

Comparison of Different Electrocoagulation Processes for Real Wastewater Degradation

Mona A. Abdel-Fatah^{1*}; Ahmed M. Awad¹; Enas M. Ahmed¹; and Ahmed T. El-Aref²

Abstract— Real wastewater containing a well defined reactive dye as one of the contaminants was subjected to a number of degradative treatments. The main problem of textile wastewater is the deep colour which must be removed before discharge to the main environmental drainage. A plan for treating this wastewater was designed to involve electrocoagulation (EC) using aluminium and iron electrodes as well as electrocoagulation / Fenton treating processes. A follow up of the extent of degradation was carried out through estimation of chemical oxygen demand (COD), colour reduction and change of pH value. The deep colour of wastewater has been sufficiently removed as much as between 84.8 % and 98.6 % decolourization efficiency depending on EC process and initial pH of the coloured medium. A comparative correlation between EC processes employed at pH 3 revealed that COD removal and decolourization were superior to those at pH 9 especially on applying EC/Fenton process. In addition, the measurements of Fe and Mn contents using atomic absorption technique revealed the total removal of both % Fe and Mn after EC/Al process, while % Fe was slightly increased due to the external Fe²⁺ added after EC/Fenton process. XRD was used to specify the sludge precipitated after processes, the main precipitated materials detected were magnetite Fe₂₄O₃₂, Pyroxene-ideal Al₄Na₄Si₈O₂₄

Keywords: Reactive dyes, Wastewater Treatment, Electrocoagulation, Oxidation processes.

1 INTRODUCTION

The main problem of textile wastewater is deeply colored matters which must be removed before discharge to the main drainage. One of the major challenges facing mankind today is to provide clean water to a vast majority of the population around the world. The need for clean water is particularly critical in Third-World Countries. Rivers, canals, estuaries and other water-bodies are being constantly polluted due to indiscriminate discharge of industrial effluents as well as other anthropogenic activities and natural processes [1].

Water quality and available quantity are being challenged by increased pollution from point and non-point sources such as industry and agriculture, respectively, and the ever-increasing population. Third-world countries generally have neither the infrastructure nor capital to adequately address the water problem. Although the wastewater treatment process is a well-established engineering science, the need for process incorporation, decentralized treatment and simplified processes have opened new challenges and new opportunities particularly in developing countries [2].

Treatment of wastewater by electrocoagulation (EC) has been practiced for most of the 20th century with limited success and popularity. In recent years, various treatment technologies have been employed to enhance water quality by removing inorganic contaminants. Both photo and electrochemical oxidation technologies recently have become more popular in water treatment [3]. In addition, these technologies have been increas-

ingly used in South America and Europe for treatment of industrial wastewater containing metals [4].

At present, a large part of pollution in the public water system is caused by industry. The textile industry represents an important economic sector in many countries, but in parallel generates large amounts of heavily polluted wastewater. This industry in particular has been classified as a major polluting industry because of the large volumes of wastewater that are typically discharged to surface water. To protect the eco-balance, the removal of dyes and other toxic contaminants from textile effluent has become imperative. Many of these organic dyes applied in dyeing processes resist conventional chemical and biological wastewater treatment due to their complex poly aromatic structure, and hence they cause aesthetic and environmental problems [5].

Hence removal of effluent colour has become the integral part of effective textile wastewater treatment. Dyestuffs and textile industries have become increasingly subject to international, federal and state regulation, since 1970, designed to improve health, safety and environment. The removal of colouring contaminants from wastewater is, therefore, a challenge to the related industries.

Like many other industrial effluents, textile industry wastewater not only varies significantly in quantity, but also in composition. Textile wastewater is highly coloured which creates an environmental as well as aquatic problems. Pollution of water by dyes is a serious problem in the developed countries. Many industries use dyes to colour their products. These highly coloured components when discharged in the water drainage stop the re-oxygenation capacity of the receiving water and cut-off sunlight, thereby upsetting biological activity in aquatic life.

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Furthermore, the expanded use of dyes has shown that some of them and some of their reaction products, such as aromatic amines, are highly carcinogenic [6].

The principal route by which dyes enter the environment is via wastewater from batch processes in both the dye-manufacturing and the dye-consuming industries. For textile dyeing operations, Brown [7] has indicated that the predicted environmental concentration (PEC) of dye in receiving water may be calculated from daily use of the dye, degree of dye fixation on substrate, degree of dye removal during any effluent treatment process and dilution factor in the receiving water.

The use of reactive dyes has increased ever since their introduction in 1956, especially in industrial countries. Reactive dyes are bearing functional groups that form covalent bonds with -OH, -NH, or -SH groups in fibres (cotton, wool, silk, nylon). Timothy & Southern [8] reported that many researchers have studied the treatment of wastewater by different methods such as concentration technologies; Membrane technologies; use of adsorbents; biochemical oxidation and to a more limited extent bio-reduction and chemical oxidation technologies. Innovative, cheap and effective methods of purifying water for human consumption as well as to clean the wastewater from industrial effluents before discharging into any other water systems are needed.

Coagulation is a phenomenon in which the charged particles in colloidal suspension are neutralized by mutual collision with counter ions and are agglomerated, followed by sedimentation. Electrocoagulation (EC) is an electrochemical wastewater treatment technology that is currently experiencing both increased popularity and considerable technical improvements. Electro-Fenton process involves the combined advantages of electrochemical and Fenton treatment methods, and each of them is a powerful treating choice.

In the present work, it is required to know that the strategy should be based on search for comprehensive solutions to this problem, mainly in the developing countries. Most organic compounds are resistant to conventional chemical and biological treatments. For this reason, other methods are being examined as an alternative to biological and classical physico-chemical processes. A comparative study of electrocoagulation using different types of electrodes; electro-Fenton and Advanced Oxidation Process (AOP) methods have been investigated by treating real wastewater (RWW) of Al-Alamia Company for Dyeing & Finishing, 10TH of Ramadan, industrial region Egypt.

2. EXPERIMENTAL

2.1. Materials

Samples of textile dyeing wastewater were collected from the dyeing sector of Al-Alamia Company for Dyeing & Finishing, 10th of Ramadan, industrial region Egypt. The dyestuff employed in this stage was C.I. Reactive Black 5 (RB5). Specifications of RB5 are displayed in Table 1 whereas characteristics of the collected RWW mixed with the simulated rinsing process

water are illustrated in Table 2.

Table 1: Specifications of RB5 reactive dye

Reactive Black B	C.I. Reactive Black 5 (RB5)
Synonym:	Remazol Black B
	Tetra-sodium (3Z)-5-amino-4-oxo-6-[4-(2-sulfonatoxyethylsulfonyl)phenyl] diazenyl-3-[[4-(2-sulfonatoxyethylsulfonyl)phenyl] hydrazinylidene] naphthalene-2,7-disulfonate
Molecular Formula	C ₂₆ H ₂₁ N ₅ Na ₄ O ₁₉ S ₆
Molecular Weight	991.82 g/mol
Color Index No.	20505
CAS Number	12225-25-1
Composition	Dye content 55%
Wavelength max	597 nm

Table 2: Characteristics of dye house effluent and simulated rinsing process water.

pH	Temperature (°C)	λ_{max} (nm)	Colour (absorbency)	COD (mg/l)
8.54	25±2	600	0.812	1810

2.2. Procedures

2.2.1. Treatment of Real Wastewater

Real wastewater (RWW) from the drain of dyeing and process factory was employed for the electrochemical treatment. Electrocoagulation method was applied using electrodes of aluminum and iron. Hybrid method of combined electrocoagulation and Fenton oxidation was adopted and compared with other methods. The experiments were carried out at constant potential 10V for 60 minutes. Electrodes of aluminum 99.5% and iron 99% (11 x 7.5 cm) were used for the generation of positive electric field. Graphite electrode was used as cathode for generation of negative electric field. Glass cell 10 x 8 x 15 cm was used as the electrolytic cell where two electrodes system was employed. GW 3030 was used as the power supply for supporting DC electric current through waste water solution. The most widely used electrode materials in electrocoagulation process are aluminum and iron, whereas steel electrodes are employed in few studies.

2.1.2. Electrocoagulation using Aluminum Electrode

Electrocoagulation (EC) is electrochemical water and wastewater treatment technology which in its simplest form uses an electrochemical cell where a DC voltage is applied to the electrodes, usually made of Iron or Aluminum, and the electrolyte is represented by water or wastewater. In this process, Al electrode was connected with DC power supply (30 V/3A) into electrolytic cell as anode, where wastewater was employed as the electrolyte. Graphite electrode was used as cathode and connected with the negative terminal of DC power.

2.1.3. Electrocoagulation using Iron Electrode

In the same cell, aluminum electrode was replaced by iron electrode as an anode for the treatment of dye containing wastewater. Graphite electrode was also used as a cathode and both electrode were connected with the DC power supply, where electric current was passed through the electrolyte wastewater.

2.1.4. EC using Iron Electrode and Fenton Reagent

This combined was conducted where process, Fe electrode was used as anode for Fe²⁺ ions generation of the surface to the solution. Graphite was used as cathode, where electric current was passed between both electrodes according to potential applied (10 V).

2.1.5. X-Ray Diffraction

A Philips X-Ray Diffraction equipment model X'Pert PRO with Monochromator, Cu-radiation ($\lambda=1.542\text{\AA}$) at 50 K.V., 40 M.A. and scanning speed 0.020/sec. were used. The reflection peaks between $2\theta = 2^\circ$ and 60° , corresponding spacing (d, \AA) and relative intensities (I/I₀) were obtained. The diffraction charts and relative intensities are obtained and compared with ICDD files.

2.1.6. X-Ray Fluorescence (XRF)

The XRF analysis was carried out for powder (<200 mesh) samples using a philips X-Ray fluorescence equipment model PW/2404, with Rh radiation tube and eight analyzing crystals. Crystal (LIF-200) was used for estimating Ca, Fe, K, Ti and Mn, while crystal (TIAP, PX-1) was used for determining Mg and Na. Crystal (Ge) was used for estimating P and crystal (PET) for determining Si and Al. The Concentration of the analyzed elements was determined by using software Super-Q with accuracy 99.5% and confidence limit 95.6%.

2.1.7. Atomic Absorption Spectroscopy (AAS)

Atomic absorption spectroscopy (AAS) is known to be a spectro-analytical procedure for the quantitative determination of chemical elements using the absorption of optical radiation (light) by free atoms in the gaseous state. The analytical chemistry technique used is SM-3111 by an atomic absorption spectroscopy model GBC -Avanta - Sigma for determining the concentration of a particular element in a sample to be analyzed.

3. RESULTS AND DISCUSSION

The current work is undertaken with view of development of desired wastewater treatment via Electrocoagulation (EC). Hence, a target is designed to fulfil these requirements. Methodology of the treatment involving electrocoagulation and electro coagulation / electro Fenton has been investigated. A number of analyses, assessments and evaluations of the treated samples have been carried out. Results obtained and their appropriate discussions are given below in some details.

3.1. Electrocoagulation Processes

Current theory of EC states that it involves several successive

stages:

1. Generation of metal ions.
2. Hydrolysis of metal ions and generation of metal hydroxides and polyhydroxides. This is beyond question; it has been studied and explained for coagulation process in water treatment.
3. Water is also electrolyzed in a parallel reaction, producing small bubbles of Oxygen at anode and Hydrogen at the cathode. Although, the presence of magnetite and magnetite identified in EC sludge can suggest oxygen evolution at the anode this does not happen. To examine whether there is O₂ evolution, an EC cell was prepared using two cylindrical iron electrodes supported on a PVC stand and covered with graduated cylinders full of water to observe the displacement of water if any gas is generated.

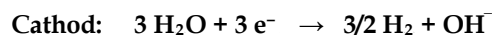
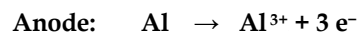
3.1.1. Electrocoagulation using Aluminum Electrode

Electrocoagulation (EC) technology offers an alternative to the use of metal salts or polymers and polyelectrolyte addition for breaking stable emulsions and suspensions. The technology removes metals, colloidal solids and particles, and soluble inorganic pollutants from aqueous media by introducing highly charged poly metal hydroxide species. Electrocoagulation of wastewater using an aluminum electrode has been reported elsewhere [9-13].

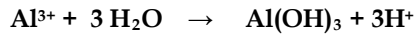
The electrical current causes the dissolution of metal into wastewater. The metal ions, at an appropriate pH value, can form wide ranges of coagulant species and metal hydroxides that destabilize and aggregate the suspended particles or precipitate and adsorb dissolved contaminants [14]. After few minutes, a high effervescence was observed adjacent to Al electrode as a result in the oxidation of Al surface to Al ions:

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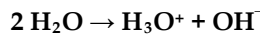
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The generated Al³⁺ and OH⁻ react with each other to form Al(OH)₃.

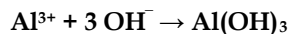


At the same time water molecules was decomposed by electric current:



Where OH⁻ groups were formed and play an important role for the organic compounds oxidation to form short chain compounds and evolution of CO₂, SO₂, NO₂ and H₂.

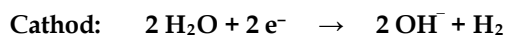
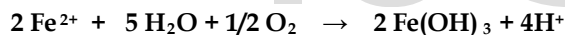
On the other hand, OH⁻ group react with Al³⁺ ions to form high adsorbable and coagulant Al(OH)₃, it can be called flocks:



The adsorption of suspended ions released the Al(OH)₃ weigh and then all of them settled down and separated by filtration.

3.1.2. Electrocoagulation using Iron Electrode

Iron upon oxidation in an electrolytic system produces iron hydroxide, Fe(OH)_n, where n = 2 or 3. The Fe(OH)_n(s) formed remains in the aqueous stream as a gelatinous suspension, which can remove the pollutants from wastewater either by complication or by electrostatic attraction, followed by coagulation. In the case of iron electrode, the mechanisms for the production of metal hydroxide can be represented as given below [15]:



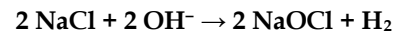
Electric current was passed according to the potential difference between electrodes. Fe²⁺ ions were generated on iron electrode (by anodic oxidation) and move to the solution. Ferrous hydroxide Fe(OH)₂ was formed into the bulk of the solution and behave as a flocks suspended into the solution. These flocks have the ability to absorb most of suspended contaminants by coagulation and then settled down. Fe(OH)₂ may be oxidized to Fe(OH)₃ which behave as coagulant for the suspended matter and then Fe(OH)₃ and adsorbed species were settled down by gravity force.

During electro-coagulation process, metal hydroxides flocks formation occurs, these flocks have a large surface area, which are beneficial for a rapid adsorption of soluble organic compounds and trapping of colloidal particles. Finally, these flocks are removed easily from aqueous medium by sedimentation or flotation.

An impermeable oxide film may be formed on the cathode leading to loss of efficiency of the EC unit; High conductivity of the wastewater suspension is required. Gelatinous hydrox

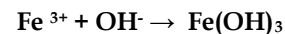
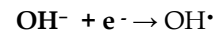
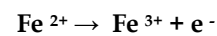
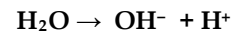
ide may tend to solubilize in some cases. Addition of NaCl has

the advantage of increasing conductivity at the wastewater solution and guarantees the high electric current density which; accelerate the oxidation reaction. Also, a new oxidant species like NaOCl was formed and participate in the oxidation of organic compounds by OCl⁻ hypochlorite ions.



3.1.3. Electrocoagulation/Fenton

Fe(OH)₂ was formed by electric oxidation at electrode surface and the electrolysis of water molecules. Moreover, Fenton reagent was added to the electrolytic solution waste water in this case including 1 g FeSO₄, 5 ml of H₂O₂ (30 %). The presence of Fenton reagent pairs the conditions of highly oxidant hydroxyl group free radical OH•.



Hydroxy free radical species has an oxidation force higher than OH⁻, so organic compounds were inherently oxidized and COD value was expected to decrease with higher limits due to the high in concentration of hazardous long chain materials to safe short chain materials.

Changes of pH, COD values and Color

Real wastewater of pH 9 was used as the electrolytic solution into the electrocoagulation cell using either iron or aluminum electrodes. The electrocoagulation treatment at initial pH, 9 using both iron and aluminum electrodes for samples 2 and 3 induced an increase in the pH value to 10.59 and 10.84 respectively when the initial pH value of the real waste water was 9 which could be explained by the excess of hydroxyl ions produced at the cathode. While as in case of electrocoagulation and Fenton (sample 4), the pH has been slightly altered. Both color and COD were considerably decreased as displayed in Table 2.

Table 2: Characteristics of treated IWW (Initial pH, 9; Temperature, 25 ± 2 ° C)

Likewise, the electro-coagulation treatment at initial pH, 3

Sample No.	Sample	pH	COD (%)	Color Removal (%)
1	Blank	9	0	0
2	EC/iron	10.59	50.4	90
3	EC/Aluminum	10.84	43.1	92.7
4	EC/Fenton	9.52	41.3	84.8

using both iron and aluminum electrodes and electrocoagulation /Fenton (sample 5, 6 and 7) also give rise to an increase in the pH values (Table 3).

Table 3: Characteristics of treated IWW (Initial pH, 3; Temperature, 25 ± 2 ° C)

By applying electric current, a few amounts of Fe²⁺ and Al³⁺ ions were generated at the surface of both electrodes by elec-

Sample No.	Sample	pH	COD (%)	Color Removal (%)
5	EC/iron	7.8	65.7	94.7
6	EC/Aluminum	8.1	60.9	93.7
7	EC/Fenton	6.2	66.6	98.6

trochemical oxidation in alkaline medium pH 9. The charges transfer was reduced in alkaline medium comparing with acidic medium (pH 3).

In addition, the efficacy of Fenton reagent is imploded at pH 9 due to low •OH generation in the deficient of H⁺ and then low oxidation of the organic contaminants was occurred. On the other hand, in acidic medium (pH 3), high amounts of Fe²⁺ and Al³⁺ ions were generated by electrochemical oxidation, where excess flocks of Fe(OH)₂ and Al(OH)₃ were formed which own high adsorption force for the suspended ions. Charges transfer was improved at pH 3 than pH 9, this renders to the high conductivity of the solution in the presence of free H⁺.

Moreover, in acidic medium Fe(OH)₂ of higher adsorption force remains a long time into the solution during electrochemical treatment more before turning to Fe(OH)₃. It was observed that the high COD values were obtained at pH 9 due to low concentration of Fe²⁺ and Al³⁺ ions and low charges transfer. So, COD values were slightly decreased from 1860 to 1080 and to 980 mg/l using Fe and Al electrodes, respectively. In addition, low effect of Fenton reagent was expected in alkaline medium (pH 9), so, low removal efficiency (COD=1080 mg/l) was obtained. Low charge transfer leads to slowing down the ionic mobility through the solution for redox reactions in both positive and negative electric field regions, as a result the presence of low electric current intensity and low degradation of contaminants.

In contrast, using acidic medium (pH 3), there is a high concentration of H⁺, which stimulate the generation of Fe²⁺ and Al³⁺ ions by high current efficiency of electrochemical oxidation. Also, the efficacy of Fenton reagent was highly improved using initial pH 3, where high numbers of OH radicals were formed, so COD values were obviously decreased. (COD= 605 mg/l). The results revealed that decolourisation due to the attack of the chromophoric groups by hydroxyl ions might be a primary step and COD removal indicated the ultimate oxidation of wastewater as shown in Figure 1.

Effect of pH (EC/Iron)

The effect of initial pH on the COD removal efficiency during the treatment of the dye wastewater was investigated. To examine effect of pH, a series of experiments were performed by adjusting the initial pH in the interval from 3, 5, 7 and 9.



Figure 1: Real and treated wastewater samples using different electro-processes (1) real wastewater (2) treated sample using iron electrode (3) treated sample using aluminum electrode (4) treated sample using electrocoagulation/Fenton method.

The effect of pH on EC is presented in Figure (2), which indicates that COD removal was decreases by increasing the pH value. We observed that although the maximum COD and color removal was obtained at pH around 3, the pH effect was not very significant in the range studied. When the pH is increased from 7, the amount of hydroxide ions in solution is increased. Consequently, some of the hydroxide ions are probably oxidized at the anode. This action prevents the production of the same proportion of the iron ions and therefore the removal of COD decreased.

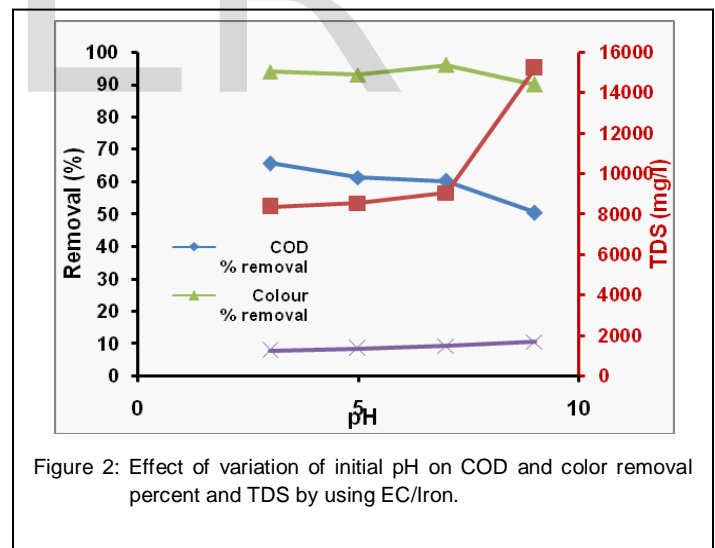


Figure 2: Effect of variation of initial pH on COD and color removal percent and TDS by using EC/Iron.

3.3. X-Ray Diffraction

3.3.1. Electrocoagulation using Aluminum Electrode

In this process aluminum ions were produced via anodic oxidation and move under the influence of electric potential (10V) towards the bulk solution to combine with hydroxyl groups and formation of aluminum hydroxide Al(OH)₃. Aluminum hydroxide is characterized by high adsorption, gelatinous flocks, and suspended colloids, so, it is advantageously formed into the solution to adsorb the paramount of suspend-

ed ions. Consequently, they settled down as precipitated sludge separated by filtration and then characterized by XRD analysis. XRD analysis revealed the presence of high content of Pyroxene-ideal 65% of chemical formula $Al_4Na_4Si_8O_{24}$, Magnetite 16% of chemical formula $Fe_2_4O_{32}$, Omphacite 11% of chemical formula $Na_{2.1}Ca_{1.9}Mg_{1.87}Fe_{0.32}Al_{1.81}Si_8O_{24}$ and Quartz Si_3O_6 7%. In this sample, it may be possible that iron aluminum spinel ($FeAl_2O_4$) to be formed (Figure 3 and Table 4).

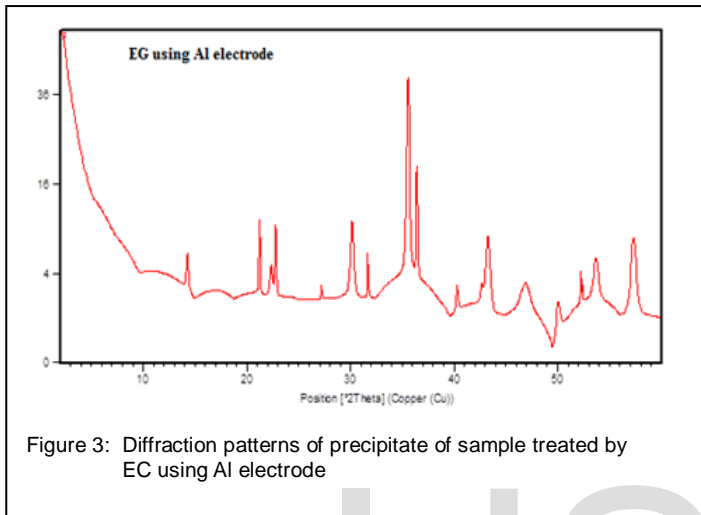


Figure 3: Diffraction patterns of precipitate of sample treated by EC using Al electrode

Table 4: XRD of the precipitate of EC process using aluminum electrode

Ref. Code	Mineral Name	Chemical Formula	Semi Quant [%]
96-900-7707	Magnetite	Fe 24.00 O 32.00	16
96-900-3407	Pyroxene-ideal	Al 4 Na 4 Si 8 O 24	65
96-901-2602	Quartz	Si 3.00 O 6.00	7
96-900-9603	Omphacite	Na 2.1 Ca 1.9 Mg 1.87 Fe 0.32 Al 1.81 Si 8 O 24	11

3.3.2. Electrocoagulation using Iron Electrode

During the process, Fe^{2+} ions are liberated from anode and migrate towards the bulk solution of highly OH^- groups produced from the decomposition of water molecules. So, $Fe(OH)_2$ was easily formed as a fine greenish flocks suspended in the solution. These flocks are characterized by highly adsorption force to suspended ions and behave as colloids in the solution, and then these particles were settled down by gravity with continuous aggregation of ions.

XRD patterns of process 2 revealed that the precipitation contains mainly minerals such as Magnetite 62 % of chemical formula $Fe_{24}O_{32}$ and Diopside 38% of chemical formula $Na_2Ca_2Cr_2Mg_2Si_8O_{24}$. In this sample, low content of Magnetite $Fe_{21.16}O_{31.92}$ and traces of Cristobalite SiO_2 are expected to be present (Figure 4 and Table 5).

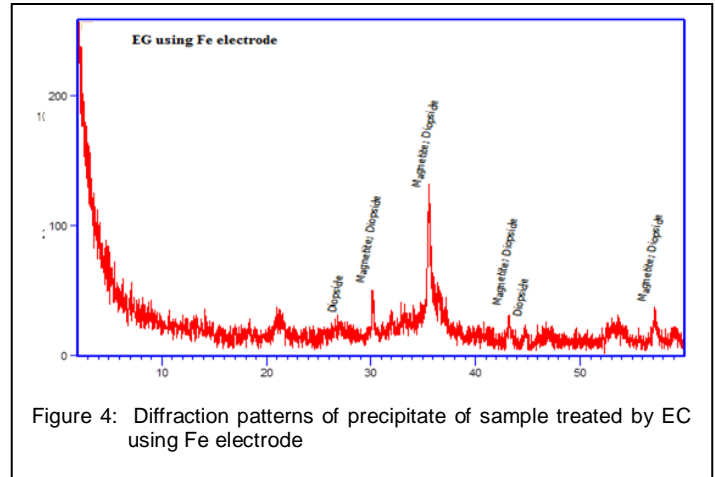


Figure 4: Diffraction patterns of precipitate of sample treated by EC using Fe electrode

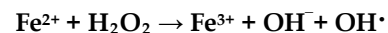
The results of XRF revealed the presence of 73 % of Fe_2O_3 , SO_3 36 %, Na_2O 9%, CaO 4% as shown in Table 5.

Table 5: XRD of the precipitate of EC process using an iron electrode

Ref. Code	Mineral Name	Chemical Formula	Semi Quant [%]
96-900-5839	Magnetite	Fe 24.00 O 32.00	62
96-900-5703	Diopside	Na 2.00 Ca 2.00 Cr 2.00 Mg 2.00 Si 8.00 O 24.00	38

3.3.3. EC using Fe Electrode and Fenton Reagent

In this process, it is expected that high oxidation originated from both anodic oxidation and chemical oxidation by addition of H_2O_2 and $FeSO_4$ may influence the removal efficiency and precipitation of salts. There is a high probability for the formation of highly oxidant hydroxyl free radical OH^\bullet , which is produced according the reaction



X-ray diffraction analysis of the sludge revealed the presence of a few amorphous humps in the XRD chart. The major content appeared was Magnetite 85% of chemical formula $Fe_{24}O_{32}$, Garronite 10% of chemical formula $Ca_2.80Al_5.66Si_{10.34}O_{32.00}At_{13.76}$ and Eosphorite 5% of chemical formula $Mn_{6.4}Fe_{1.6}Al_8P_8O_{56}H_{32}$ (Figure 5 and Table 6).

Table 6: XRD of the precipitate of EC process using aluminum electrode

Ref. Code	Mineral Name	Chemical Formula	Semi Quant [%]
96-901-0942	Magnetite	Fe 24.00 O 32.00	85
96-900-5299	Garronite	Ca 2.80 Al 5.66 Si 10.34 O 32.00 At 13.76	10
96-900-9484	Eosphorite	Mn 6.40 Fe 1.60 Al 8.00 P 8.00 O 56.00 H 32.00	5

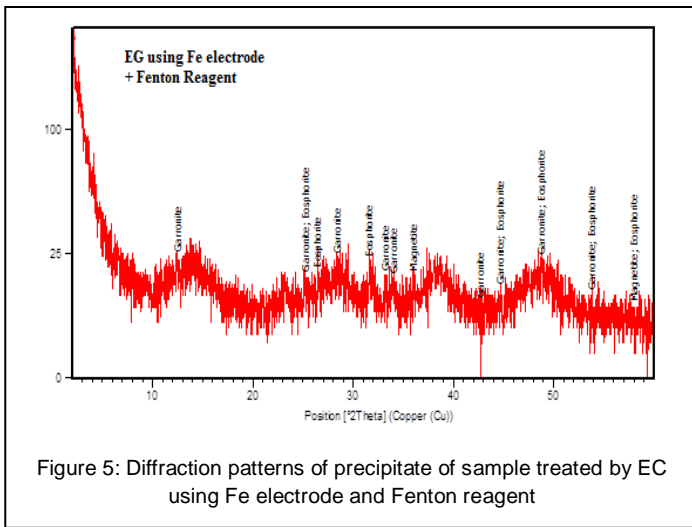


Figure 5: Diffraction patterns of precipitate of sample treated by EC using Fe electrode and Fenton reagent

Table 7 illustrates the results obtained for samples under investigation after measurements of Atomic Absorption. The results revealed that Fe^{2+} concentration was reduced from 0.15 to 0.11 mg/l and 0.02 mg/l by EC using iron and aluminum electrodes at initial pH 9, respectively. This indicates that the adsorption force of $Al(OH)_3$ flocks have a higher strength more than $Fe(OH)_2$ flock for Fe^{2+} ions attraction and sorption.

On the other hand, the Mn^{2+} concentration was decreased from 0.035 mg/l to 0.019 mg/l and 0.001 by EC using iron and aluminum electrodes, respectively. Using iron electrode and Fenton reagent (ferrous sulphate heptahydrate $FeSO_4 \cdot 7H_2O$ and H_2O_2); indicates a mild increase of both Fe^{2+} and Mn^{2+} concentrations.

Table 7: Atomic Absorption of the precipitate of the treated samples for samples treated at pH, 3 and 9

pH	Method	Fe^{2+}	Mn^{2+}	T.D.S
	Blank	0.15	0.035	15200
3	EC/Fe	0.26	0.86	9080
	EC/Al	N.D	N.D	8560
	EC/Fenton	0.9	0.26	8970
9	EC/Fe	0.11	0.019	14880
	EC/Al	0.02	0.001	20320
	EC/Fenton	0.18	0.038	18560

Moreover, the treatment at pH, 3, the results showed that increase of Fe^{2+} concentration by EC using iron electrode, while

as in case of EC using aluminum electrode the presence of Fe^{2+} and Mn^{2+} was nil. The treatment by EC/Fenton at pH, 3 causes a marked increase of Fe^{2+} from 0.15 mg/l to 0.9 mg/l, the production of Fe ions may due to the effect of pH 3. The addition of H_2O_2 may accelerate the oxidation of highly adsorption $Fe(OH)_2$ molecules to low adsorption of $Fe(OH)_3$ molecules and hence a few amounts of Fe^{2+} and Mn^{2+} were adsorbed and remain in the solution. Also Mn^{2+} was slightly increased to 0.26 mg/l. Total dissolved solids was decreased in all treatment processes, but the decrease was marked at pH 3.

CONCLUSION

The performance of electrochemical processes of EC/iron, EC/aluminum and EC/Fenton were investigated for the treatment of real textile wastewater. All the processes sufficiently removed color from the wastewater in as much as between 84.8% and 98.6%. The experimental results revealed that the COD removal efficiency dependant on the initial pH of the colored waste water and the process employed. A comparative correlation between EC processes employed at pH 3 revealed that COD removal and decolourization were superior to those at pH 9 especially on applying EC/Fenton process. The results showed that the treatment and the removal of Fe and Mn is influenced by pH value, the process EC/Al revealed the best removal efficiency of Fe and Mn at pH 3 (non detected) and TDS was also decreased from 15200 to 8560 ppm. XRD analysis of sludge showed the main precipitation of 62 % Magnetite Fe_2O_3 using EC/Fe, the precipitation of 65 % Pyroxene-ideal $Al_4Na_4Si_8O_{24}$ using EC/Al and the precipitation of 85 % Magnetite Fe_2O_3 using EC/Fenton reagent.

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