Mineralization of Synthetic and Industrial Food Effluent Containing Acid Red18 by Electro-Fenton Process using a Graphite-Felt Cathode

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Abstract: ***The oxidation of Acid Red18, in aqueous solutions by electro-Fenton method was optimized.The reactor is an undivided glass electrochemical cell with a graphite-felt cathode and a platinum anode. The value of 250 mA as applied current and** Fe^{2+} **as a catalyst with a concentration of 0.5 mM are found to be the optimum operating parameters for the efficient mineralization of** $6.6X10^{-2}$**mM of AR18. The evolution of its concentrations with processing time shows a pseudo first order kinetics. The relevance of the process was then confirmed on a Tunisian industrial food effluent. Progress of decolorization through treatment time was monitored; it achieves 100% decolorization for the AR18 synthetic solution and 98% for the industrial effluent. Mineralization of the dye solutions were examined by the estimation of the chemical oxygen demand removal, which achieves 73% for the synthetic AR18 solution and 50% for the industrial effluent after 4h of treatment. The energy consumption per unit COD mass (**EC_{COD}**) of the EFP is determined for the treatment of AR18 synthetic solution and for the real industrial effluent.***

Keywords: Azo Dye, Advanced Oxidation Processes, Hydroxyl Radicals, Mineralization, Industrial Effluent.

1. Introduction

Environment contamination by toxic substances has been associated with society since the beginning of industrialization. Their presence in the environment through many pathways, including industrial discharges, municipal waste and run-off from agricultural induce environmental hazards [1]. Over 800,000 tons of dyestuffs are annually produced throughout the world. An amount of 10–15% of dyes is released into the environment during manufacturing, and it has been estimated that 60–70% of the total dyes produced per year, are azo dyes [2]. In fact synthetic azo dyes are widely used in food colorants, textile, printing, cosmetic, and pharmaceutical industries. The use of these dyes as food additives is prohibited in some countries due to their mutagenic and/or carcinogenic actions, while in others, they are used indiscriminately [3]. Studies have shown that azo dyes are difficult to biodegrade under aerobic conditions [4].As reported in many studies, azo dyes and their breakdown products are toxic, mutagenic and carcinogenic to both humans and aquatic life [2]. The release of important amounts of synthetic dyes to the environment causes public concern and introduces serious challenges for environmental scientists.

Various methods for the removal of synthetic dyes from wastewaters have been reported in the literature using biological microorganisms (biodegradation) and/or physico-chemical processes (flocculation,chlorination and ozonation), usually followed by filtration and adsorption based separations, which are capable of treating a majority of anthropogenically-polluted water sources [5]. However these traditional wastewater treatment technologies are ineffective for handling wastewater of synthetic dyes because of the chemical stability of these pollutants. Moreover, the cost of these processes and their production of secondary waste products such as sludge may need further disposal as well as refractory toxic chemicals [6],[5]. The focus on more efficient waste treatments resulted in the discovery of Advanced Oxidation Processes (AOPs). AOPs are emerging alternative technologies for efficient removal of organic wastewater pollutants with high chemical stability and low biodegradability.The main function of AOPs is the generation of highly reactive hydroxyl radicals (HO•) at nearly ambient temperature and pressure that react rapidly, unselectively and are effective in destroying organic pollutants into non-toxic products like CO_2, H_2O and inorganic salts [7], [5]. These radicals react with organic pollutants and thus lead to their degradation by hydrogen abstraction reaction (dehydrogenation), electron transfer (oxido-reduction) or electrophilic addition to π systems (hydroxylation) reactions [8]. Electro-Fenton oxidation method as an indirect electrochemical advanced oxidation process was developed and widely applied for oxidation of various organic pollutants. Several publications describe the efficiency of decolonization of azo dye as well as their complete mineralization [9]-[14]. In this process, H_2O_2 is continuously generated in the contaminated solution through oxygen (O_2) reduction by two electrons in an acidic medium, using suitable cathodes according to (1), along with the addition of an iron catalyst to the treated solution to produce oxidant $^{\bullet}OH$ at the bulk via the classical Fenton's reaction as in (2).

$$O_2 + 2H+ + 2\,e^- \longrightarrow H_2O_2\ (1) Fe^{2+} + H_2O_2 + H^+ \rightarrow H_2O + {}^{\bullet}OH\ (2$$

Molecular oxygen necessary for the production of H_2O_2 is also generated at the anode by oxidation of water in the electrochemical cell according to (3).

$$H_2O \leftrightarrow \tfrac{1}{2}\,O_2 + 2H^+ + 2e^-\ (3)$$

In a cyclic way Fe^{2+} are regenerated at the cathode by reduction of Fe^{3+} through reaction (4).

$$Fe^{3+} + e^- \leftrightarrow Fe^{2+}\ (4)$$

The major advantages of this indirect electro-oxidation method are as follow according to E.Brillas and coworkers [15]: The on-site production of H_2O_2 avoiding risks related to its use. Likewise the possibility of controlling the degradation kinetics, allows mechanistic studies. Moreover, it allows for a higher degradation rate of organic pollutants thanks to the continuous regeneration of Fe^{2+} at the cathode, which avoids sludge production [5]. In fact dyes totally decompose to low-molecular-weight compounds (e.g., small aldehydes, carboxylic acids or small inorganic compounds), CO_2, and H_2O, and no significant pollution is generated [16]. Finally, the feasibility of the mineralization process at relatively low cost.

Acid Red18 (AR18) azo dye (Trisodium(8Z) -7-oxo-8-[(4-sulfonatonaphthalen-1-yl) hydrazinylidene] naphthalene-1, 3-disulfonate), (figure1), is used in the present study. AR18 also known as Ponceau 4R, is widely used in food industry [17]. There is no information reported in the literature to date concerning AR18 degradation by electro-generated Fenton's reagent using a graphite-felt cathode and a platinum anode. H_2O_2 /Fe^0 Fenton process, was found to be efficient for discoloring a simulated wastewater containing 100 mg/dm^3 of a commercial azo dye AR18 [18]. Moreover, the removal of AR18 was also reported in previous photocatalyticstudy [19], where the effectiveness of the photodecomposition increased with increasing the catalyst concentration; however this may lead to unfavorable light penetration through the solution. Additionally, AR18 degradation by photodegradation [20]and adsorption onto activated carbon [3] were successfully done. However these methods are costly and/or do not solve the pollution issue totally. A biological treatment was studied as well using mushroom specie where an increased concentration of azo dye above 100mg/l inhibited the growth of *Schizophyllum commune* [21]. The electro-Fenton Process (EFP) is appealing as it is environmentally friendly and doesnot use any harmful reagents [7]. This paper introduces the electrochemical oxidation of AR18 azo dye in aqueous solutions by electro-generated Fenton's reagent ($Fe^{2+/}H_2O_2$) in an undivided glass electrochemical cell using a carbon felt cathode and a platinum anode. We applythe EFP to the treatment of synthetic AR18 solution as well as a Tunisian wastewater food industry. The planning of the experimental work for investigating the influence of the azo dye initial concentration, current intensity, and catalyst concentration were chosen asmain operating parameters to optimize the removal of this organic pollutant. The optimum operating conditions were applied to the treatment of an industrial food effluent. Moreover the operating temperature was investigated in order to determine the activation energy. Chemical oxygen demand (COD), color removal and the energy consumption per unit COD mass (EC_{COD}) of the EFP were investigated for both solutions.

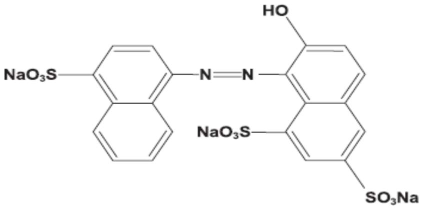

Figure 1:AR18 chemical structure

2. Materials and Methods

2.1. Chemical reagents

The azo dye Acid Red18 ($C_{20}H_{11}N_2Na_3O_{10}S_3$) was obtained as powder from a Tunisian food industry and was used without further purification. Its characteristics are displayed in (table1). Heptahydrated ferrous sulfate ($FeSO_4{\cdot}7H_2O$), a ferrous ion source, was supplied by (VWR BDH Prolabo). Anhydrous sodium sulfate (Na_2SO_4), an inert supporting electrolyte, was purchased from (Acros organics). All other chemicals were analytically graded and were used without further purification (VWR BDH Prolabo) and (Sigma-Aldrich).

Table 1:AR18 Structure and main characteristics

Molecular formula	*λmax*	*Molecular Weight*
$C_{20}H_{11}N_2Na_3O_{10}S_3$	510 nm	604.47g·mol^{-1}

2.2. Electrochemical cell

Electrolytic experiments were conducted in an open,cylindrical, and non-divided cell of 6 cm diameter and 250 ml capacity. This cell was equipped with two electrodes; a 3D carbon felt (Carbone Lorraine RVG 4000 Mersen) of 27cm^2 area as a cathode and a spiral rod of platinum as an anode of 5.5cm height. In all treatments, the anode was placed in the center of the electrochemical cell and was surrounded by the cathode, which covered its inner wall. Electrolyses were performed with a METRIX AX322 potentiostat by applying a constant current in the range of 100-300 mA. The temperature of the reaction medium was kept constant, using a thermo-stated bath. The pH was maintained at 3, the optimal value for this process[5],[15], by adding 0.1M of H_2SO_4, its value was measured with a Mettler Toledo EL20 pH-meter. Prior to electrolysis, continuous O_2saturation at atmospheric pressure was assuredby bubbling compressed air in the solution, starting10 min before electrolysis to reach a steady O_2concentration. Fe^{2+} ions, were added initially to the solution and were continuously regenerated catholically(eq.4) in a continuous mode. 50mM Na_2SO_4 was added as well in order to maintain the ionic strength constant. In all trials, the solution was vigorously stirred with a magnetic bar (600rpm) to enhance the masstransport towards/from the electrodes. Meanwhile, samples were withdrawn at regular electrolysis periods.

2.3. AR18 color removal

The color removal was monitored by measuring the decrease in absorbance using a single cell module, Life Science UV/Vis spectrophotometer (BECKMAN DU-530, California) by determining the absorbance at (Y_{max} = 510nm). Experimentally, the discoloration percentage was determined by the following expression:

$$\text{Color removal (\%)} = \left(\frac{ABS_o - ABS\ t}{ABS_o}\right) *100$$

Where ABS_o and $ABS_t$are the initial and final absorbances respectively, during the electrolysis at a time *t*.

2.4. Chemical oxygen demand (COD)

Progress of oxidation of AR18 was also monitored by the quantitative determination of the chemical oxygen demand at different time intervals (0-t) of the electro Fenton's reaction.COD measurements were taken every 1 h of electrolysis, by sampling 2 mL of the electrolyzed solution. Then, aliquots of an acidic solution (1mL) containing $K_2Cr_2O_7$ and $HgSO_4$ were added to the electrolyzed samples followed by the addition (3mL) of concentrated H_2SO_4 containing $AgSO_4$. These solutions were heated at 150°C for 2 h in a COD block reactor to complete the oxidation of the remaining organic matter. In order to measure the organic matter of a sample susceptible to oxidation by strong chemical oxidant, the COD measures were monitored using HANNA photometer COD and its removal percentage were estimated using the following equation.

$$\%\text{COD removal} = (1- (\frac{\text{COD}_t}{\text{COD}_0}) \text{ X } 100)$$

Where COD_o and COD_t, represent the values of the chemical oxygen demand at reaction time 0 and t of the electro-Fenton treatment of the target compound.

2.5. Energy Consumption

The energyconsumption per volume of treated effluent was estimated. The average cell voltage during electrolysis is used in the following calculation[10].

$$EC_{COD} = \frac{\text{Ecell I t}}{(\Delta COD)t \text{ Vs}}$$

Where EC_{COD} is the energy consumption per unit COD mass $(kWh(g\ COD)^{-1})$, E_{cell} is the average cell voltage (V), I is the applied current (A), t is the electrolysis time (h), $(\Delta COD)_t$ is corresponding decays in COD (mg O_2 L^{-1}) and V_s is the solution volume (L).

3. Results and Discussion

3.1 Decay kinetics of AR18's degradation with EFP

3.1.1.Effect of AR18 concentration on its degradation

The effect of AR18 concentration on its decay kinetic during EFP at 200mA and 0.2mM of catalyst is given in (figure2). As expected, longer time of electrolysis is required to remove AR18 as its initial concentration increases. This is due to the great amount of organics in the medium[22]. Moreover, the pseudo-first order rate constant slightly decreasesas the AR18 concentration increases (table2), which is due to the gradual acceleration of competitive reactions between hydroxyl radicals and the newly formed oxidant intermediates of AR18 during the process [9],[23].

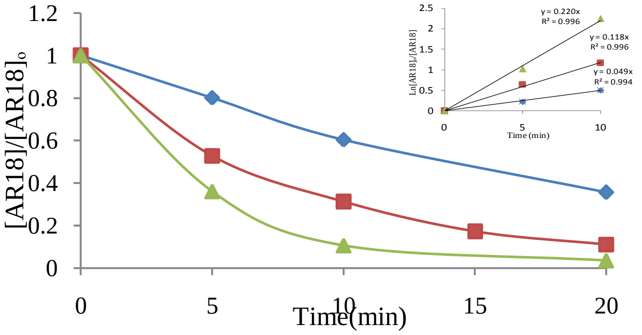

Figure 2: Effectof AR18 concentration on its degradation efficiency([AR18]: 9.9X10^{-2} (◊), 6.6X10^{-2}(□), 3.3X10^{-2}(Δ)mM. $[Fe^{2+}]$ = 0.2 mM, $[Na_2SO_4]$ = 50 mM, pH = 3, V = 250 mL, I=200mA)

Table 2: AR18Kinetic constants

Run	*1*	*2*	*3*
[AR18](mM)	9.9X10^{-2}	6.6 X10^{-2}	3.3 X10^{-2}
K_{app}	0.049	0.118	0.220

3.1.2. Effect of applied current on AR18's degradation

In order to pronounce the optimum conditions of degradation of 6.6X10^{-2}mM of AR18, the effect of applied current was investigated at different values in a range of 100mA to 300mA inthe presence of 0.2mM of Fe^{2+}as catalysts at ambient temperature. The oxidation of organic pollutants in the electro-Fenton system is related to the amount of $^{\bullet}OH$produced as depicted in (figure3). In fact, the degradation rate increases, rising the applied current up to 250mA. This faster oxidation rate at higher current isassociated to an enhancement of the continuous generation rate of H_2O_2 according to (1) and also to the faster electro-generation ofFe^{2+} as in (4), leading to the formation of higher amountof hydroxyl radicals from Fenton's reaction, (2) [14],[7]. Similar results were also obtained by Panizza et al. [22] for the oxidation of Alizarin Red by electro-Fenton process.

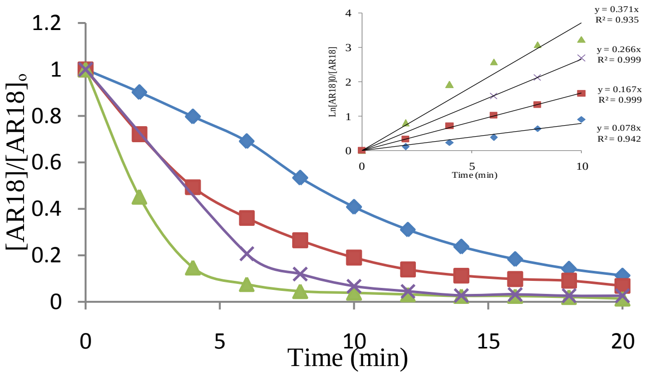

Figure 3: Effect of applied current on AR18 degradation efficiency(I= 100(◊), 200(□), 300(x) and 250 (Δ)mA, $[AR18]_0$=6.6X10^{-2}mM, $[Fe^{2+}]$ = 0.2 mM, $[Na_2SO_4]$ = 50 mM, pH = 3. V = 250 mL)

In contrast, a decrease in the degradation efficiency is observed at a current value of 300mA (figure3). This is due to the competitive electrode reactions in the electrolyticcell. The discharge of oxygen at anode shown in (7) and the evolution of hydrogen at cathode as in (8) occur at a higher current[24].

$$2H_2O \rightarrow 4H^+ + O_2 + 4e^- \quad (5)$$

$$2H^+ + 2e^- \rightarrow H_2 \quad (6)$$

Withal, it can be seen that for all current values,the degradation of AR18 can be satisfactory described by a pseudo-first order reaction kinetic (insert of Figure3). A significant enhancement was recorded for the pseudo-first rate constant (k) to shift from 0.078min^{-1} for 100mA to 0.371min^{-1} for 250mA.It is attributed to the enhancement of the degradation rate. Correspondingly, the first order constant decreased to 0.266min^{-1} for 300mA which confirms the occurrence of waste reactions at this current value. These results are in accordance with those obtained by Kourdali et al.[14].

3.1.3. Influence concentration of the catalyst Fe^{2+}

To elucidate the role of Fe^{2+}initial concentration in the oxidation of 6.6X10^{-2}mM AR18 by electro-Fenton's reagent,the experiment was examined in 50mM Na_2SO_4 solution (pH 3) at 250mA and ambient temperature.

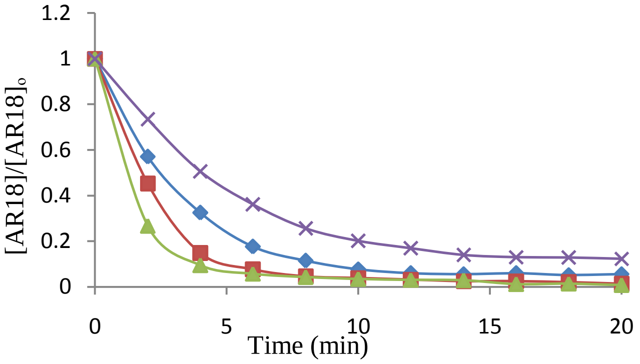

Figure 4: Effect of concentration of catalytic ferrous ions(**[**Fe^{2+}]: 0.1(◊), 0.2 (□), 0.5(Δ), 1 (*) mM. $[AR18]_0$ =6.6X10^{-2}mM, [Na_2SO_4] = 50 mM, pH = 3, V = 250 mL, I = 250 mA)

Figure4 reveals an obvious enhancement of the oxidation rate as a consequence of the increase in the amount of Fe^{2+} concentration up to 0.5mM. However, an excess of ferrous ions led to a decrease in the degradation efficiency. The negative effect of the higher catalyst concentration on the degradation kinetic can be explained by an increase of the rate of waste reactions occurring between the hydroxyl radicals and the excess of ferrous ions. Indeed, these reactions consume hydroxyl radicals at higher concentrations of Fe^{2+} ions as in (9). This inhibitory effect at high Fe^{2+} concentration is in agreement with that obtained for the degradation of AR18 trough classical Fenton process[18].

$$Fe^{2+} + {}^{\bullet}OH \rightarrow Fe^{3+} + OH^- \quad (7)$$

Conclusivelythe critical concentration of Fe^{2+} ions was an important prerequisite in the electro-Fenton oxidation of AR18 azo dye. The efficient oxidation by electro- Fenton was achieved in the presence of 0.5mM and is used for the further experiments.

According to the foregoing results, the optimal operation conditions for oxidation of 6.6X10^{-2}mMAR18 in aqueous solution by electro-generated Fenton's reagent were: 250mA, 0.5 mM Fe^{2+} as a catalyst at ambient temperature and pH=3.

3.1.4. Determination of the activation energy

The effect of temperature on the degradation of AR18 was studied at 20, 30 and 40°C and the obtained results are shown in (figure5)**.**

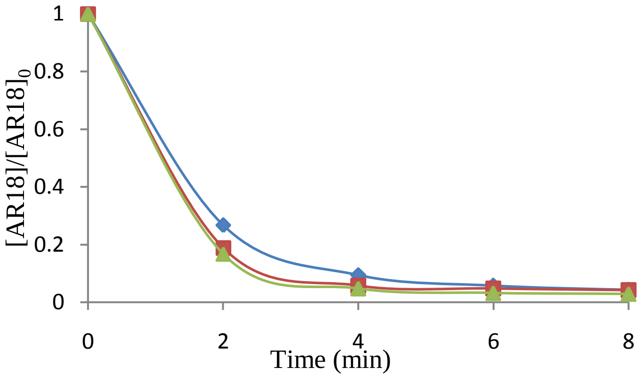

Figure 5: Effect of temperature on AR18 degradation (T: 20(◊), 30 (□), 40(Δ)ºC. $[AR18]_0$ =6.6X10^{-2}mM, [Na_2SO_4] = 50 mM, pH = 3, V = 250 mL, I = 250 mA, [Fe^{2+}]=0.5mM)

The change in temperature from 20 to 30ºC led to a slight increase in the degradation rate efficiency due to the increase in the pseudo-first order rate constants (k_{app} was 0.399, 0.414 and 0.47 min^{-1} at 20, 30 and 40°C, respectively). Although temperature has a positive effect on the treatment efficiency in this process, the increase in the degradation rate is relatively small compared to the other factors; this conclusion is in agreement with Nidheesh et al.[7].The rate constant k at different temperatures was then applied to estimate the activation energy of AR18 with the Arrhenius law as shown below:

$$k = A \exp\left(\frac{-Ea}{RT}\right)$$

Where k is the apparent kinetic rate constant (min^{-1}), A is the pre-exponential factor, E_a is the activation energy (Jmol^{-1}), R is the ideal gas constant (8.314Jmol^{-1} K^{-1}) and T is the reaction temperature (K).

The activation energy was found to be 9.1kJ mol^{-1}. Its value was determined from the Arrhenius plot of $\ln k_{app}$ versus 1/T and the application of the Arrhenius law (figure6)**.**

It can be observed from Figure6 that a linear correlation between the apparent rate constants and the reaction temperatures exists in the range of 20ºC-40ºC. A similar relationship between the apparent first-order constant (k_{app}) andreaction temperature was obtained by Maamar et al [25].

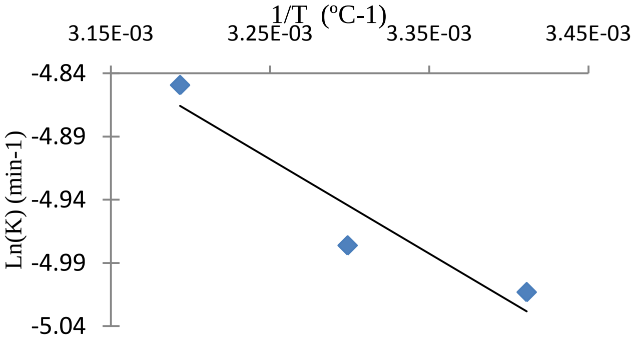

Figure 6: Kinetic analysis for the pseudo-first order reaction of AR18

The activation energies of the degradation of Orange GandAcid Red 73 by advanced Fenton oxidation process are respectively34.84 kJmol^{-1}[26]and31.98 kJmol^{-1}[23].Generally, the reaction activation energy of ordinary thermal reactions is usually between 60 kJ mol^{-1} and 250 kJ mol^{-1}[26].These results imply that the degradation of AR18 in aqueous solution by EFP requires low activation energy and hence can be easily achieved.

4. Mineralization of AR18

4.1. Evolution of COD removal

The extent of oxidation of AR18 by EFP was monitored by estimating the chemical oxygen demand removal (% COD removal) at optimal conditions ([AR18]=6.6X10^{-2}mM; I=250mA ; [Fe^{2+}]=0.5mM) during 240min. The curves depicted in (figure7) reveal that the %COD removal increases with the progress of treatment time. In fact, the initial COD value is 56mg O_2 L^{-1}for the synthetic AR18 solution. It decreases quickly at the beginning of the electrolysis giving rise to theremoval of more than 50 % in only 2 h. Then, the removal rate gradually slows at the end of treatment. This is due to the formation of hardly oxidizable compounds such as short-chain carboxylic acids [27]. In fact, carboxylic acids formed by oxidative ring opening reactions are less reactive toward hydroxyl radicalscompared to the aromatics [28], in contrast to the azo bond which are oflowest energy absorption band assigned to the $n \rightarrow \pi^*$ transition [9].Nevertheless, an abatement of 73.2 % of the initial COD value is reached at the end of 4 h of electrolysis.

Concerning the industrial effluent, the initial COD value was 1002 mgO_2/l. This value revels the relatively important amount of other dyes and organic pollutants in the solution in addition to AR18. The COD percentage decreases after 4h of electrolyses and reaches 50% (489 mgO_2/l).This satisfactory result can be explained by the fact that EFP achieves a slow removal rate due to the refractory by-products.

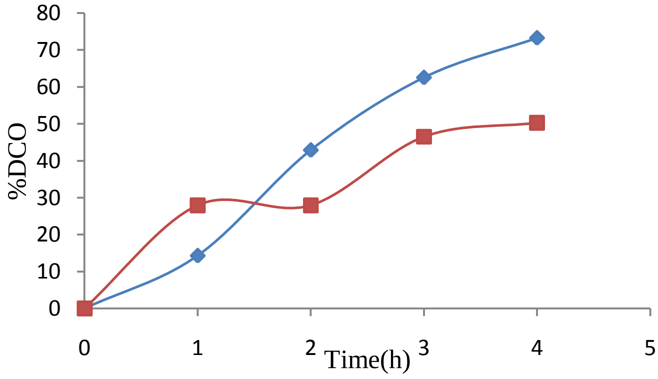

Figure 7: Evolution of the COD removal percentage of a AR18 synthetic solution and industrial effluents containing AR18(DCO: Synthetic AR18 solution (◊), industrial food effluent (□). [AR18] =6.6X10^{-2}mM, [Na_2SO_4] = 50 mM, pH = 3, V = 250 mL, I = 250 mA, [Fe^{2+}]=0.5M, T=20ºC)

4.2. Evolution of Color Removal

The nitrogen double bonds (-N=N-) characterize the azo dyes. They are usually attached to two radicals of whom at least one isan aromatic group (benzene or naphthalene rings).The absorption in the visible region can be attributed to chromophore containing azo linkage, whereas the bands observed in the UV region can be assigned to aromatic (naphthalene) rings substituted with SO^{3-} and OH groups, which are present in AR18 molecule[20]. Indeed, the effectiveness of the decolorization of AR18 is a consequence to the cleavage of (-N=N-) bonds of the lowest energy leading to theopening of the (-N=N-) double bonds, then destructing the longconjugated π systems, leading to the decolorization of theinvestigated solution[9].On theother side, the rate of decolorization is relativelyrapid at the early stages of electro-Fenton oxidation. As depicted in (figure 8), the same phenomenon occurs with regards to the industrial effluent which achieves 98% of decolorization. Whenimpurities are present in the wastewater, they may slow down, to some extent,the rate of decolorization of the examined azo dyeby electro-Fenton oxidation.Under the described conditions, total visual discoloration was achieved. In fact, the efficiency of color removal of AR18 solution reaches 100%, and the one of the industrial effluent reaches 98%. This behavior indicates dye degradation through its reaction with electro-generated $^\bullet$OH radicals on the electrode surface[10].

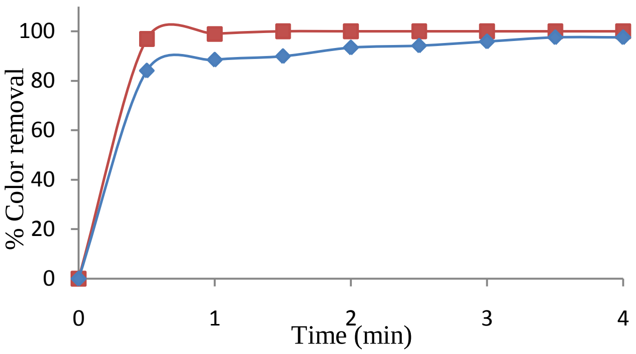

Figure 8: synthetic solution and industrial food effluent color removal(Synthetic AR18 solution (□), industrial food effluent (◊). [AR18] =6.6*10^{-2}mM, [Na2SO4] = 50 mM,pH = 3,V = 250 mL, I = 250 mA, [Fe^{2+}]=0.5M, T=20ºC)

4.3. Energy consumption(EC)

To better analyze the viability of the EF treatment, the energy cost of the synthetic AR18 solution and the industrial effluent were calculated. Operating at constant applied current, EC_{COD} is obtained from the above equation[25]:

$$EC_{COD} = \frac{E_{cell}\ I\ t}{(\Delta COD)_t V_s}$$

Where EC_{COD} is the energy consumption per unit COD mass (KWh(g COD)$^{-1}$), E_{cell} is the average cell voltage (V), I is the applied current (A), t is the electrolysis time (h), $(\Delta COD)_t$ is corresponding decays in COD (mg O_2 L^{-1}) and V_s is the solution volume (L).

The EC_{COD} of the EFP was calculated for the mineralization of the synthetic solution of AR18 and for the industrial effluent as shown in (table3).

Table 3: Energy consumption

Time(h)	*EC_{COD}(AR18)* *(kWh(g COD)$^{-1}$)*	*EC_{COD}(Industrial Effluent)* *(kWh(g COD)$^{-1}$)*
1	1	0.028
4	0.78	0.063

The AR18 synthetic solution has an energetic cost equal to 1kWh(g COD)$^{-1}$ at the beginning of the electrolyses to reach 0.78 kWh(g COD)$^{-1}$ after 4h of treatment. This decrease was the consequence of the efficient mineralization [29]. In contrast, the energy cost of the food effluent increased with time, which is explained by the formation of by-products and by waste reactions that consume hydroxyl radicals as in (8) and in (9). This result is in agreement with the finding of Maamar et al. [25].

$$2^{\bullet}OH \rightarrow H_2O_2 \ (8)$$

$$H_2O_2 + \bullet OH \rightarrow HO_2^{\bullet} + H_2O \ (9)$$

Moreover, these observed results confirms that the fast mineralization of some initial intermediates enhances the degradation rate efficiency leading to drop the energy cost, whereas more persistent final byproductsthat are present in the industrial effluent causes a deceleration of the process resulting in a greater energy cost[30].

5. Conclusion

Oxidation, decolorization and degradation of both synthetic and industrial food effluent containing Acid Red18by electro-generated Fenton's reagent has beenoptimized using an undivided electrochemical cell with a graphite-felt cathode and a platinum anode.The kinetics of the oxidation reaction of AR18 by hydroxyl radicals followsa pseudo-first order.Theobtained results of % COD removal and the disappearance of the UV–visible absorption for both synthetic and industrial AR18 solution clearly indicated the complete decolorizationand significant mineralization of the azo dye by electro-generatedFenton's reagent. The energy cost of EFP for both solutions were investigated as well, showing that the fast mineralization of some initial intermediates enhances the degradation rate efficiency leading to drop the energy cost. Whereas,both parasitic reactions and persistent final byproducts presentin the industrial food effluentscause the deceleration of the process resulting in a greater energy cost.

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