleaning water, pre-treatment, dyeing and finishing process water non-contact cooling water and others (Kim *et al.*, 2003). The amount of wastewater varies widely depending on the type of process operated at the mill. Various toxic chemicals such as complexing agents, sizing, wetting, softening, anti-felting and finishing agents, wetting agents, biocides, carriers, halogenated benzene, surfactants, phenols, pesticides dyes and many other additive are used in wet processing, which are mainly called washing scouring, bleaching, mercerizing, dyeing, finishing (Selcuk, 2005).

The water employed in the process eventually ends up as wastewater (Lin and Chen, 1997). Main pollutants from dyeing and finishing units include high suspended solids (SS), chemical oxygen demand (COD), biochemical Oxygen demand (BOD), heat, colour, acidity, basicity, and other organic pollutants (Ahn *et al.*, 1999; Karim *et al.*, 2006). This means that most textile industry is developing on site or in-plant facilities to treat their own effluent before discharge (Banat *et al.*, 1996).

III EXPERIMENTAL SETUP AND PROCEDURE:

Commercially available reactive dye, CLB Red was obtained from one of the textile industry in Tirupur, Tamil Nadu. Distilled water was used to prepare the desired concentration of dyestuff solution. The simulated wastewater was prepared by dissolving a given amount of CLB Red in distilled water at initial dye concentrations of 0.01, 0.02 and 0.05%. The experimental device is schematically shown in figure (2). The EC unit consists of an electrochemical reactor which is a glass beaker with magnetic stirring, a D.C power supply and two Fe electrode materials were used as sacrificial electrodes. Here used this iron plates as the cathode and the consumable anode to generate ferric and/or ferrous ions.



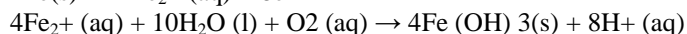
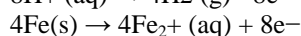
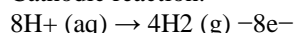
Experimental setup of electro coagulation cell

The iron cathodes and anodes were made from plates with dimensions of 9cm × 3.2cm × .5cm. The total effective electrode area was 28.16 cm² and the spacing between electrodes was 3cm. The electrodes were connected to a digital dc power supply (var tech) providing a current density ranging from 1.42 to 7.81 mA/cm². Before each run, electrodes were washed with acetone to remove surface grease, and the impurities on the iron electrode surfaces. 500ml electro coagulation cell that contained the 300 ml test solution with addition of 3% of sodium sulphate and a magnetic stirrer was used to stir the solution, thereby enhancing the efficiency. The current density was adjusted to a desired value and the coagulation was started. In each run, 300 ml of dye solution was

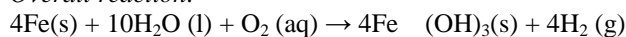
placed into the electrolytic cell. At the end of electro coagulation, the solution was filtered and then analyzed.

A number of researchers have investigated the theory of EC. Metal ion generation takes place at the anode and hydrogen gas is released from the cathode. The reactions are as follows:

Cathodic reaction:



Overall reaction:



The $\text{Fe}(\text{OH})_3$ remains in the aqueous phase as a gelatinous suspension, which can remove pollutants from wastewater either by electrostatic attraction or by complexation followed by coagulation.

Before every run, the iron electrodes were immersed for 5 min in dilute H_2SO_4 solution to remove oxide and then were rinsed with pure water. Finally, they were polished by sandpaper to further remove oxide. An aqueous solution (300 ml) containing CLB Red was placed into the electrolytic cell. In all experiments, adjusted the initial dye concentration, current densities, salt concentration, and distance between electrodes were fixed at the desired value before beginning the experiments.

Concentration of dye (%)	Absorbance (nm)		
	542	290	218
0.01	0.9215	1.7334	1.7249
0.02	1.871	3.4087	3.4043
0.03	2.5697	4.1348	4.1603
0.04	2.9697	4.2227	4.2558
0.05	3.6	-	-
0.06	4.1	-	-

The ultraviolet-visible spectrophotometer (Jasco V-670 spectrophotometer) was used to measure the wavelength (542 nm) of CLB Red. The equation used to calculate the colour removal efficiency in these experiments was:

IV COLOUR REMOVAL EFFICIENCY (%) = $100 \times (\text{A}_0 - \text{A}_t) / \text{A}_0$

Where A_0 and A_t were the absorbance of the dye in solution before electrocoagulation and at the time t , respectively.

The electrical conductivity and pH of different dye concentration were measured by using conductivity meter (Elico CM180) and pH meter (Eutech)

V RESULTS AND DISCUSSION

Here used an ultraviolet-visible spectrophotometer to measure the maximum wavelengths of three peaks (542 nm, 290nm, 218nm) of CLB Red. The ultraviolet

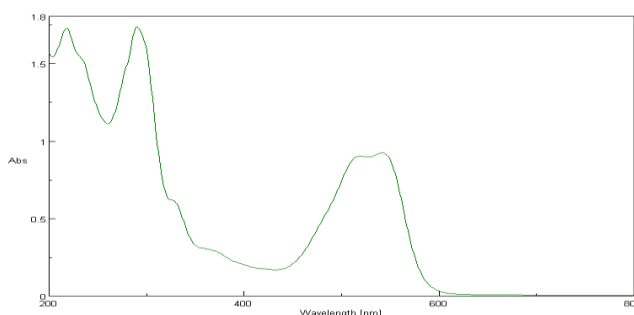


Figure 1: UV-visible spectrum of CLB Red dye

Visile spectrum of CLB Red for 0.01 % concentration and Calibration Table are shown below. Figure (2) shows that the calibration curve for CLB Red.

The ultraviolet visible spectrum of dye with addition of sodium]sulphate solution at 0.01% concentration, calibration table and calibration curve are given below figure(3), Table 2 and figure (4) respectively.

Table 1: Calibration Table for CLB Red dye alone

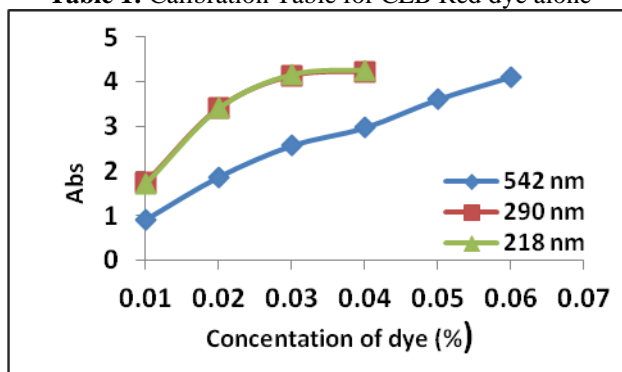


Figure 2: Calibration curve for CLB Red dye alone

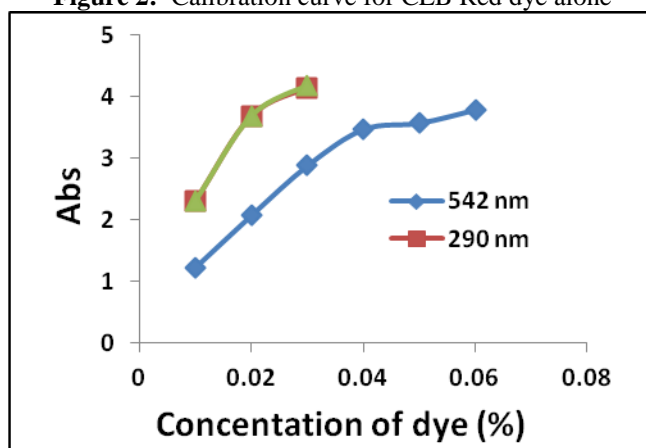


Figure 4: Calibration Curve for CLB Red dye with Na₂SO₄

Figure 3: UV-visible spectrum of CLB Red dye with Na₂SO₄

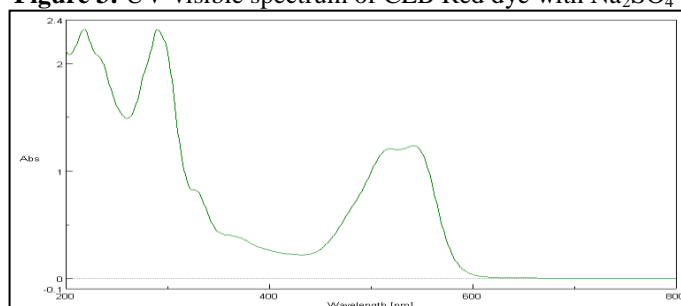


Table 2: Calibration Table for CLB Red dye with Na₂SO₄

Concentration (%)	Absorbance (nm)		
	542	290	218
0.01	1.23	2.309	2.313
0.02	2.079	3.691	3.687
0.03	2.887	4.144	4.181
0.04	3.476	-	-
0.05	3.577	-	-
0.06	3.793	-	-

Table 3: Electro coagulation for Concentration of dye is 0.01% (20 min)

Current density (A/m ²)	pH	Conductivity (mS)	Abs (542 nm)	Colour Removal efficiency (%)
0.106	6.30	0.32	1.097	12.09
0.142	6.28	0.30	1.037	16.82
0.213	6.24	0.26	1.008	19.15
0.280	6.19	0.25	0.9090	27.16
0.355	6.14	0.23	0.3707	70.35
0.426	6.03	0.21	0.1820	85.41

Table 4: Electro coagulation table for Concentration of dye is 0.01% (40 min)

Current density (A/m ²)	pH	Conductivity (mS)	Abs (542nm)	Colour Removal efficiency (%)
0.106	6.28	0.30	0.8897	28.70
0.142	6.25	0.27	0.8457	32.2
0.213	6.20	0.25	0.8052	35.4
0.280	6.18	0.23	0.6361	48.9
0.355	6.13	0.21	0.0566	95.4
0.426	6.02	0.20	0.0460	96.31

Table 5: Colour removal efficiency

Current density(A/m ²)	Colour removal efficiency (%)	
	20 min	40 min
0.106	12.09	28.7
0.142	16.82	32.2
0.213	19.15	35.4
0.280	27.16	48.9
0.355	70.35	95.4
0.426	85.41	96.31

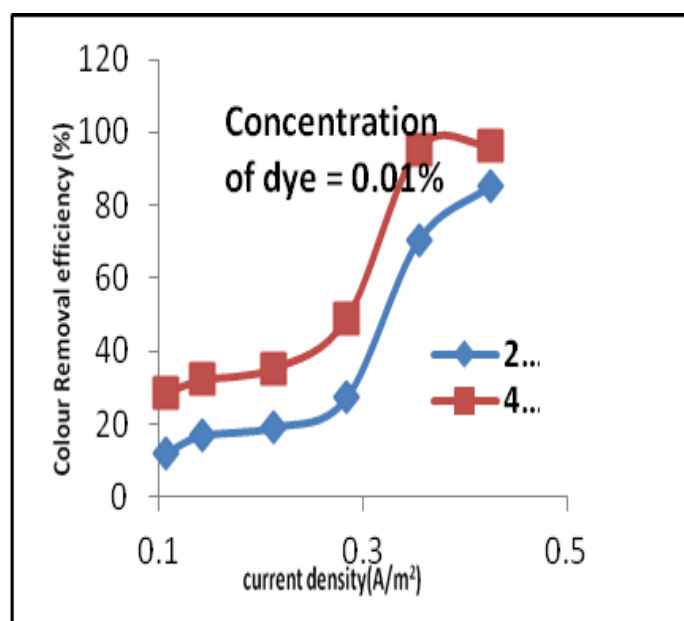


Figure 5: Colour removal efficiency (%)

Table 6: Electro coagulation table for Concentration of dye 0.02% (20 min)

Current density (A/m ²)	pH	Conductivity (mS)	Abs (542nm)	Colour Removal efficiency (%)
0.213	5.80	0.64	1.92	7.5
0.284	5.74	0.58	1.76	15.3
0.355	5.67	0.51	0.456	78
0.426	5.61	0.48	0.212	89.8
0.532	5.54	0.46	0.171	91.2

Table 7: Electro coagulation table for Concentration of dye 0.02% (40 min)

Current density (A/m ²)	pH	Conductivity (mS)	Abs (542nm)	Colour Removal efficiency (%)
0.213	5.78	0.60	1.64	20.7
0.284	5.71	0.54	1.56	24.6
0.355	5.62	0.42	0.145	93
0.426	5.57	0.35	0.119	94.2
0.532	5.51	0.31	0.088	95.7

Table 8: Colour removal efficiency

Current (mA)	Colour removal efficiency (%)	
	20 min	40 min
0.213	7.5	20.68
0.284	15.34	24.57
0.355	43.67	93
0.426	89.79	94.25
0.532	91.2	95.76

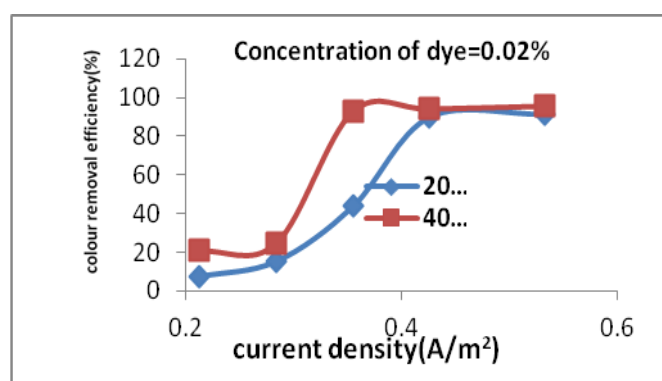


Figure 6: Colour Removal Efficiency

Table: 9 (Time - 40 min)

Current density (A/m ²)	Colour Removal efficiency (%)	
	pH - 6.36	pH - 7.5
0.142	32.2	31.8
0.213	35.4	40.62
0.284	48.9	63
0.355	95.4	96.6
0.426	96.31	98.9

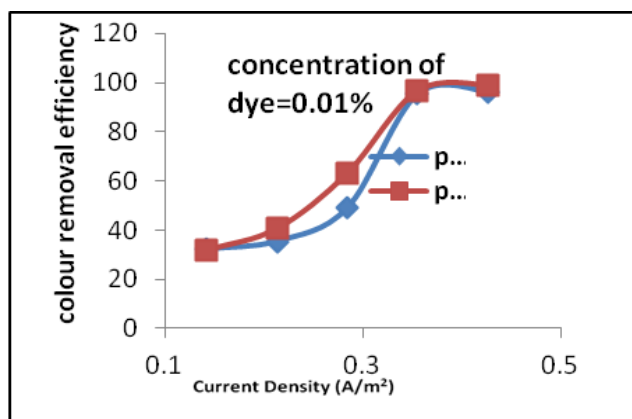


Figure: 7 Colour Removal Efficiency

Table: 10 (40 mins)

Current density(A/m ²)	Colour Removal efficiency (%)	
	pH-5.56	pH - 7.5
0.532	10.3	12.8
0.603	96.8	97.7
0.639	97.1	98.1
0.71	96.3	98.9
0.781	95.5	97.8

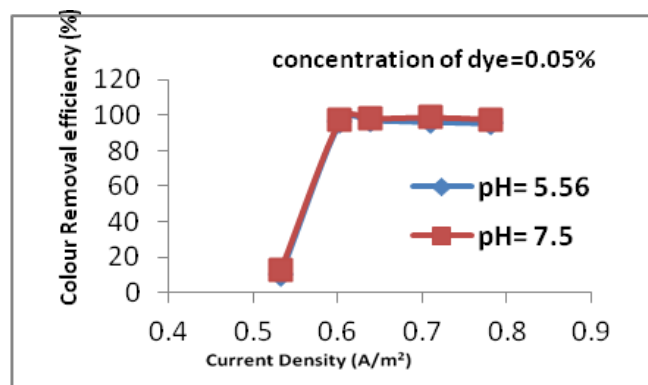


Figure: 8 Colour Removal Efficiency

1. **Effect** of current density on the efficiency of colour removal. In all electrochemical process, current density is the most important parameter for controlling the reaction rate within the reactor. It is well known that the amount of current density determines the coagulant production rate, and adjusts the rate and size of the bubble production, and hence the growth of flocks.

Figures 5, 6, 7 show the effect of current density applied on the colour removal in the EC process. Increasing the current density causes a corresponding increase in the oxidized iron production from electrodes, so the higher the current density is, the higher the colour removal efficiency. The current density determines the coagulant dosage rate. Thus, this parameter should have a significant impact on the removal efficiency of the pollutants.

Fig (5) depicts the effect of current density on the colour removal efficiencies. The colour removal efficiency was increased to 85% at 0.425A/m² from 12% at 0.106 A/m² after 20 min reaction. And the colour removal efficiency was increased from 28% to 96% at the same concentration and the same current density when changed time 40 min instead of 20 min reaction. At a high current density, the extent of anodic dissolution of iron increases, resulting in a greater amount of precipitate and removal of CLB Red dye molecule.

2. Effect of initial concentration on dye removal efficiency Comparing the figures (5) and figure (6) it may be seen that increasing initial dye concentration results in decreasing removal efficiency. At 0.213

A/m² The colour removal of 0.01% dye concentrations for 20 & 40 minutes were 19 & 35% while in the 0.02% concentration it shows 7 and 20 percentages. Figure (8) shows the colour removal efficiency of 0.05% dye concentration it also indicate that over 95% of removal efficiency was attained when applied current density more than 0.639A/m².

3. Effect of initial pH on the efficiency of colour removal.

It has been established that the influent pH is an important parameter influencing the performance of the EC process. To examine its effect, the dye solution was adjusted to the desired pH for each experiment by adding sodium hydroxide or sulphuric acid solution.

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