

## Investigation of the Removal Efficiency of C.I Acid Red 88 by Coupling Electrocoagulation with UV/H<sub>2</sub>O<sub>2</sub>

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**Abstract.** The aim of this study was to investigate the decolorization of Acid Red 88 (AR<sub>88</sub>) using electrocoagulation and photoelectrocoagulation techniques. The effect of operational parameters such as initial dye concentration, electrolysis time and electrolyte concentration was studied. The electrochemical cell comprised Al as cathode and Fe as anode which were placed inside a container having a low pressure mercury lamp at the top. 40 mg L<sup>-1</sup> of dye solution was withdrawn for each experiment and after adjusting the electrode distance to 15 mm, current density to 41.8 A m<sup>-2</sup>, different electrolytes at varying concentrations were added and the absorbance was measured at several reaction times. The results showed that electrocoagulation was more effective than photoelectrocoagulation using NaBr, KBr, NaCl and KCl as electrolytes and decolorization rate increased with increasing electrolyte concentration. Results also revealed that the coupled system was more satisfactory than electrocoagulation method with Na<sub>2</sub>SO<sub>4</sub> as an electrolyte. Also the coupled system with NaF electrolyte showed better decolorization rate than electrocoagulation, but the decolorization rate was higher at low concentrations of electrolyte. Therefore, it is concluded that electrocoagulation was more effective than coupled system in most cases and type of electrolyte plays an important role since employed NaCl/KCl would enhance the decolorization rate considerably.

**Keywords:** Electrocoagulation, Photoelectrocoagulation, Decolorization, Coupling, Acid Red 88.

### 1. Introduction

One of the most important challenges facing the mankind is to provide clean water to a majority of people around the world. Textile effluents from dyeing and finishing processes in the textile industry have been a serious threat to environment. Carcinogenic products such as aromatic amines due to the large consumption of azo dyes in dyeing processes contain considerable amount of strong color with high degree of COD and low biodegradability [1]. These are usually treated by conventional methods such as biological oxidation, coagulation and adsorption processes [2, 3]. These methods have their own disadvantages and are not effective for the removal of dissolved dyestuffs [4]. Adsorption processes essentially transfer the waste from liquid phase to solid phase, hence imposing high waste disposal cost. Other processes such as ozonation, UV, and Ozone/UV combined oxidation, photocatalysis (UV/TiO<sub>2</sub>), Fenton and photo-Fenton are not economically feasible [5]. Electrocoagulation (EC) has been shown to be an effective method to treat wastewaters [6]. In addition, EC has been employed to treat water containing foodstuff waste [7], chemical and mechanical polishing wastes [8], mine wastes [9] and many other wastes. EC process causes anodic dissolution of materials such as aluminium and iron followed by hydrolysis to generate hydroxide flocs, which in turn aggregate and destabilize suspended particles and finally precipitates. EC technique is considered to be potentially an effective tool for treatment of wastewaters with high removal efficiency [10]. Advanced oxidation process using UV/H<sub>2</sub>O<sub>2</sub> has also been reported to be a promising technique in removing dyes by producing oxidizing species (generally hydroxyl radicals) in the medium. In this technique, UV light is absorbed directly by hydrogen peroxide. Then, hydroxyl radicals are generated by photolysis of peroxide

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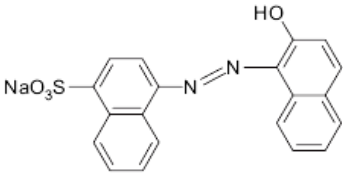
bond. The highest amount of hydroxyl radicals are obtained when short wave ultraviolet radiations (200-280 nm) are utilized. Hydroxyl radicals are very powerful oxidizing agent, which can degrade organic contaminants unselectively [11].

The aim of this study is to investigate the coupling effect of electrocoagulation with UV/H<sub>2</sub>O<sub>2</sub> on the removal of Acid Red 88 in the presence of various electrolytes, utilizing iron and aluminium electrodes as anode and cathode, respectively.

## 2. Materials and Methods

Acid Red 88 (AR88) a monoazo anionic dye was purchased from ACROSS organics (USA). The characteristics of the AR88 have been summarized in Table 1. Other chemicals used were Merck (Germany). The electrolytic cell consists of iron and aluminum electrodes as anode and cathode, respectively. The cell was placed inside a wooden box which was equipped with UV lamp (15 W, UV-C,  $\lambda_{\max}$  = 254 nm manufactured by Philips, Holland) at the top. A magnetic stirrer was used to agitate the solution. A DC power supply (REC 8-P-6) was employed to apply the voltage. After applying different current density in presence of different electrolytes, 2 mL of the solution was withdrawn at 5 min intervals, filtered and centrifuged, then the absorbance was determined by means of UV-Vis spectrophotometer (Ultrospec 2000, England) at 506 nm. The AR88 concentration was determined by relating it to absorbance using a calibration graph. The EC reactor comprised of Fe and Al as anode and cathode respectively with distance of 15 mm. All experiments were carried out at ambient temperature.

Table 1: Characteristics of the AR88.

CAS number	Molecular formula	Molar mass (g/mol)	$\lambda_{\max}$	Chemical structure
1658-56-6	C <sub>20</sub> H <sub>13</sub> N <sub>2</sub> O <sub>4</sub> Na	400.38	508 nm	 <p style="text-align: center;">AR88</p>

## 3. Results and Discussion

### 3.1. Effect of UV Radiation in Presence of H<sub>2</sub>O<sub>2</sub>

The decolorization efficiency of UV radiation in presence of H<sub>2</sub>O<sub>2</sub> was carried out at different times. As it can be observed from Fig. 1, a considerable decrease occurs in the concentration of the dye as the time of irradiation increases. This loss can be related to the generation of hydroxyl radicals, which is a powerful oxidizing agent.

### 3.2. Effect of Electrocoagulation

In order to study the effect of EC process different electrolytes with varying amount were used to increase the conductivity of the medium [12, 13]. These electrolytes include KCl, NaCl, Na<sub>2</sub>SO<sub>4</sub>, KBr, NaBr and NaF. KCl and NaCl were used together since their combination would result in better decolorization. Dye and electrolyte concentrations were 40 and 50 mg L<sup>-1</sup> respectively, and current density was adjusted to 41.8 A m<sup>-2</sup>. Results revealed that decolorization could be achieved over 90%. The order of decolorization efficiency was as follows regarding electrolytes:



KCl and NaCl act more efficient than othe electrolytes due to generation of Cl<sup>-</sup> and hence formation of ClO<sup>-</sup>. In the case of Na<sub>2</sub>SO<sub>4</sub>, due to the formation of insoluble CaSO<sub>4</sub> and MgSO<sub>4</sub> on the electrode surface, the rate of electrocoagulation reaction decreases which ends in low production of flocs and consequently the decolorization efficiency decreases. KBr exhibits better role than NaBr due to the more ionic bond and hence

better conductivity at equally applied voltage, but NaF seems to impose more ions than other electrolytes per unit volume and as a result, the collision between ions may play significant role in the low efficiency.

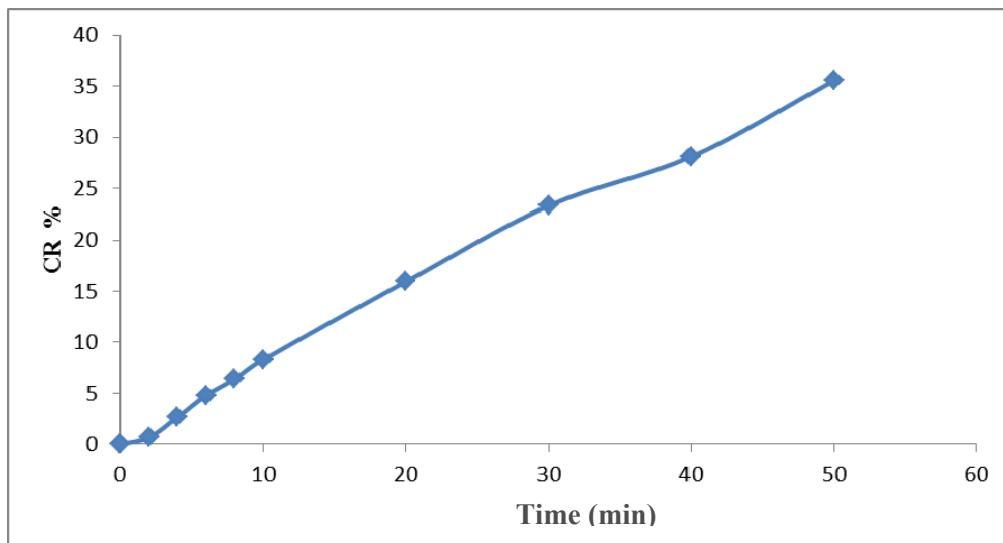
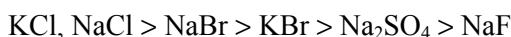


Fig. 1: Decolorization efficiency of UV radiation in presence of H<sub>2</sub>O<sub>2</sub> ( $C_{Dye} = 40 \text{ mg L}^{-1}$ ,  $H_2O_2 = 850 \text{ mg L}^{-1}$ ,  $I_0 = 15 \text{ W m}^{-2}$ ,  $\lambda_{max} = 508 \text{ nm}$ ).

### 3.3. Effect of Photo-electrocoagulation

The removal efficiency of photo-electrocoagulation process was evaluated in presence of different electrolytes as in previous section.  $40 \text{ mg L}^{-1}$  of dye solution was taken with  $850 \text{ mg L}^{-1}$  of H<sub>2</sub>O<sub>2</sub> and  $50 \text{ mg L}^{-1}$  of each electrolyte individually. EC/UV process was applied with Al/Fe as cathode and anode respectively with electrode distance of 15 mm under UV irradiation with light intensity of  $15 \text{ W m}^{-2}$ . The results indicated that the following order governs the process:



It can be seen from Fig. 2 that increasing electrolyte concentration increases the decolorization efficiency due to enhancement in the ionic strength of the medium. The high efficiency in the case of NaCl, KCl could be related to the decolorization ability of generated hypochlorite (ClO<sup>-</sup>) ions.

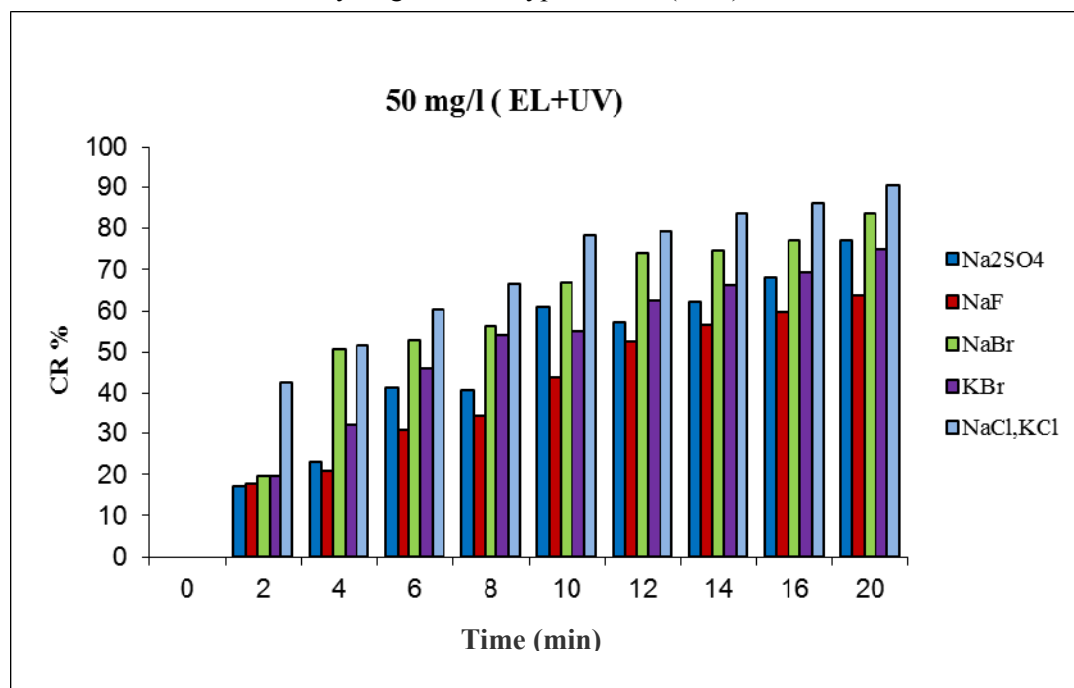


Fig. 2: The removal efficiency of photo-electrocoagulation process in presence of different electrolytes ( $C_{Dye} = 40 \text{ mg L}^{-1}$ ,  $I = 41.8 \text{ A m}^{-2}$ ,  $H_2O_2 = 850 \text{ mg L}^{-1}$ ,  $I_0 = 15 \text{ W m}^{-2}$ ,  $C = 50 \text{ mg L}^{-1}$ ,  $\lambda_{max} = 508 \text{ nm}$ ,  $d = 15 \text{ mm}$ , Fe/Al Anode/Cathode).

### 3.4. Comparison between EC and EC/UV Processes

EC and EC/UV processes employed in decolorization of AR88 were compared in presence of different electrolytes and findings postulate that EC process is more efficient than EC/UV except for the case of Na<sub>2</sub>SO<sub>4</sub>, because the formation of calcium and magnesium sulfate which could retard the EC process. Therefore, hydroxyl radicals play a significant role in EC/UV process. It should be mentioned that at the initial stages EC process exhibits a lower efficiency than EC/UV process due to the low amounts of ions in EC process and generation of hydroxyl radicals in EC/UV process. However, as the reaction proceeds, EC process performs better than EC/UV process. This is because of the recombination of hydroxyl radicals and also formation of hydroperoxyl radicals which have lower activity and also consumption of hydroxyl radicals [14]. This phenomena occurs using all electrolytes with different concentrations except for Na<sub>2</sub>SO<sub>4</sub>.

## 4. Conclusion

The decolorization of AR88 by means of UV/H<sub>2</sub>O<sub>2</sub>, EC and EC/UV processes was investigated under different operational conditions. The results demonstrated that although UV/H<sub>2</sub>O<sub>2</sub> process is a useful process but it is less efficient than two others. Comparison between EC and EC/UV processes in presence of different electrolytes firmly revealed that the type of electrolyte is the determining factor in the efficiency of the process. It also concluded that using sulphate salt as an electrolyte in EC process should be avoided.

## 5. References

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