EFFECTIVENESS OF ELECTROCOAGULATION PROCESS FOR COLOUR REMOVAL FROM THE TEXTILE EFFLUENT

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ABSTRACT

Suitability of Electrocoagulation (EC) process with Aluminium and Iron electrodes were investigated for decolourization of textile effluent. Number of electrodes, electrolysis time, input voltage, pH and electrode distance are considered as operating parameters for the study on the optimal removal of colour. It was found that electrocoagulation method with two number of Iron electrodes removed colour more efficiently and effectively with removal efficiency of approximately 92% for an input voltage of 30V, pH of 9, electrolysis time of 60 min and 14cm spacing. Whereas, decolourization efficiency of the EC process with Aluminium electrode is about 68% for a voltage supply of 30V at a pH of 5 electrolysis time of 90 min and 18cm spacing. Hence, from the obtained results it can be suggested that electrocoagulation method is an effective and efficient treatment method for textile park effluent.

Keywords: Electrocoagulation, Industrial textile effluent, Decolourization, Aluminium, Iron electrodes

INTRODUCTION

Textile industries are one of the prominent industries contributing to the India's economy. The materials or substances used during manufacturing and processing are diverse in chemical composition ranging from dyes, inorganic compounds to polymers and organic products (Kudlich, M. et al., 1996). Resulting wastewater is unique in character and not easily handled by the conventional treatment processes. Coloured textile industry wastewater treatment is important because the release of coloured effluents in water bodies restricts the photosynthetic activity of aquatic flora and sometimes toxic to the aquatic life and harmful to the human health (Gupta, G.S. et al., 1990). The textile dyes, particularly the synthetic ones, are highly reactive during processing and it is difficult to treat. About 100,000 commercially available dyes are known and nearly 1 million tons of dyes are produced throughout the year, whereas out of the total usage, 10% of dyes are released in environment as dyestuff waste (Satyendra, K.G., and Manikant,T., 2016). Synthetic textile dyes used each year are lost during manufacture and processing operations and 20% of these dyes enter the environment through effluents that result from the treatment of residual industrial waters (Weber, E. J., and Stickney, V. C.,1993). Hence, the colour removal has been the target of great attention since several years. The conventional physical, chemical and biological treatment processes have been applied to overcome the environmental problems. Most of these methods are effective but quite expensive and have their own disadvantages and limitations. In recent times focus is getting shifted towards Electrochemical methods that facilitate good decolourization yields as they require insignificant or less chemicals before and after treatment, thus producing no or low residue or sludge, requirements of small area and low investment costs (E-S.Z. El-Ashtoukhy and Amin, N.K., 2010). Electrochemical methods include electro photo catalysis, electro Fenton process, anodic oxidation and electrocoagulation. Among these methods, electrocoagulation method provides an attractive simple technique for dye wastewater treatment due to its ease of applicability, automation, high efficiency and low cost (Liu, N., and Wu, Y., 2019). Hence, the applicability of the EC process considering different process parameters for a textile park wastewater treatment is studied.

ELECTROCOAGULATION

Electrocoagulation process involves the application of direct current (DC) source between metal electrodes immersed in wastewater. The electric current causes the dissolution of metal ions at anode and hydroxyl ions and H_2 gas at cathode to form metal hydroxides which enhance the destabilization and aggregation of the suspended or soluble pollutants or substances. The material of the electrode is one of the important aspects in electrocoagulation method. Aluminium and Iron electrodes have been most commonly used as the electrode material because of their low cost, better availability and relatively safe. Apart from the type of electrodes the process depends on several other factors such as the power supply and cell configuration, wastewater characteristics, pH, electrolysis time, number of electrodes, electrode spacing and so on. Therefore, the EC process studies on laboratory scale were conducted on the removal of colour from real textile wastewater using Aluminium and Iron electrodes. A monopolar electrochemical cell is used to evaluate the effects of various experimental parameters including voltage, electrolysis time, pH, electrode distance and number of electrodes on the dye removal efficiency. This study was performed in the Environmental Engineering Laboratory of Andhra University and Environmental Laboratory of Brandix India Apparel City, SEZ, Pudimadaka Road, Atchutapuram, Visakhapatnam, Andhra Pradesh, India from March 2020 to September 2020.

EXPERIMENTAL SETUP

The experimental setup was established in the laboratory. It consists of the fabrication of an electrolytic fluid cell with an effective volume of 6L, along with the electrodes, power supply, connection system, and other accessories. The electrochemical cell is made up of a 6mm thick glass panel with internal dimensions of 250mm×150mm×200mm and a freeboard of 40mm from the top. In the electrolytic fluid cell, either 2, 4, or 6 electrodes are used during an experiment. These electrodes are arranged in a monopolar configuration, where 50% of the electrodes are connected to the positive outlet, acting as anodes, and the other 50% are connected to the negative outlet, acting as cathodes during the treatment of colored wastewater. The effective dimensions of each electrode are 40mm×140mm×3mm. These electrodes are connected to DC power source. The electrolytic fluid cell is placed on a magnetic stirring controller. The schematic diagram of the experimental setup cell is shown in Figure 1.

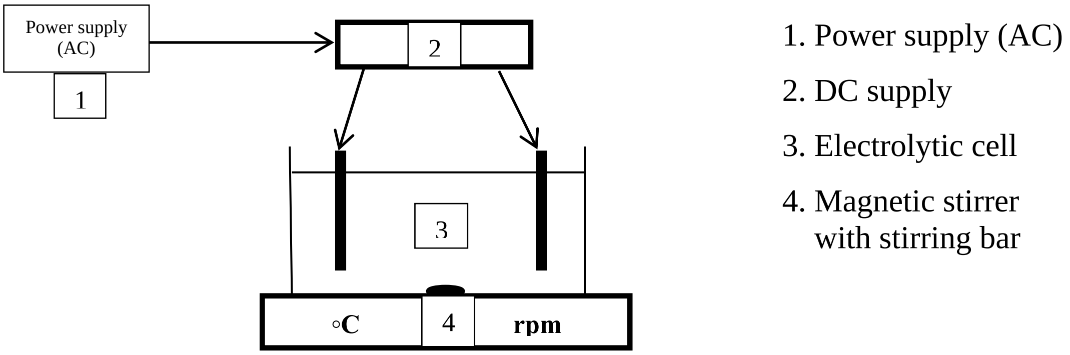

Figure 1: The Schematic Diagram of Electrolytic Cell Setup.

EXPERIMENTAL METHODOLOGY

The experimentation consists of usage of number of electrodes at electrodes spacing, varying the voltage supply, collection of wastewater samples at different electrolysis times and their analysis in the laboratory for various parameters of interest. In the present study, batch process is opted to study the performance of electrocoagulation method for the wastewater treatment focusing on colour removal. Six liters of textile wastewater of known characteristics is placed in the electrochemical cell consisting of two Al electrodes arranged as shown in Figure 2(a). DC power is supplied to the electrodes with alternative positive and negative connections in a batch reactor. The initial wastewater quality parameters are measured with respect to colour and pH. The magnetic stirrer is placed at bottom of the reactor and the stirring bar is agitated to maintain uniform wastewater characteristics and for better distribution of the reaction. The EC experiments were conducted with an input voltage varying in the range of 10V-30V with 5 unit's interval. The treated wastewater samples of 25 ml volume are collected periodically from the EC cell or reactor at every 15 minutes interval. Thus collected samples during the experimental process are kept in quiescent condition for 15 minutes and then used to measure colour removal efficiency and for the estimation of other parameters such as pH, alkalinity etc. The observed mean pH of the textile park raw wastewater is 9.7. The experiments were carried out without altering the pH and then varying pH from 5 to 10. Subsequently, experiments were carried out at varying electrode spacing's under acceptable voltage, electrolysis time, and pH for removal of colour. Experimental procedure as carried out with two Al electrodes is repeated similarly for both four and six number of Al electrodes set up.

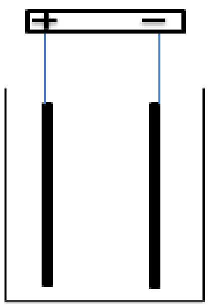

Figure 2 (a)

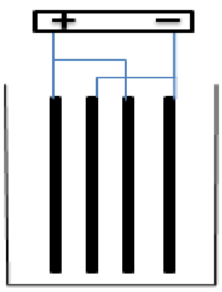

Figure 2 (b)

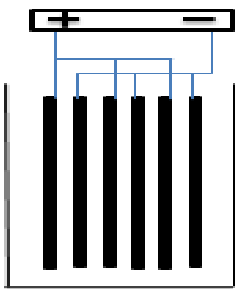

Figure 2 (c)

Figure 2: Schematic Diagram of Electrodes Arranged in Monopolar Configuration with (a) 2, (b) 4 and (c) 6 Numbers of Electrodes.

Replacing Al electrodes with Fe electrodes, similar experiments were conducted following same configuration followed in case of EC Cell with Al electrodes and the same procedure mentioned earlier.

OBSERVATIONS AND RESULTS

The effect of number of electrodes and their spacing, electrolysis time, pH variation on the performance of EC process was assessed during the study.

Effect of Number of Electrodes

In case of EC process with Al electrodes without any pH adjustment, the highest colour removal efficiency of approximately 69% was observed with two numbers of electrodes placed at 12cm clear spacing in the EC cell as shown in Figure 3. The Observed colour removal efficiency with four number of Al electrodes spaced at 5 cm electrode spacing is 56% and when six Al electrodes are used with 4cm electrode spacing, the removal efficiency is almost 52% as shown in Figure 4 and Figure 5 respectively. In case of Fe electrodes the highest colour removal efficiency of around 93% was observed with two numbers of electrodes placed at 4cm spacing in the EC cell as shown in Figure 6. It can be observed that the colour removal efficiency with 2 electrodes spaced at 6 cm and 7 cm almost similar with around 80% as shown in Figure 6. Observed colour removal efficiency is around 95% for 4cm electrode spacing with four number of Fe electrodes and about 93% when six electrodes are used with 3cm electrode spacing as shown in Figure 7 and Figure 8 respectively. The DC power supply unit used during the present studies has a maximum supply capacity of 30V. The same is given as input supply to the EC cell during the process. However, in spite of the full 30 volts supply, the voltage carried out in the cell is less than 30V. It is because of the resistance offered by the EC cell configuration. The highest colour removal efficiencies achieved by EC process using Al electrodes at 2, 4 and 6 number of electrodes are 69%, 56% and 52% respectively. Whereas, the highest colour removal efficiencies achieved using Fe electrodes at 2, 4 and 6 numbers of electrode are 93%, 95% and 90% respectively were observed during EC process. Hence, two numbers of electrodes were considered further throughout the experimentations as it fetched better removal efficiencies which may not be the maximum but it is comparable.

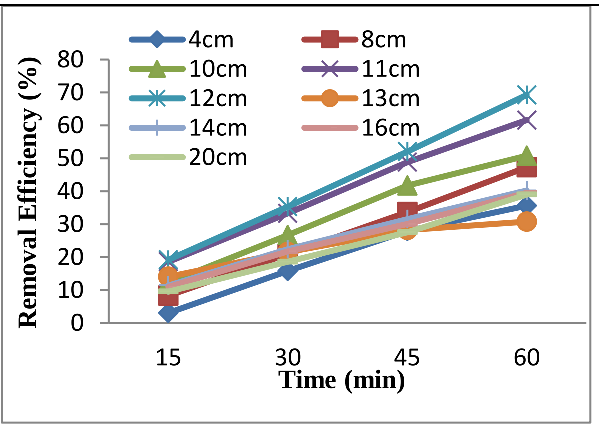

Figure 3: Observed Colour Removal Efficiency of the EC Process with Electrolysis Time using Two Number of Al Electrodes Placed at Different Spacing.

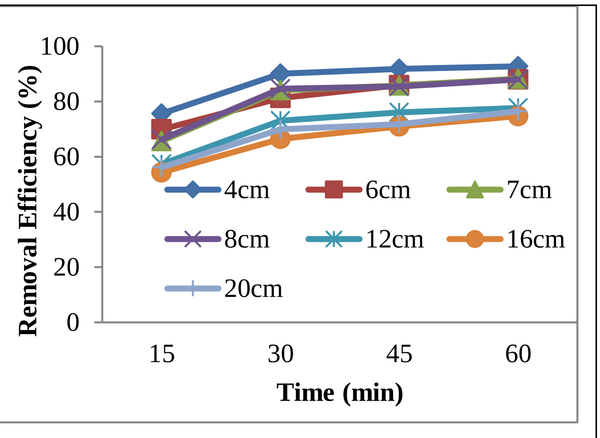

Figure 6: Observed Colour Removal Efficiency of the EC Process with Electrolysis Time using Two Number of Fe Electrodes Placed at Different Spacing.

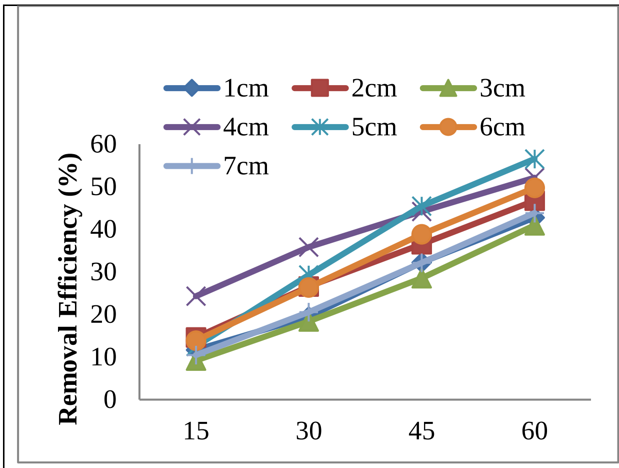

Figure 4: Observed Colour Removal Efficiency of the EC Process with Electrolysis Time using Four Number of Al Electrodes Placed at Different Spacing.

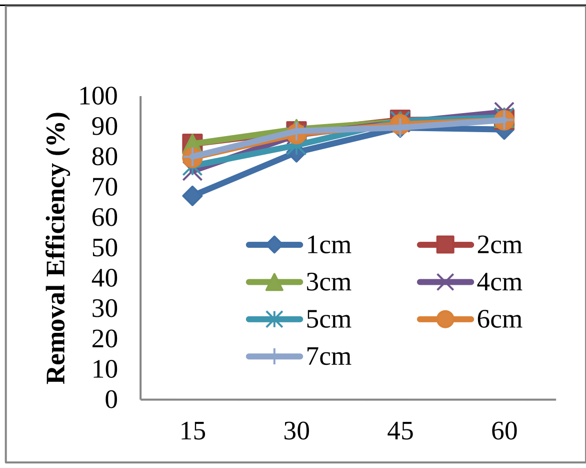

Figure 7: Observed Colour Removal Efficiency of the EC Process with Electrolysis Time using Four Number of Fe Electrodes Placed at Different Spacing.

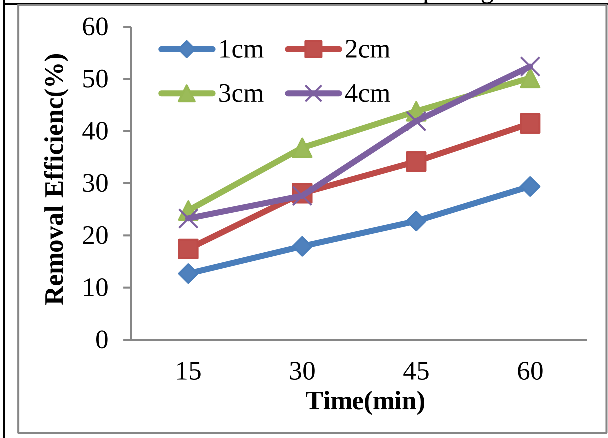

Figure 5: Observed Colour Removal Efficiency of the EC Process with Electrolysis Time using Six Number of Al Electrodes Placed at Different Spacing.

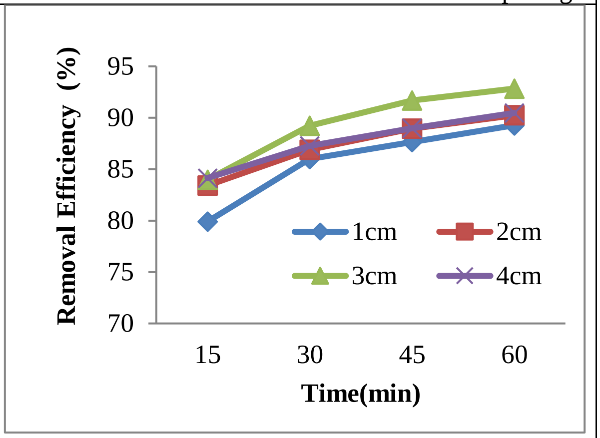

Figure 8: Observed Colour Removal Efficiency of the EC Process with Electrolysis Time using Six Number of Fe Electrodes Placed at Different Spacing.

Effect of Electrolysis Time

The influence of electrolysis time with respect to varying voltages on colour removal through EC process using Al and Fe electrodes was investigated. In case of EC process using Al electrodes, colour removal efficiency was observed to be increased with time up to 90 minutes; thereafter no significant changes were observed till 120 minutes electrolysis time as shown in Figure 9. However, in case of EC process using Fe electrodes, colour removal efficiency was observed to be increased with time up to 60 minutes; thereafter no significant change was observed till 90 minutes electrolysis time as shown in Figure 10. Researchers observed that the increase in coagulant dose does not have significant effect on pollutant removal due to the presence of sufficient number of coagulants (Choudhary, A., et al., 2016 and Bazrafshan, E. et al., 2015). This may be the reason for insignificant increase in colour removal even with increase in electrolysis time result in increased leaching of metal ions into the cell contents. The negative affect of increase in electrolysis time is on the cost of the treatment due to increase in electrode consumption and energy at longer electrolysis time. Hence, subsequent experimentation was carried out with two numbers of Al and Fe electrodes with 90 minutes and 60 minutes electrolysis time respectively.

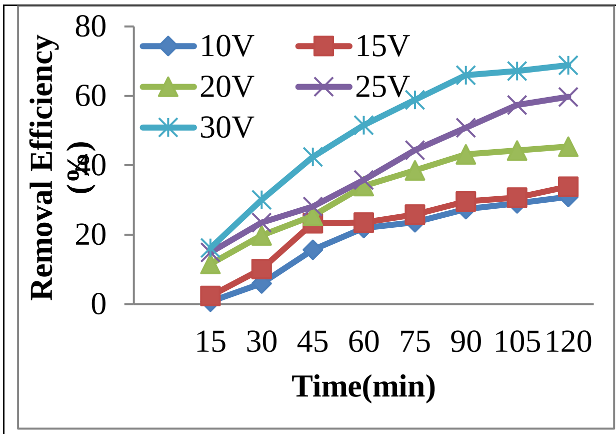

Figure 9: Influence of electrolysis time on the removal of colour with two Al electrodes, electrode spacing of 11cm and with no adjustment of pH.

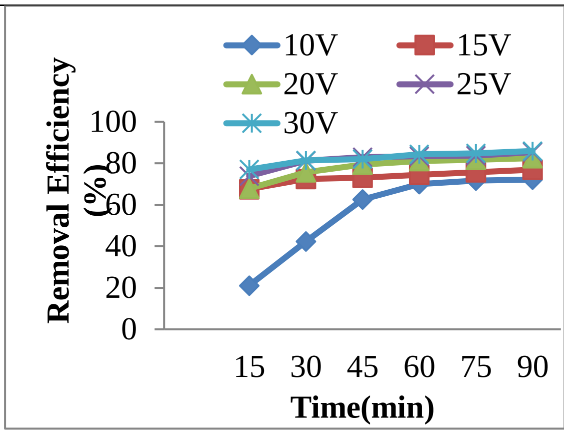

Figure 10: Influence of electrolysis time on the removal of colour with two Fe electrodes, electrode spacing of 8cm and with no adjustment of pH.

Effect of Input Voltage

The supply voltage is a vital parameter and several experimental works has been carried out on its effects on EC method as this parameter is important for monitoring reaction rate within the electrochemical reactor (Mollah, M.Y.A. et al., 2001). During EC treatment process with Al electrodes, the maximum and minimum colour removal efficiency of about 67% and 27% was observed at an input voltage of 30V and 10V respectively as shown in Figure 11. However, EC process using Fe electrodes, observed maximum and minimum colour removal efficiency are around 84% and 70% at an input voltage of 30V and 10V respectively as shown in Figure 11. The performance of EC process with Fe electrodes in colour removal is superior even at lower input voltage when compared with Al electrodes. The reason for increasing colour removal rate at higher input voltage than lower voltages is due to the releasing of necessary coagulating ions at higher rates which ultimately promote destabilization and aggregation of the flocs (Salman, H.A., and Wail, H.A., 2018) as shown in Table 1.

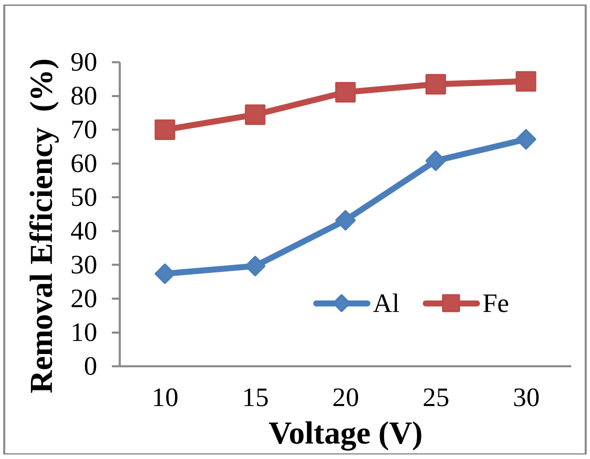

Figure 11: Influence of Input Voltage on the removal of colour by Al and Fe electrodes.

Table 1: Influence of Input Voltage on the Removal of Colour Using Al and Fe Electrodes at Electrolysis Time 90min and 60min Respectively.

S.No	Voltage supplied (V)	Colour removal efficiency using Al (%)	Colour removal efficiency using Fe (%)
1	10	27.4	70.01
2	15	29.63	74.5
3	20	43.18	81.11
4	25	60.83	83.49
5	30	67.19	84.36

Effect of Initial pH

Electrocoagulation process is highly dependent on wastewater pH and an important operational parameter affecting performance of EC process. Electrochemically generated metal cations (Fe^{3+} or Al^{3+}) and anion (OH^-) will spontaneously react and produce corresponding hydroxide and /or poly hydroxides. Many monomeric species of Al^{3+} and Fe^{2+}or Fe^{3+} transform into $Al(OH)_3$ and $Fe(OH)_3$ (Kobya, M., et al, 2003). It brings in pH change during the process. Hence, the observations of pH changes during the experimentation were analyzed. The initial pH and the corresponding final pH after electrolysis time of 90minutes and 60minutes during the colour removal due to EC process using Al and Fe electrodes are given in Figure 12 and Figure 13 respectively. An increase in pH from an initial value of 5 to 8.5 was observed during EC process with Al electrodes. The similar trend continued during experiments up to an initial wastewater pH of 9. However, from an initial pH above 7 till 10, the increase in pH is beyond 8.5 and even went up to 9.6 as shown in Figure 12. Neutralization and colour removal are taking place simultaneously when the pH of raw wastewater is in the acid range. As shown in Figure 12, for an initial pH of 5 and 30V voltage supply, higher colour removal efficiencies of around 79% can be obtained using EC process with Al electrodes. Minimum color removal efficiency of around 65% was observed at pH 10. In case of EC process using Fe electrodes, final pH observed is higher than 9.5 while treating wastewater with an initial pH varying between 5 and 10. Higher removal efficiencies up to 92% can be achieved in the colour removal while treatment wastewater with an initial pH 8 to 10 and an input voltage of 30V as shown in Figure 13. Whereas, lowest removal efficiency of around 81% was observed at pH 5. Hence, it maybe concluded that EC treatment process using Fe electrodes removes colour more efficiently at alkaline medium on the contrary, EC process using Al electrodes removes colour favorably at acidic medium.

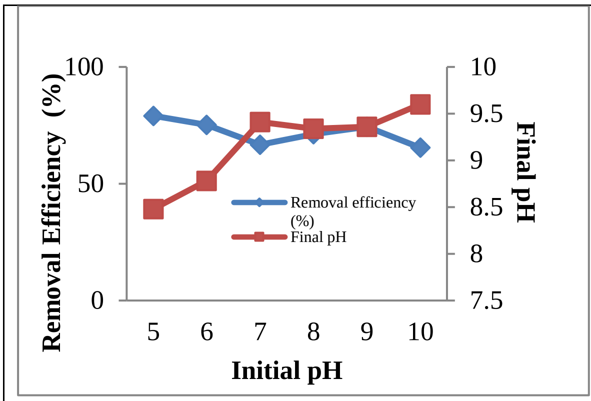

Figure 12: Influence of initial pH on the removal of colour with two Al electrodes, electrolysis time of 90min, Input voltage of 30V and electrode spacing of 11cm.

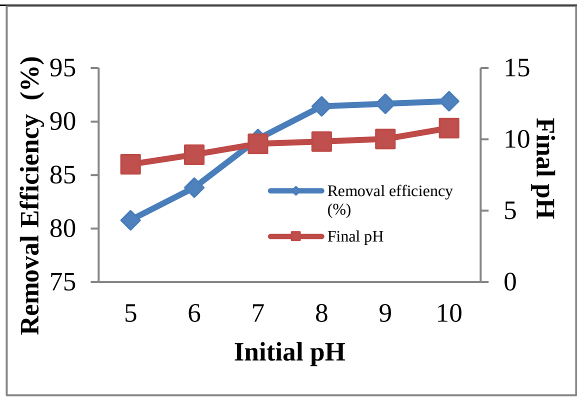

Figure 13: Influence of initial pH on the removal of colour with 2Fe electrodes, electrolysis time of 60min, Input voltage of 30V and electrode spacing of 8cm.

Effect of Electrode Spacing

Electrode spacing significantly effects colour removal efficiency. Therefore, a practical distance is required for maximum pollutant removal. During the present EC process study using two Al electrodes, along with 90 min electrolysis time, 30V Input voltage, initial pH of 5, and varying electrode spacing, it was identified that the highest colour removal efficiency is about 70% at 13cm electrode spacing and the lowest colour removal efficiency is 62% at 14cm electrode spacing as shown in Figure 14. Whereas, In case EC process using 2Fe,along with 60 min electrolysis time, 30V Input voltage, initial pH of 9, and varying electrode spacing, it was identified that the highest colour removal efficiency is about 92% at 10cm electrode spacing and the lowest colour removal efficiency is 82% at 20cm electrode spacing as shown in Figure 14. From the obtained results, shown in Figure 14, it can be observed that the cause for low colour removal efficiencies at confined spacing's is due to hindrance in movement of wastewater between the narrow spaces (Sharm, D., 2014). However, at greater spacing the time needed to form coagulants from ions generated from anode and cathode increases with increasing inter electrode spacing which ultimately decreases removal efficiency (Kobya, M. et al., 2003). Hence, the spacing identified during the present study is optimum spacing to achieve maximum possible colour removal from the textile wastewaters. Based on the study, it was found that the EC process observed to perform well for the removal of color under different settings of the cell and the parameters as given in Table 2.

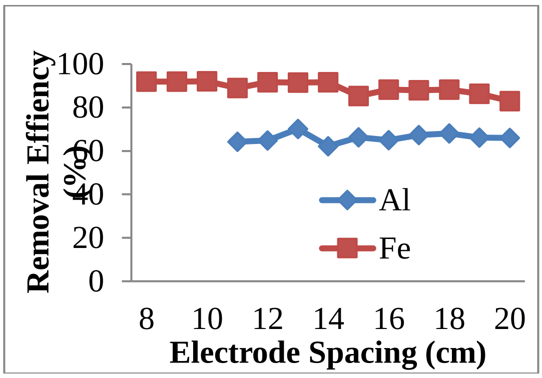

Figure 14: Influence of electrode spacing's on the removal of colour by Al and Fe electrodes.

Table 2: The color removal efficiency with fe and al electrodes at specified settings.

Number of electrodes	Using Al Electrodes				Using Fe Electrodes			
	Optimum Electrode Spacing (cm)	Electrolysis time (min)	pH	Colour removal efficiency using Al (%)	Optimum Electrode Spacing (cm)	Electrolysis time (min)	pH	Colour removal efficiency using Al (%)
2	18	15	9.8	59.85	14	15	9.8	62.01
		30		63.78		30		84.92
		45		65.63		45		87.84
		60		67.08		60		91.66
		75		67.80		--		--
		90		68.11		--		--
4	5	15	9.7	12.53	4	15	9.7	75.34
		30		29.31		30		87.17
		45		45.49		45		91.28
		60		56.54		60		94.76
6	4	15	9.9	23.27	3	15	9.9	83.98
		30		27.63		30		89.23
		45		41.89		45		91.68
		60		52.39		60		92.84

CONCLUSIONS

The study investigated the effects of process parameters such as type of electrode, input voltage, number of electrodes, electrode spacing, electrolysis time and pH on effective removal of colour from textile effluent using electrocoagulation. After experimentation it was found that EC process using Iron electrodes removed colour more efficiently and effectively with removal efficiency around 92% with operational parameters with 2 numbers of electrodes, 30 voltage, pH of 9, electrolysis time of 60min and 14cm spacing. Whereas, decolourization efficiency of EC process using Aluminium is about 68% with operational parameters with 2 number of electrodes, 30 voltage, pH of 5 electrolysis time of 90min and 18cm spacing. Hence, from the obtained results it can be concluded that for effective and efficient treatment of textile wastewater Iron electrodes should be used along with the recommended optimized parameters as presented in the study.

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