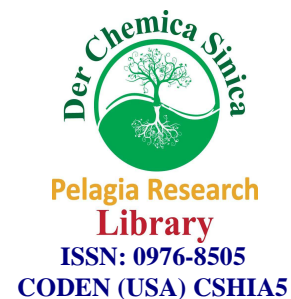




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### Direct current electrocoagulation of azo-2-naphthol dye using aluminium electrodes: Effect of metal ion on dye colour removal

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#### ABSTRACT

A solution of azo-2-naphthol dye containing a metal ion was subjected to direct current electrocoagulation (DCE). Different initial dye concentration in the range 0.01-1.0 % (w/v) was investigated with different metal ions including  $Fe^{2+}$ ,  $Fe^{3+}$  and  $Cu^{2+}$ . The results obtained showed significant complexation of the metal ions with dye.

**Keyword:** Electrocoagulation, direct current electrocoagulation, aluminium electrodes, azo-2-naphthol, colour removal.

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#### INTRODUCTION

Electrocoagulation is an electrochemical technique in which a variety of unwanted dissolved particles and suspended matters can be effectively removed from aqueous solution by electrolysis. This technique was initially used by Miwa [1] to effect dechlorophyllation of an aqueous extract of stevia in order to obtain the sweet glycosidic components from stevia leaves. Since then, electrocoagulation has gained importance and its applicability is still explored in diverse areas. Separation of metals using electrocoagulation techniques has been popular of recent. Notable ones include, separation of heavy metals [2-3], purification of industrial wastewater from toxic metals [4], removal of heavy metals from waste fountain solution [5], treatment of metal-loaded soil leachates [6], removal of lead and zinc from battery industry wastewater [7], selenium from industrial wastewater [8], Chromium(III) and Chromium(VI) from synthetic wastewater [9], heavy metal ions removal from metal plating wastewater [10-13], removal of cobalt(II) [14], Nickel(II) and silver(I) [15], Manganese(II) ions [16], indium(III) ion [17], strontium and cesium [18], from aqueous solution, removal of antimony from mine wastewater [19], removal of arsenic from ground water [20-22], removal of mercury(II) [23] and iron(II) from tap water [24].

Electrocoagulation is also very important in the treatment of textile industry wastewater [25-27]. Dye removal from textile wastewater [28-30], decolourization of synthetic Methyl Orange wastewater [31], dye colour removal from simulated dye bath effluent [32], removal of Methylene Blue [33] dispersed red dye [34], decolourization of Acid Yellow 23 solution [35], have all been accomplished by electrocoagulation techniques. It has also been successfully utilized in the removal of colour from tea effluent [36] and spent wash [37].

As versatile as electrocoagulation technique is, electrocoagulation of a mixture of dye and metal ion is rarely reported. Since color and metal ions have been removed by electrocoagulation techniques independently, it will be interesting to know which of them (dye or metal ion) will be preferentially removed or if both can be removed at the same time when direct current is applied.

In this paper, we report electrocoagulation of a mixture of metal ion, Fe(II), Fe(III) Cu(II) and azo-2-naphthol dye in aqueous ethanol using aluminium electrodes.

## MATERIALS AND METHODS

### General

All chemicals used were of analytical grade. The dye, 1-phenylazo-2-naphthol (PAN) was obtained from our previous work [38]. Aluminium plates were purchased locally. Direct current was sustained by a GW Instek DC power supply. Absorbance was measured from a UV-Visible spectrophotometer (UV-780c).

### Preparation of sample solutions for electrocoagulation

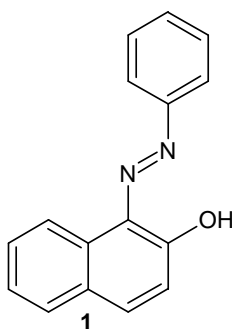
The initial concentration of dye used for the electrocoagulation was 0.01, 0.1 and 1.0 % (w/v) respectively. The metal ion concentration was fixed at 0.01 % (w/v). The various metal ions used for this study were  $\text{Fe}^{2+}$ ,  $\text{Fe}^{3+}$  and  $\text{Cu}^{2+}$ . The dye and the metal ion were dissolved in aqueous ethanol (50 %). The dye-metal ion solutions were scanned through 200-800 nm wave length using UV-Visible spectrophotometer to obtain the wavelength of maximum absorption,  $\lambda_{\text{max}}$  for each metal ion. The  $\lambda_{\text{max}}$  obtained were as follows: dye- $\text{Fe}^{2+}$  solution: 450 nm; dye- $\text{Fe}^{3+}$  solution: 500 nm; dye- $\text{Cu}^{2+}$  solution: 600 nm.

### Electrocoagulation procedures

A pair of aluminum plates (12 x 4 cm) spaced 3 cm apart was immersed 5.5 cm into each sample solution (250 mL) contained in a 400 mL beaker. The solution was agitated throughout the experiment with a magnetic plate stirrer with Teflon bar rotating at a velocity of 500 rpm. Sodium chloride (0.5 g) was added as supporting electrolyte. Direct current (0.3 A, 24 V) was passed through the solution via the two aluminium electrodes. The absorbance of the dye-metal ion solution, before and during the electrocoagulation process was measured by a UV-Visible spectrophotometer. At 15 minutes interval over a 2 hour period of electrolysis, 4 mL aliquot of the solution was withdrawn, centrifuged and the absorbance of the supernatant solution was measured at the wavelength corresponding to the absorption maximum for the dye-metal ion solution. The data obtained were used to construct electrocoagulation curves.

## RESULTS AND DISCUSSION

The structure of 1-phenylazo-2-naphthol (PAN) dye is shown (1)



The removal of the colour of dye was monitored with time in the electrocoagulation of a mixture of dye and metal ion solution using aluminium electrodes. The plot of absorbance vs. time is shown in Figures 1-3 for the various metal ions at different initial dye concentration.

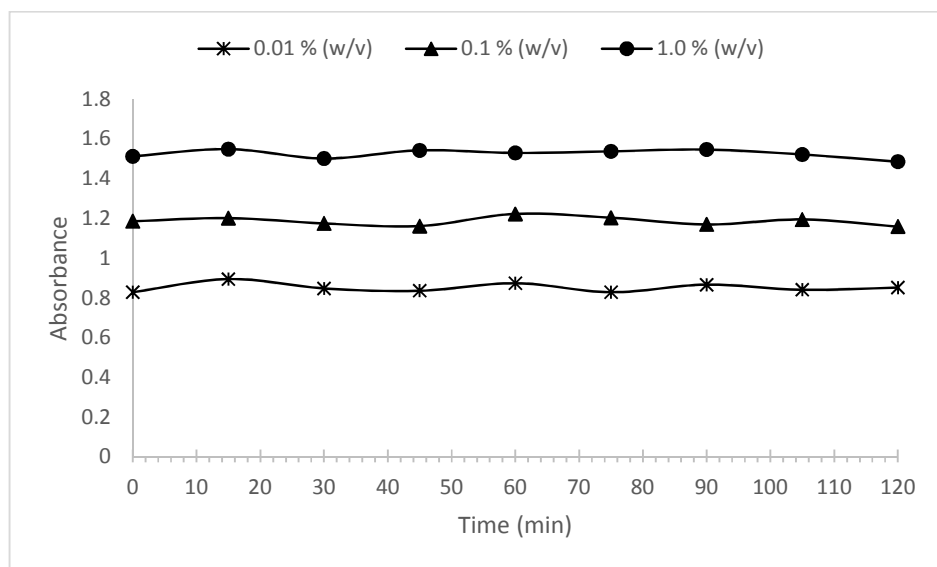


Fig. 1. Electrocoagulation curve for dye- $\text{Cu}^{2+}$  solution at different initial dye concentrations

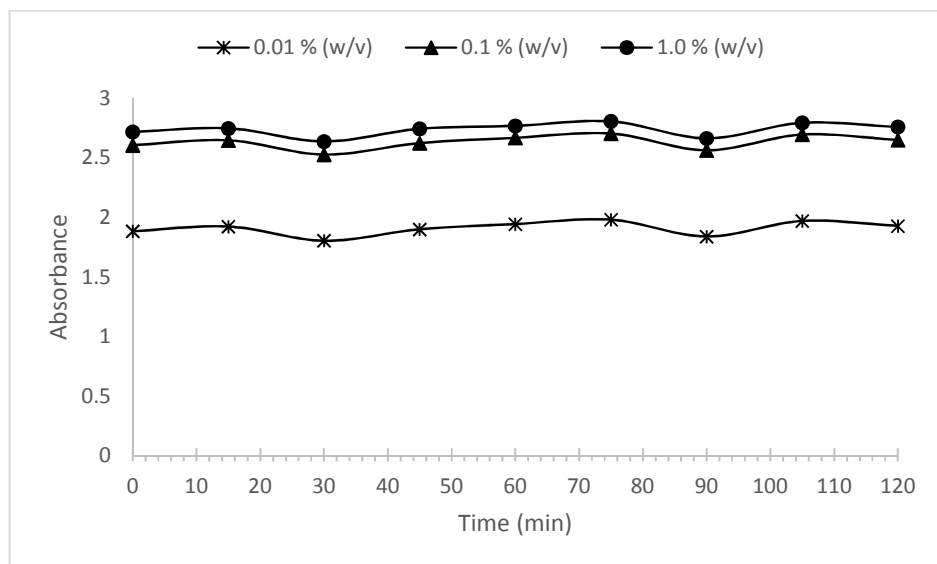


Fig. 2. Electrocoagulation curve for dye- $\text{Fe}^{2+}$  solution at different initial dye concentrations

The electrocoagulation curve obtained takes a similar pattern for the three metal ions studied. A wave-like pattern shows that either there was no effective electrocoagulation or the property monitored (dye colour) was not effective to resolve the electrocoagulation process or the presence of metal ion prevents electrocoagulation. Assuming that the presence of metal ion is responsible for inability to obtain the expected electrocoagulation curve with a well-defined coagulation point, metal ion may affect the electrocoagulation process by either reacting with the coagulant and interfering with the adsorption process or forming complexes with the dye that prevent electrocoagulation. Since electrocoagulation has been successfully applied in the removal of metal ions in solution, including cadmium [39-41], nickel and chromium [42], cobalt [43], and lead [44] using aluminium electrodes, metal ion interference can be neglected. Also, the presence of hydroxide forming metal ions such as  $\text{Fe}^{2+}$  and  $\text{Fe}^{3+}$  in the dye solution would have resulted in a faster coagulation due to possible formation of more coagulants.  $\text{Fe}^{2+}$  and  $\text{Fe}^{3+}$  ions have been known to combine with the  $\text{OH}^-$  ions generated during the electrocoagulation process to form  $\text{Fe}(\text{OH})_2$  and  $\text{Fe}(\text{OH})_3$  which are also potential coagulants when iron electrodes are used [45]. The fact that electrocoagulation was not observed, let

alone accelerated by additional coagulants from the metal ions used, eliminates possibility of metal ion interference. The plausible explanation lies with the formation of complexes with the dye.

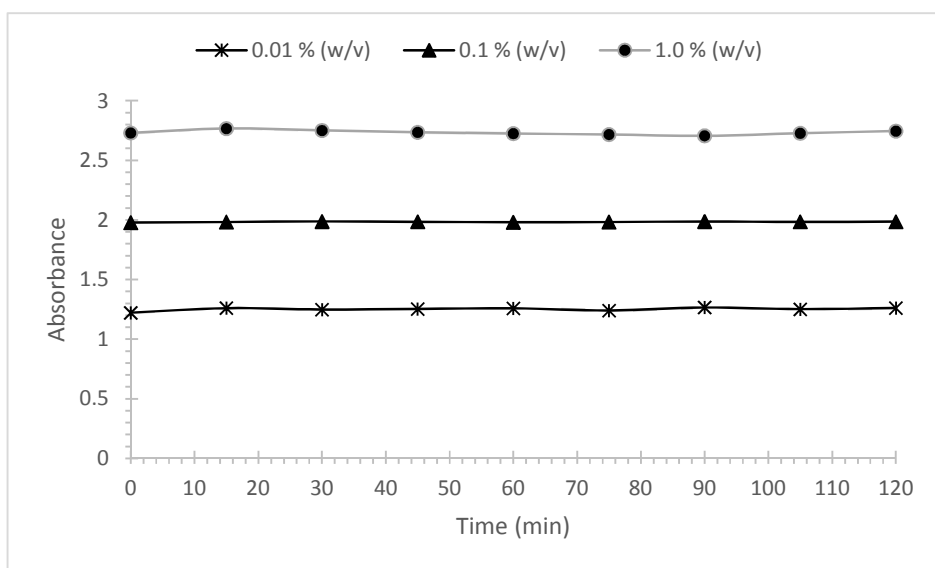
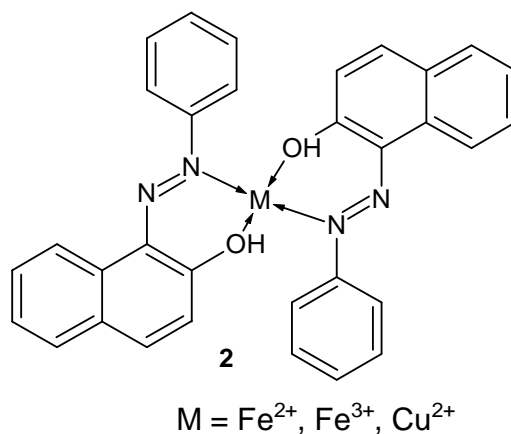


Fig. 3. Electrocoagulation curve for dye-Fe<sup>3+</sup> solution at different initial dye concentrations



The position of the azo and hydroxyl groups is consistent with such observation and azo group has been known to possess excellent donor properties which enable them to be used in coordination chemistry [46].

It therefore appears that the metal ions form complexes with the dye which makes the dye unable to be coagulated by the coagulant, Al(OH)<sub>3</sub> generated in the electrocoagulation process. The dye-metal ion complex may be represented as shown (2).

Since a similar electrocoagulation pattern was observed for all the dye-metal ion solutions and for all the initial concentrations of the dye, it therefore means that the three metal ion investigated behave alike in the dye solution. Therefore, complexation is implicated.

### CONCLUSION

A solution containing azo-2-naphthol dye and metal ion including Fe<sup>2+</sup>, Fe<sup>3+</sup> and Cu<sup>2+</sup> respectively was subjected to electrocoagulation using aluminium electrodes. The dye-metal ion solution did not show significant

electrocoagulation for all the initial concentration of the dye studied. The metal ions appeared to have form complexes with the dye that prevented electrocoagulation process.

#### REFERENCES

- [1] Miwa K, *JpnKokaiTokkyoKoho*, **1978**, 78, 500.
- [2] Merzouk B, Gourich B, Sekki A, Madani K, Chibane M, *Journal of Hazardous Materials*, **2009**, 164, 215.
- [3] Pocięcha M, Lestan D, *Journal of Hazardous Materials*, **2010**, 174, 670.
- [4] Gatsios E, Hahladakis JN, Gidarakos E, *Journal of Environmental Management*, **2015**, 154, 117.
- [5] Prca M, Adamovic S, Dalmacija B, Rajic L, Trickovic J, Rapajic S, Becelic-Tomin M, *Process Safety and Environmental Protection*, **2015**, 94, 262.
- [6] Meunier N, Drogui P, Mercier G, Blais J, *Separation and Purification Technology*, **2009**, 67, 110.
- [7] Mansoorian HJ, Mahvi AH, Jafari AJ, *Separation and Purification Technology*, **2014**, 135, 165.
- [8] Mavrov V, Stamenov S, Todorova E, Chmiel H, Erwe T, *Desalination*, **2006**, 201, 290.
- [9] Zewail TM, Yousef NS, *Journal of Electroanalytical Chemistry*, **2014**, 735, 123.
- [10] Al-Shannag M, Al-Qodah Z, Bani-Melhem K, Qtaishat MR, Alkasrawi M, *Chemical Engineering Journal*, **2015**, 260, 749.
- [11] Kabdaşlı I, Arslan T, Ölmez-Hancı T, Arslan-Alaton I, Tünay O, *Journal of Hazardous Materials*, **2009**, 165, 838.
- [12] Akbal F, Camcı S, *Desalination*, **2011**, 269, 214.
- [13] Adhoum N, Monser L, Bellakhal N, Belgaied J, *Journal of Hazardous Materials*, **2004**, 112, 207.
- [14] Shafaei A, Pajootan E, Nikazar M, Arami M, *Desalination*, **2011**, 279, 121.
- [15] Heidmann I, Calmano W, *Journal of Hazardous Materials*, **2008**, 152, 934.
- [16] Shafaei A, Rezaie M, Nikazar M, *Chemical Engineering and Processing: Process Intensification*, **2011**, 50, 1115.
- [17] Chou W, Wang C, Huang K, *Journal of Hazardous Materials*, **2009**, 167, 467.
- [18] Kamaraj R, Vasudevan S, *Chemical Engineering Research and Design*, **2015**, 93, 522.
- [19] Zhu J, Wu F, Pan X, Guo J, Wen D, *Journal of Environmental Sciences*, **2011**, 23, 1066.
- [20] Mohora E, Rončević S, Agbaba J, Tubić A, Mitić M, Klačnja M, Dalmacija B, *Separation and Purification Technology*, **2014**, 136, 150.
- [21] Gomes JAG, Daida P, Kesmez M, Weir M, Moreno H, Parga JR, Irwin G, McWhinney H, Grady T, Peterson E, Cocks DL, *Journal of Hazardous Materials*, **2007**, 139, 220.
- [22] Mólgora CC, Domínguez AM, Avila EM, Drogui P, Buelna G, *Separation and Purification Technology*, **2013**, 118, 645.
- [23] Nansou-Njiki CP, Tchamango SR, Ngom PC, Darchen A, Ngameni E, *Journal of Hazardous Materials*, **2009**, 168, 1430.
- [24] Ghosh D, Solanki H, Purkait MK, *Journal of Hazardous Materials*, **2008**, 155, 135.
- [25] Zongo I, Maiga AH, Wéthé J, Valentin G, Leclerc J, Paternotte G, Lapique F, *Journal of Hazardous Materials*, **2009**, 169, 70.
- [26] Zodi S, Potier O, Lapique F, Leclerc J, *Separation and Purification Technology*, **2009**, 69, 29.
- [27] Kobya M, Can OT, Bayramoglu M, *Journal of Hazardous Materials*, **2003**, 100, 163.
- [28] Zodi S, Merzouk B, Potier O, Lapique F, Leclerc J, *Separation and Purification Technology*, **2013**, 108, 215.
- [29] Phalakornkule C, Polgumhang S, Tongdaung W, Karakat B, Nuyut T, *Journal of Environmental Management*, **2010**, 91, 918.
- [30] Merzouk B, Gourich B, Sekki A, Madani K, VialCh, Barkaoui M, *Chemical Engineering Journal*, **2009**, 149, 207.
- [31] Pi K, Xiao Q, Zhang H, Xia M, Gerson AR, *Process Safety and Environmental Protection*, **2014**, 92, 796.
- [32] Kabdaşlı I, Vardar B, Arslan-Alaton I, Tünay O, *Chemical Engineering Journal*, **2009**, 148, 89.
- [33] Mahmoud MS, Farah JY, Farrag TE, *Egyptian Journal of Petroleum*, **2013**, 22, 211.
- [34] Merzouk B, Gourich B, Madani K, VialCh, Sekki A, *Desalination*, **2011**, 272, 246.
- [35] Daneshvar N, Khataee AR, Amani-Ghadim AR, Rasoulifard MH, *Journal of Hazardous Materials*, **2007**, 148, 566.
- [36] Maghanga JK, Segor FK, Etiégni L, Lusweti J, *Bull ChemSoc Ethiop*, **2009**, 23, 371.
- [37] Bhise RM, Patil AA, Rasker AR, Patil PJ, Deshpande DP, *Research Journal of recent Science*, **2012**, 1, 66.
- [38] Mkpennie V, Ebong G, Obot IB, Abasiokong B, *E-Journal of Chemistry*, **2008**, 5, 431.
- [39] Mahvi AH, Bazrafshan E, *World Applied Sciences Journal*, **2007**, 2, 34.

- [40] Bayar S, Yilmaz AE, Boncukcuoğlu R, Fil BA, Kocakerim MM, *Desalination and Water Treatment*, **2013**, 51, 2635.
- [41] Mansour SE, Negim ES, Hasieb IH, Desouky OA, Abdykalykova R, Beisebekov M, *Global Journal of Environmental Research*, **2013**, 7, 45.
- [42] Hernández MC, Barletta L, Dogliotti B, Russo N, Fino D, Spinelli P, *J Appl Electrochem*, **2012**, 42, 809.
- [43] Mansour SE, Hasieb IH, *International Journal of Chemical Technology*, **2012**, 4, 31.
- [44] Khosa MK, Jamal MA, Hussain A, Muneer M, Zia KM, Hafeez S, *Journal of the Korean Chemical Society*, **2013**, 57, 316.
- [45] Un UT, Ocal SE, *International Journal of Environmental Science and Development*, **2015**, 6, 425.
- [46] Garnovskii AP, Ureav AI, Minkini VI, *Arkivoc* **2004**, III, 29.